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Submerged Combustion Evaporator For Concentration of Brewery Spent Grain Liquor

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SUBMERGED COMBUSTION EVAPORATOR FOR CONCENTRATION OF BREWERY SPENT GRAIN LIQUOR

By

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Project 12060 HCW
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ABSTRACT

One of the major waste streams in many breweries is the liquor resulting from spent grains dewatering prior to drying. This liquor may account for a third or more of the $B.O.D._5$ and suspended solids generated by a typical brewery.

Initial studies of the spent grain liquor problem indicated that recovery rather than treatment was the best approach. A number of evaporators were evaluated to determine which design was most satisfactory for concentrating the liquor. A submerged combustion evaporator was selected on the basis of engineering analyses and pilot scale tests.

A full scale unit was installed at the Houston Brewery of Anheuser-Busch, Inc., in 1970. This evaporator was modified several times to overcome failures of the burner downcomers brought about by high temperatures. Before a final solution to these problems could be demonstrated, the project was terminated. Fuel costs above $1.60 per million kg-cal (40¢ per million BTU) coupled with thermal efficiencies approximately 3.5 times better for conventional four-effect evaporators indicated that a conventional evaporator would be more economical at these fuel price levels.

This project was submitted in fulfillment of Project Number 12060 HCW by Anheuser-Busch, Inc., under the partial sponsorship of the Environmental Protection Agency. Work was completed as of March 1973.

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ACKNOWLEDGMENTS

Pilot plant studies of the submerged combustion evaporation process were carried out by the Anheuser-Busch Technical Center. Design, construction, and start-up of the full-scale evaporator were under the supervision of the Anheuser-Busch Central Engineering Department. Personnel from the Houston Brewery were responsible for the operation and upkeep of the evaporator during the test phase.

Personnel from the Thermal Research and Engineering Corporation of Conshohocken, Pennsylvania, provided valuable assistance and cooperation during the latter phases of the project.

Personnel from the EPA Office of Research and Development Headquarters and Region VI provided assistance throughout the project.

SECTION I

CONCLUSIONS

The experiment showed that the concept of using a submerged combustion evaporator for concentrating brewery spent grain liquor is feasible, although all of the design problems involved in this application have not been completely resolved. Concentrates of 20 percent total solids can be produced from feedstocks of 2.4 to 3.2 percent solids.

Extensive pretreatment of the spent grain liquor was shown to be unnecessary. Screening of the liquor using a standard vibratory screen was adequate to assure a feed soluble-insoluble total solids ratio of 1.0 or greater, the ratio proven necessary to hold fouling and demister plugging to a minimum.

Although the testing program was cut short prior to final evaluation which included air emissions testing, it was demonstrated that smoke and odor could be minimized with proper combustion controls. Entrainment was unavoidable during operations without the stainless steel mesh demister pad, but plugging was unavoidable with the pad located at the base of the stack where it was subjected to considerable splashing. At the time of termination of the test program plans had been made to relocate the demister pad to a portion of the stack not subject to splashing.

The use of an air-cooled burner downcomer proved to be the only satisfactory method insuring reasonable downcomer life under the conditions experienced during this test. Non-cooled downcomers were subject to rapid deterioration because of the high skin temperatures developed. Single-pass cooling with water resulted in considerable heat losses and poor thermal efficiency. The closed loop system tried did not satisfactorily transfer heat to the liquor from the downcomer walls. The air-cooled downcomer which circulated air through the downcomer walls and into the firebox eliminated these problems. Evaporation was satisfactory, equipment service life was acceptable, and the thermal efficiency was maximized. Inconel 601 was judged to be a better downcomer material than Type 316 stainless steel.

Submerged combustion evaporation can be economically attractive in situations where fuel may be obtained at less than $1.60 per million Kg-cal

(40¢ per million BTU), but when fuel costs exceed this amount conventional evaporative processes are favored. Where high-cost fuels must be used the efficiency of the conventional evaporator outweighs the capital costs associated with this type of evaporator and its ancillary preprocessing equipment. Although the submerged combustion evaporator is perhaps the most efficient single-effect evaporator, conventional four-effect units, such as are now being used on concentrate spent grain liquor, offer efficiencies about 3.5 times those of the submerged combustion evaporator.

SECTION II

RECOMMENDATIONS

Because of the demonstrated low thermal efficiency of the submerged combustion evaporator and the current critical shortages of oil and natural gas, further experimentation with this system would not appear warranted at this time. Due to the shortage of petroleum fuels which has developed in the past year, it is unlikely that many breweries would be able to secure sufficient supplies to operate a submerged combustion evaporator, or even if such supplies were available that these plants could economically operate such a system due to the greatly increased costs of oil and gas.

Recent experiences have shown that conventional evaporators, such as the multiple-effect or recompression types, can be designed to overcome most of the problems which the submerged combustion evaporator eliminated. These evaporators can be operated efficiently and economically. For this reason, it is recommended that future efforts in the area of spent grain liquor recovery be directed toward the refinement and improvement of conventional evaporative techniques, with the goal of reducing the number of processing steps required for the spent grain and liquor.

SECTION III

INTRODUCTION

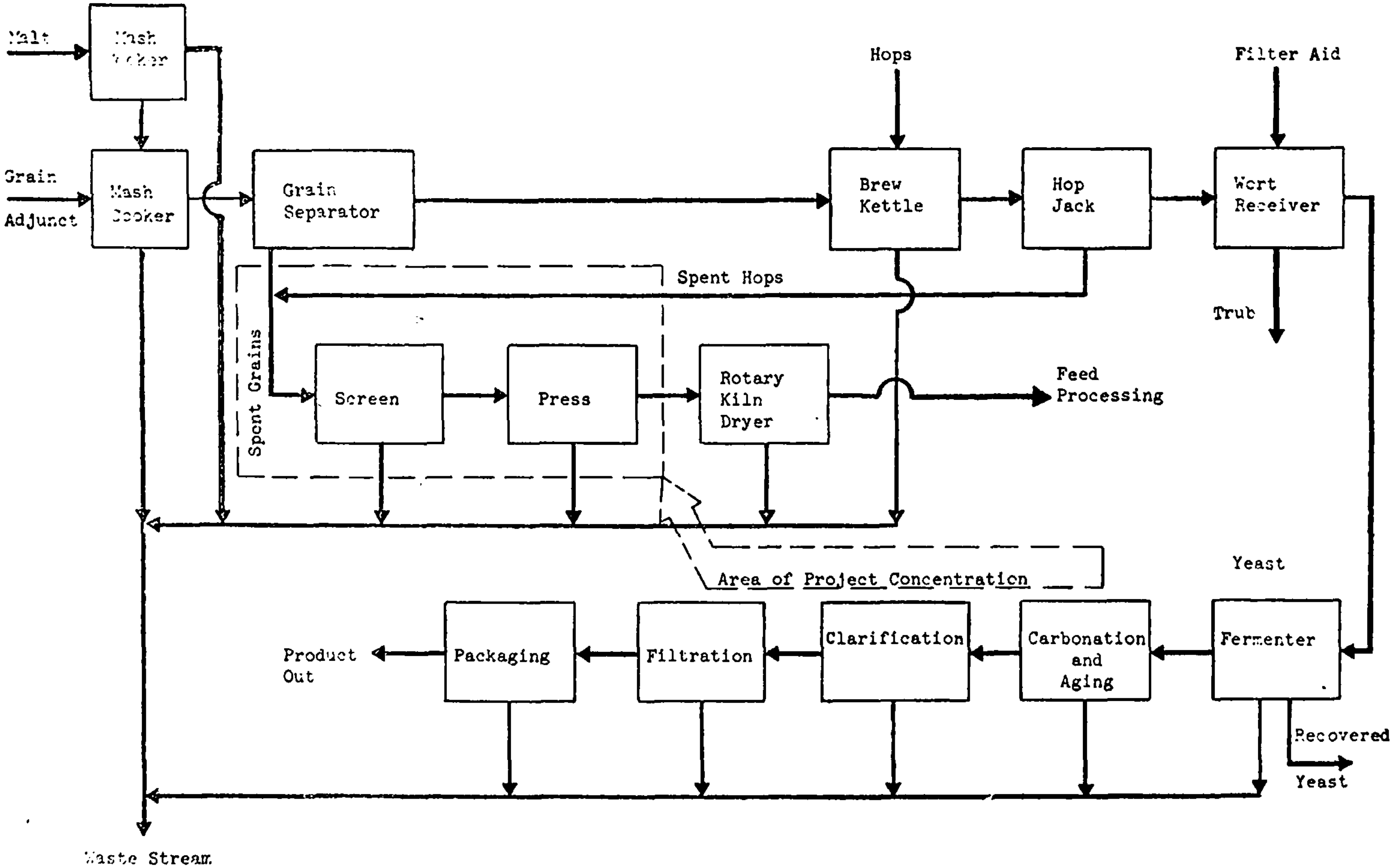
The brewing industry in the United States operates some 130 breweries across the country and produces approximately 156 million hectoliters (133 million barrels) of beer per year. The effluent control problems of the industry have been accentuated in recent years due to the closing of many small outmoded breweries in large metropolitan areas coupled with the construction of large, more modern breweries in smaller cities and towns. This trend has resulted in increased percentages of brewery wastewaters in the influent of many municipal treatment plants which have had little or no experience in the treatment of high carbohydrate wastes.[1]

BREWING INDUSTRY WASTEWATER PROBLEM

A process flow diagram for a typical brewery is shown on Figure 1.[2] Malt is crushed into fine particles and mixed in aqueous solution. A similar process is carried out with the grain adjunct (rice, corn or other grain derivative), except that the adjuncts are heated and brought to a boil before being combined with the malt. The soluble fractions are separated, and the starches are converted to sugars and the proteins into amino acids. Upon completion of the mashing operation the grain solids are separated from the malt extract, or wort. The spent grains are then normally screened and mechanically pressed to remove as much moisture as possible. The grain is then fed to a rotary kiln dryer and the dried grain is then ready for shipment to cattle feed processors. The wort is sent to the brew kettle where it is boiled and mixed with hops. All enzymes are destroyed and the resins which impart flavor are extracted from the hops. Following this operation, the hops are screened from the wort and either mixed in with the spent grains or disposed of separately. The hot wort is then cooled and prepared for fermentation. Proteins which were coagulated in the brew kettle settle to the bottom of the wort receiver and become known as trub. The trub may be mixed with spent grains or sewered.

Fermentation of the wort is then initiated with the addition of yeast. Sugars are converted to alcohol and carbon dioxide, and an excess of yeast is produced. Carbon dioxide may be recovered for counter-pressurization of lager tanks and possibly for carbonation of the beer further along in the process, or it may be drawn off for sale with any excess vented to the atmosphere. The yeast may be reused several times

Figure 1. THE BREWING PROCESS



before it is discarded. Upon completion of fermentation, the beer is ready for aging and additional carbonation, brought about by injection with carbon dioxide or through a second fermentation step. The beer is then clarified and filtered, using either cotton or diatomaceous earth filters. Following this step, the beer is ready for packaging.[3]

The principal waste streams resulting from this process are shown in Table 1.[4] The characteristics of the combined brewery waste stream are highly variable, both from plant to plant and within a specific brewery.[5] The wastes from different plants vary depending upon the raw materials used, process equipment employed, residual disposal techniques, etc. The effluent from a particular plant may vary as a function of which of the various processes are operating at any particular time. Generally speaking, brewing wastes are abundant in degradable organic matter and contain abundant amounts of suspended and dissolved solids. Variability in the amounts of biochemical oxygen demand ($B.O.D._5$) and suspended solids contained in the wastewater is caused by the numerous batch processes involved in brewing.

Due to the variability and strength of brewing wastewaters, successful conventional treatment of these wastes alone using trickling filters and/or activated sludge has been difficult and costly to achieve. Most breweries have long recognized the benefits to be realized by combining their wastes with domestic sewage, and the practice of combined treatment is widespread. (Only two breweries in the United States operate their own treatment facilities.) Different treatment plant operating techniques are needed, however, as the proportion of brewing wastes, as with many other wastes, increases in the total volume of waste handled by the municipal treatment plant. Virtually all treatment plants today also find themselves being required to meet more stringent effluent standards, and, hence, are going "upstream" in an effort to reduce the total load on their facilities.

SPENT GRAIN LIQUOR

One of the most significant sources of high strength organic wastes in the brewing industry is the liquor resulting from the spent grain recovery process.[6] In this process, waste grain from the mashing process is screened and pressed to remove as much moisture as possible by mechanical means, and then dried to produce saleable animal feed. The liquor remaining from the screening and pressing operations is characteristically high in $B.O.D._5$ and suspended solids, and somewhat variable as to the ratio of soluble to insoluble solids. Breweries with grains drying operations can usually attribute 30 to 60 percent of their total $B.O.D._5$ and suspended solids discharge to screen and press liquor. Attempts to eliminate the grain liquor problem to date have been limited in their success. Some breweries have eliminated their drying operations and sell their grains wet. Wet grain feeding operations can, however,

Table 1. PRINCIPAL WASTE

STREAMS FROM THE BREWING PROCESS[4]

Source	B.O.D.$_5$ mg/l	S.S., mg/l
Washings from kettles, cookers, and grain separators	200-7,000	100-2,000
Screen and press liquor	15,000	20,000
Trub	50,000	28,000
Yeast	150,000	800
Clarification precipitates	60,000	100
Spent filter aid		
Beer	90,000	4,000
Cleaning solutions	1,000	100

become nuisances. When grains are hauled to an independent drying operation the spent liquor problem has only been moved, not eliminated.

Brewers, then, have been forced to look at means for recovering the spent grain liquor and attention has focused on concentration processes. The use of a liquor concentration process allows the actual elimination of the grain liquor as a waste stream. The concentrate is a syrupy substance which can easily be mixed with wet grains and dried.

PROCESS SELECTION

Concentration of dilute solutions is normally carried out by evaporation of the solvent, with or without recovery of the vapor. Evaporators may be classified as follows:

1. Those in which the heating medium is separated from the evaporating liquid by tubular heating surfaces.

2. Those in which the heating medium is confined by coils, jackets, double walls, flat plates, and other surfaces.

3. Those in which the heating medium is brought into direct contact with the evaporating liquid.

Most industrial evaporators fall into the first or second category. This group may be further subdivided into forced-circulation, long-tube vertical, horizontal-tube, and other lesser known types.[7]

The forced circulation evaporator is suitable for a wide variety of applications. In this type of evaporator liquid is pumped through a tube bundle in a steam chest. As the liquid rises through the tubes, it becomes heated and begins to boil, causing vapor and liquid to exit from the tubes at high velocity. The vapor and liquid are ejected into a vapor head to effect an effective separation of the two. Forced circulation evaporators do have high heat-transfer coefficients and are relatively free from scaling and fouling, but they are not universally attractive because of their high capital cost and the high energy requirements for recirculation. These evaporators frequently suffer from plugging of tube inlets by deposits detached from walls of equipment, poor circulation due to high head losses, and corrosion and erosion.[7]

The long-tube vertical evaporator is a one-pass vertical shell-and-tube heat exchanger which discharges into a small vapor head. Liquid may be fed to the bottom of the tube, starting to boil part way up the tube and then exiting as a mixture of vapor and liquid at the top where separation occurs. In the case of the falling film version liquid is fed to the tops of the tubes and flows down the walls as a film. Vapor-liquid separation normally takes place at the bottom. Long-tube vertical evaporators have the advantages of low initial cost, good heat transfer coefficients, and short residence time. Their drawbacks include high headroom requirements, problems with scaling liquids, poor heat transfer coefficients with the rising-film version at low temperature differences, and the necessity for recirculation for most falling-film versions. Long-tube vertical evaporators are especially useful where heat sensitive liquids are being concentrated (including many liquids in the food and beverage industry), where foaming is a problem, and where high evaporation loads are encountered.[7]

Horizontal-tube evaporators may be used for severely scaling liquids. In this design the liquid flows or is sprayed over a tube bundle containing steam. These evaporators are favored because of their low headroom requirements, relatively low initial cost, and good heat-transfer coefficients. Care must be exercised in design and operation or serious scaling problems may develop. Horizontal-tube evaporators are not as widely used for concentration as are forced-circulation or long-tube vertical evaporators.[7]

The most widely used evaporator which does not depend upon a heating surface is the submerged combustion evaporator. Here hot combustion gases passing through the liquid transfer the heat. The submerged combustion evaporator normally consists only of a tank, a burner and gas distributor and a combustion control system. The evaporator is well suited for severely scaling liquids because of the lack of any heating surfaces. Because of the simplicity of design, the submerged combustion evaporator is much less expensive to construct than those utilizing heat transfer surfaces. High entrainment losses can be a problem; and because the vapor is mixed with large quantities of non-condensable gases, it is impossible to reuse the heat in the vapor. For this latter reason, the use of submerged combustion evaporators is normally limited to areas where low-cost fuel is plentiful.[7, 8]

One type of concentrator which does not fit into the category of an evaporator is the membrane concentrator. Membrane concentrators are normally classified as a reverse osmosis or ultrafiltration devices, depending upon the size of the solids which the membrane is designed to exclude. Membrane devices function by pumping liquid feed at high pressures through a permeable membrane. These devices are highly efficient from an energy standpoint, since they effect a solid-liquid separation without a phase change. They are, however, highly susceptible to fouling and as a result the feed liquor must be virtually free of suspended solids. Membranes presently available are highly sensitive to pH and as a result special cleaning solutions, usually detergent-enzyme formulations are necessary. This concentration technique has had little use in the food industries, although the process has been proposed for spent grain liquor recovery.[9]

Although dryers also remove moisture from a liquid or semi-liquid feed, they are not normally compared with evaporators because evaporators are used only to transfer heat to liquids, whereas dryers transfer heat to liquids and solids.

The decision to proceed with full scale investigation of spent grain liquor concentration using submerged combustion evaporation was based upon compatibility with existing grain drying and recovery equipment and the success of preliminary pilot plant investigations. Prior to the commencement of the design of a full-scale submerged combustion system several other methods for the disposal of the spent grain liquor were explored. These approaches involved the use of a dry grain recycle system and a number of evaporative systems. One system involved the elimination of screening or pressing of the grain; the wet grain was mixed with dry recycled grain and then added to the dryer. This process required considerable additional dryer capacity coupled with greatly increased fuel costs. A modification was examined in which the grain was screened but not pressed prior to mixing with the recycled grain. An evaporator of the submerged combustion type was used to concentrate the screened liquor so that it could also be mixed with the recycled material. This process showed considerable merit for new installations, but not for existing plants where the added dryer capacity would be difficult to install and presses were already in place.

Two systems designed around evaporators were studied which were applicable to both new and existing breweries. The first involved the use of a centrifuge to remove the suspended material from the screen and press liquor prior to evaporation in a conventional multiple-effect evaporator. The second utilized a vibrating screen to remove coarse solids from the spent liquor before adding the liquor to a submerged combustion evaporator. The multiple-effect evaporation system was estimated to be more costly to install than the submerged combustion type, but slightly less expensive to operate. Questions arose, however, concerning the ability of the conventional evaporator to tolerate the suspended solids in the spent liquor, as well as the ability of either centrifuges or screens to reduce the suspended solids concentration to an acceptable level. It was concluded that the submerged combustion system could offer the greatest degree of reliability and the lowest overall cost, and additional research was directed toward this area.

Preliminary studies to determine the practicality of the process and to identify potential problem areas were conducted in May, 1970, by the Anheuser-Busch Technical Center. A pilot plant evaporator and a vibrating screen were obtained in order to carry out these studies. A series of twelve tests was run with the 61 cm. (24 inch) vibrating screen. These tests indicated that the minimum required concentration of 20 percent solids could be guaranteed for most feed conditions and that concentrates in the 30-35 percent solids range might be obtainable.

The studies showed that the feed soluble-insoluble solids ratio should be maintained above 1.0 to avoid stack plugging and entrainment of solids. It was found that foaming was dependent on concentration and at concentrations of 7 to 10 percent excessive foaming ceased. Burning of grain was not a significant problem due to the small amount of surface area available. It was considered that there would be no problem in removing what grain material was burned and that the amount of material would be insignificant in any event. It was also determined that the evaporator would not violate any existing air pollution regulations. Odors were detected in the pilot plant operation, but it was felt that these should be localized in nature.[10]

SECTION IV

EXPERIMENTAL PROGRAM

TEST FACILITY

Based upon the success of the pilot studies, a decision was made to design a full scale evaporator installation and to seek a Research/Development/Demonstration grant from the Environmental Protection Agency. The grant was approved and a complete testing and evaluation program was set up. The Houston Brewery of Anheuser-Busch, Inc., was selected as the test site.

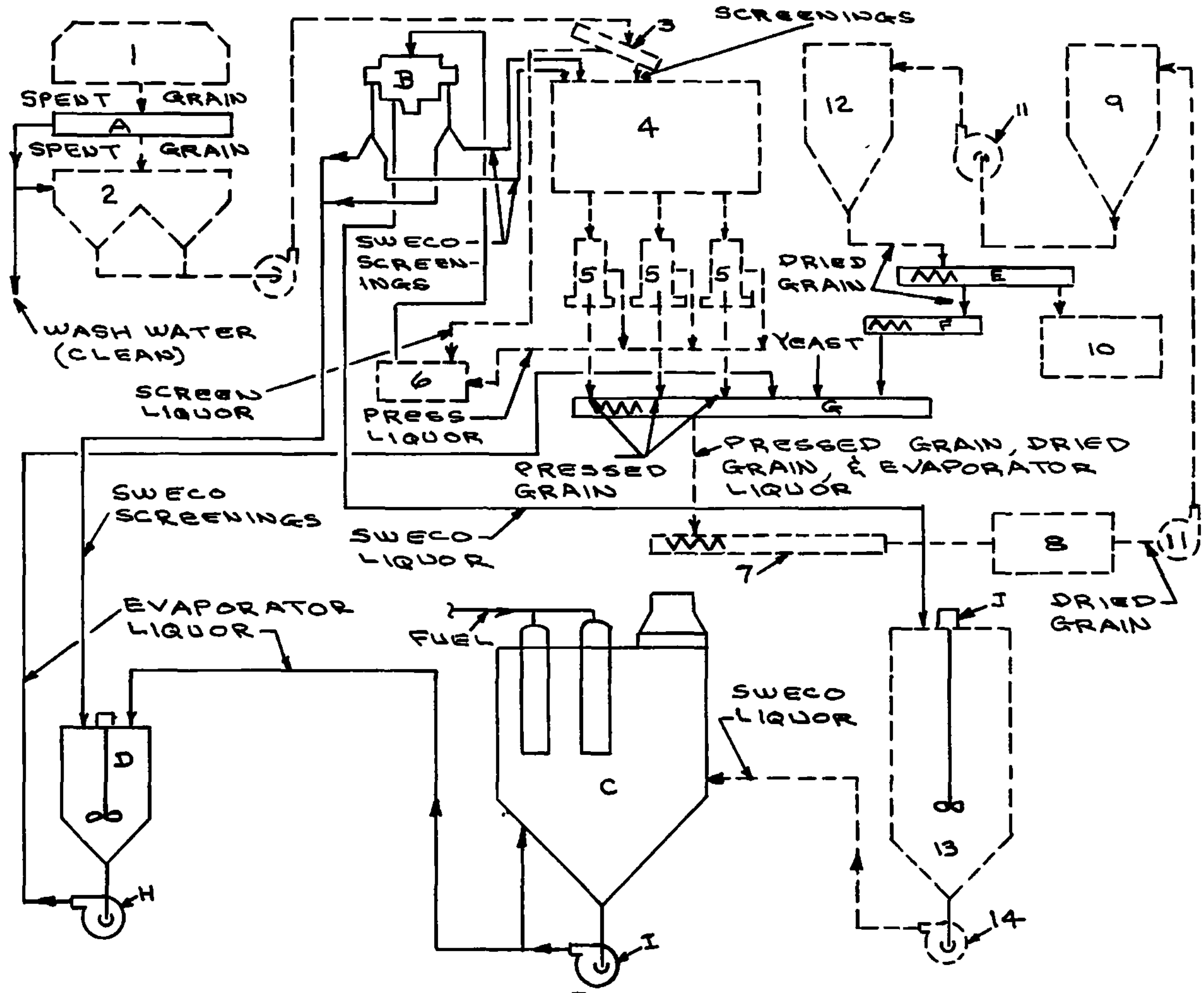
The system as designed following the pilot plant work is shown in Figure 2. Cooked grain mash is dumped into the grain separator, where the wort used to make the beer is drawn off. Water under high pressure is then used to force the grain from the grain separator to a dewatering screen and then to a holding tank. Water from the first six minutes of washing, which is high in $B.O.D._5$ and suspended solids, is recycled to the holding tank because it is impractical to by-pass the screen or to carry the rinse water to the SWECO ® * screen which is located in another building. The remainder of the wash water is sufficiently clean to be sent directly to the sewer. Wastes from the brewing operation, such as spent hops, are also sent to the holding tank.

The contents of the holding tank are then pumped to a dewatering screen ahead of the spent grain holding tank. The spent grains are then sent to a series of presses for further dewatering. Liquor from the dewatering screen and the presses is delivered to a common sump, and then sent through the SWECO ® dewatering screen. Here large particles which have passed through the presses are recovered, and along with any other recoverable suspended matter, are returned to the spent grain holding tank for recycle. Alternately, these solids may be sent to the concentrate storage tank.

Liquor from the SWECO ® screen is sent to the evaporator feed tank, where it is agitated until being sent to the evaporator itself. In the evaporator the solids content of the liquor is brought to the 20-25 percent range. The concentrate is then delivered to the concentrate storage tank where solids from the SWECO ® screen may be added.

* A product of SWECO, Inc., Los Angeles, California

FIGURE 2. PROCESS FLOW DIAGRAM



NEW EQUIPMENT	PRESENT EQUIPMENT
A. DEWATERING SCREEN	1. STRAINMASTER ®
B. SWECO SCREEN	2. HOLDING TANK
C. EVAPORATOR	3. DEWATERING SCREEN
D. CONCRETE STORAGE TANK	4. SPENT GRAIN HOLDING TANK
E. CONVEYOR	5. GRAIN PRESSES
F. CONVEYOR	6. WATER SUMP
G. MIXING SCREW CONVEYOR	7. CONVEYOR
H. PUMP	8. GRAIN DRYER
I. PUMP	9. AERATOR CYCLONE
J. AGITATOR	10. DRY GRAIN STORAGE
	11. BLOWER (DUAL)
	12. COOLER CYCLONE
	13. EVAPORATOR FEED TANK
	14. EVAPORATOR FEED PUMP

LINE LEGEND

---- PRESENT EQUIPMENT

——— NEW EQUIPMENT

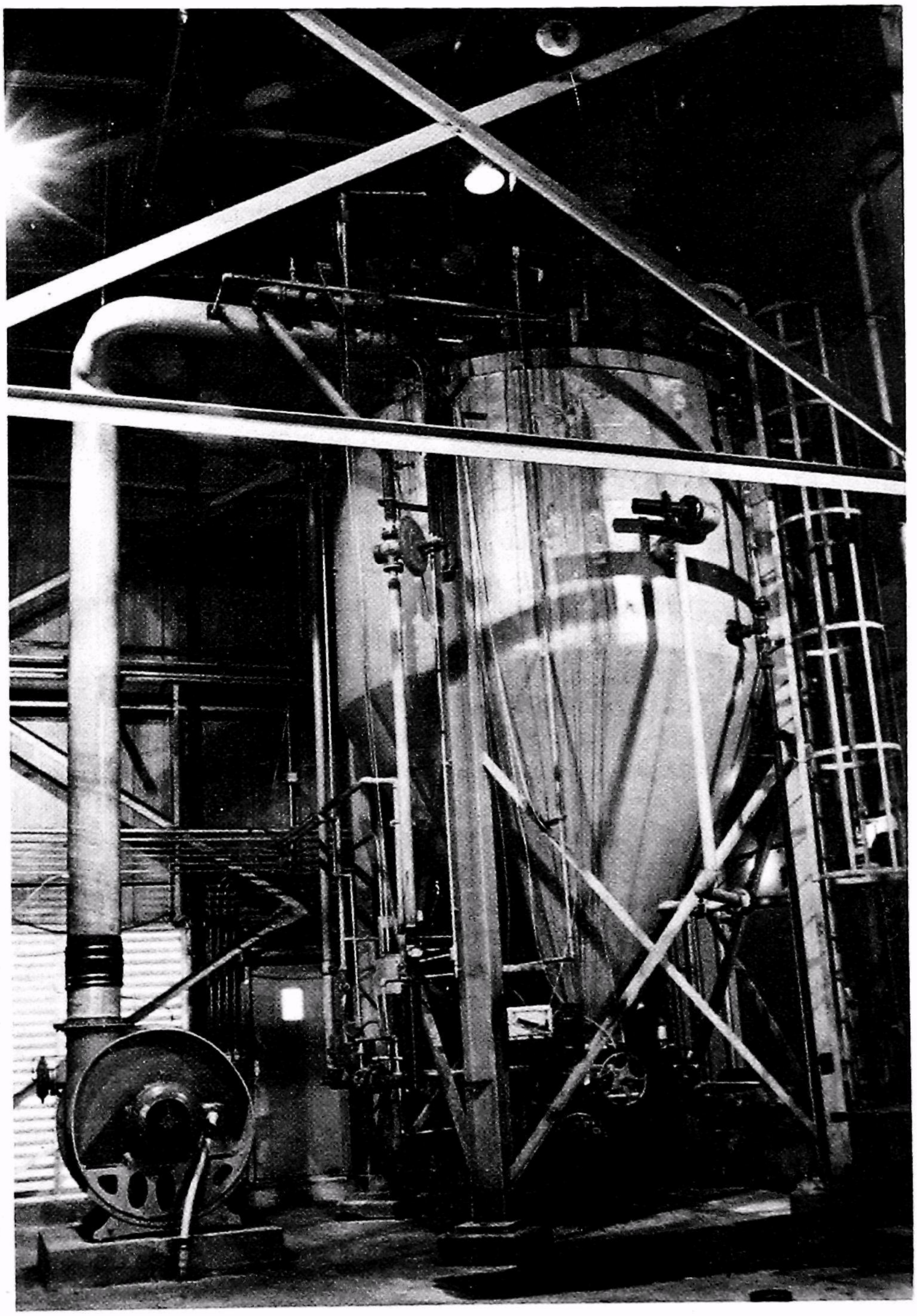
This concentrate is then delivered to a mixing screw conveyor where it is combined with the spent grain pressings, spent yeast, beer clarification precipitate (if available) and recycled dry grain, and then sent to the grain dryer. Once the grain has left the dryer, it is then cooled and ready for recycle or shipment as Brewers Dry Grain.

Principal items of equipment for the process include the SWECO® screen and the submerged combustion evaporator. The SWECO® screen is a 183 cm. (60 inch) unit with two decks. The top deck is a 30-mesh screen and the lower deck is a 74-mesh screen. The SWECO® unit was chosen over other types because of the extensive experience Anheuser-Busch has had with the screen. The evaporator chosen was not of the same design as that used in the preliminary studies. A 6.3 million Kg-cal/hr (25 million BTU/hr) unit manufactured by Thermal Research and Engineering Corporation, Conshohocken, Pennsylvania, was selected for reasons of lower first cost and fire safety features. The evaporator tested uses natural gas only as a fuel, although burners are available which will burn gas and No. 2 oil. The evaporator is shown in Figure 3.

TEST PROGRAM

Testing of the evaporator system was to be divided into equipment evaluation and effluent analysis. The equipment evaluation phase included development of complete material and heat balances for the system. The efficiency of the entire process was to be assessed, as well as the performance of the specific items of equipment. The effluent analysis phase was designed to measure the impact of the spent grain liquor recovery system upon the overall brewery sewer loading. Plans called originally for an eight-month test period, four with the evaporator in operation and four without. Two total brewery effluent samples were to be taken each week during the entire period. The analytical parameters included five-day biochemical oxygen demand ($B.O.D._5$), chemical oxygen demand (C.O.D.), total solids, total suspended solids, volatile suspended solids, total Kjeldahl nitrogen, total phosphorus, nitrate, and nitrite. In addition, this sampling program was to be augmented with spot sampling of the individual waste streams in the grain drying area. These spot samples were to be analyzed only for C.O.D. and total suspended solids.

Figure 3. SUBMERGED COMBUSTION EVAPORATOR



SECTION V

EVALUATION OF PROCESS

In the course of the evaluation of the submerged combustion system, critical problems developed with the burner downcomer. The downcomer is a cylindrical duct which directs the hot gases from the burner into the liquor. Much of the work on the process was devoted to the development of a durable and efficient downcomer. Aside from the downcomer problems the performance of the submerged combustion system was virtually as predicted. Considering the extensive work done on downcomer design, this section is organized to reflect the development of this crucial element. Test results are summarized in the following sections. More complete data tabulations will be found in the Appendices.

PHASE I - TESTS USING WATER-COOLED DOWNCOMER

Initial tests of the submerged combustion evaporator utilized a water-cooled downcomer. The purpose of the water jacket was to reduce the skin temperature of the metal downcomer sufficiently to avoid buckling. A single-pass cooling system using city water was used with the intention of switching to a closed loop cooling system once the evaporator was proven out. The test data are summarized in Table 2.

PHASE II - TESTS USING JACKETED DOWNCOMER AND CLOSED LOOP COOLING SYSTEM

In an effort to reduce the heat losses from the jacketed downcomer and the single-pass water cooling system, a decision was made to replace water as the cooling agent and to use in its place a commercially available heat transfer fluid circulated through a panel coil attached to the inside of the weir shell surrounding the downcomer. Therminol® 66* was selected as the heat transfer fluid. The cooling system design called for maintenance of a downcomer skin temperature of 123°C (254°F). The testing of this downcomer design was cut short because of serious cooling problems.

PHASE III - TESTS USING NON-JACKETED DOWNCOMER

Because of the unsatisfactory performance of the jacketed downcomer design a decision was made to test non-jacketed burner downcomers. These

* A product of Monsanto Co., St. Louis, Missouri

Table 2. EVAPORATOR PERFORMANCE

USING WATER-COOLED DOWNCOMER

Parameter	Design	Actual Average
Feed rate, l/sec (gpm)	3.47 (55)	1.70 (27)
Evaporation rate, l/sec (gpm)	2.80 (44)	N. D.[a]
Heat input, Kg-cal/hr (BTU/hr)	6.3×10^6 (25×10^6)	6.91×10^6 (27.4×10^6)
Boiling point, $^\circ$C ($^\circ$F)	88.8 (192)	88.2 (191)
Concentration of product, percent	15-25	20-25
Time to reach final concentration, hrs.	--	24

[a]Not determined

downcomers were fabricated and installed, and the test results are summarized in Table 3.

PHASE IV - TESTS USING INCONEL DOWNCOMER

Due to the failures of the stainless steel downcomers a decision was made to switch to Inconel 601. It was decided that two different downcomer designs would be tried, one jacketed for air cooling, with the return air directed to the burner, and the other non-jacketed as before. The results of this series of tests are summarized in Table 4.

Based upon the results of these tests, two similar downcomers were tested but with the gas nozzles on the sides omitted. The results of these tests are summarized in Table 5.

PHASE V EVAPORATOR PERFORMANCE USING DOWNCOMER COOLED WITH DILUTION AIR

Because of the demonstrated need for a jacketed, cooled downcomer all efforts were directed toward this area. An air-cooled downcomer with dilution air to reduce the firebox temperature to 1203°C (2200°F) was proposed by Thermal Research and Engineering, and this scheme was approved by Anheuser-Busch. In order to reduce development costs it was decided that only one burner would be fitted with the new downcomer. The design of this downcomer is shown in Figure 4. The results of this test series are summarized in Table 6.

EFFLUENT SAMPLING PROGRAM

Numerous samples of the plant effluent were taken during the study period. Due to the difficulties in finding a satisfactory design for the burner downcomers, few samples were obtained while the evaporator was in operation, although numerous samples were taken with the evaporator out of service. Sampling was suspended during the latter phases of the experiment because the evaporator was being tested at 50 percent capacity, and the results obtained during this period would not have been meaningful. Sampling with the evaporator out of operation was suspended because of a lack of data with the evaporator running which would have allowed some comparison of effluent quality. The results of the effluent sampling program are tabulated in the Appendices.

Table 3. EVAPORATOR PERFORMANCE

USING NON-JACKETED DOWNCOMER

Parameter	Design	Actual Average
Feed rate, l/sec (gpm)	3.47 (55)	2.52 (40)
Evaporation rate, l/sec (gpm)	2.80 (44)	2.21 (35)
Heat input, kg-cal/hr (BTU/hr)	6.3×10^6 (25×10^6)	6.05×10^6 (24×10^6)
Boiling point, °C (°F)	88.8 (192)	88.2 (191)
Concentration of product, percent	15 - 25	22
Time to reach final concentration, hrs.	--	30

Table 4. EVAPORATOR PERFORMANCE

USING INCONEL 601 DOWNCOMERS - SERIES 1

Parameter	Design	Actual Average
Feed rate, l/sec (gpm)	3.47 (55)	2.15 (34)
Evaporation rate, l/sec (gpm)	2.80 (44)	1.83 (29)
Heat input, Kg-cal/hr (BTU/hr)	6.3×10^6 (25×10^6)	4.54×10^6 (18×10^6)
Boiling point, °C (°F)	88.8 (192)	88.2 (191)
Concentration of product, percent	15 - 25	20 - 22
Time to reach final concentration, hrs	--	34

Table 5. EVAPORATOR PERFORMANCE

USING INCONEL 601 DOWNCOMERS SERIES 2

Parameter	Design	Actual Average
Feed rate, l/sec (gpm)	3.47 (55)	1.58-1.70 (25-27)
Evaporation rate, l/sec (gpm)	2.80 (44)	1.45 (23)
Heat input, Kg-cal/hr (BTU/hr)	6.3×10^6 (25×10^6)	$3.53\text{-}4.03 \times 10^6$ ($14\text{-}16 \times 10^6$)
Boiling point, °C (°F)	88.8 (192)	88.2 (191)
Concentration of product, percent	15 - 25	21
Time to reach final concentration, hrs	--	N. D.[a]

[a]Not determined

Figure 4. FINAL DOWNCOMER DESIGN

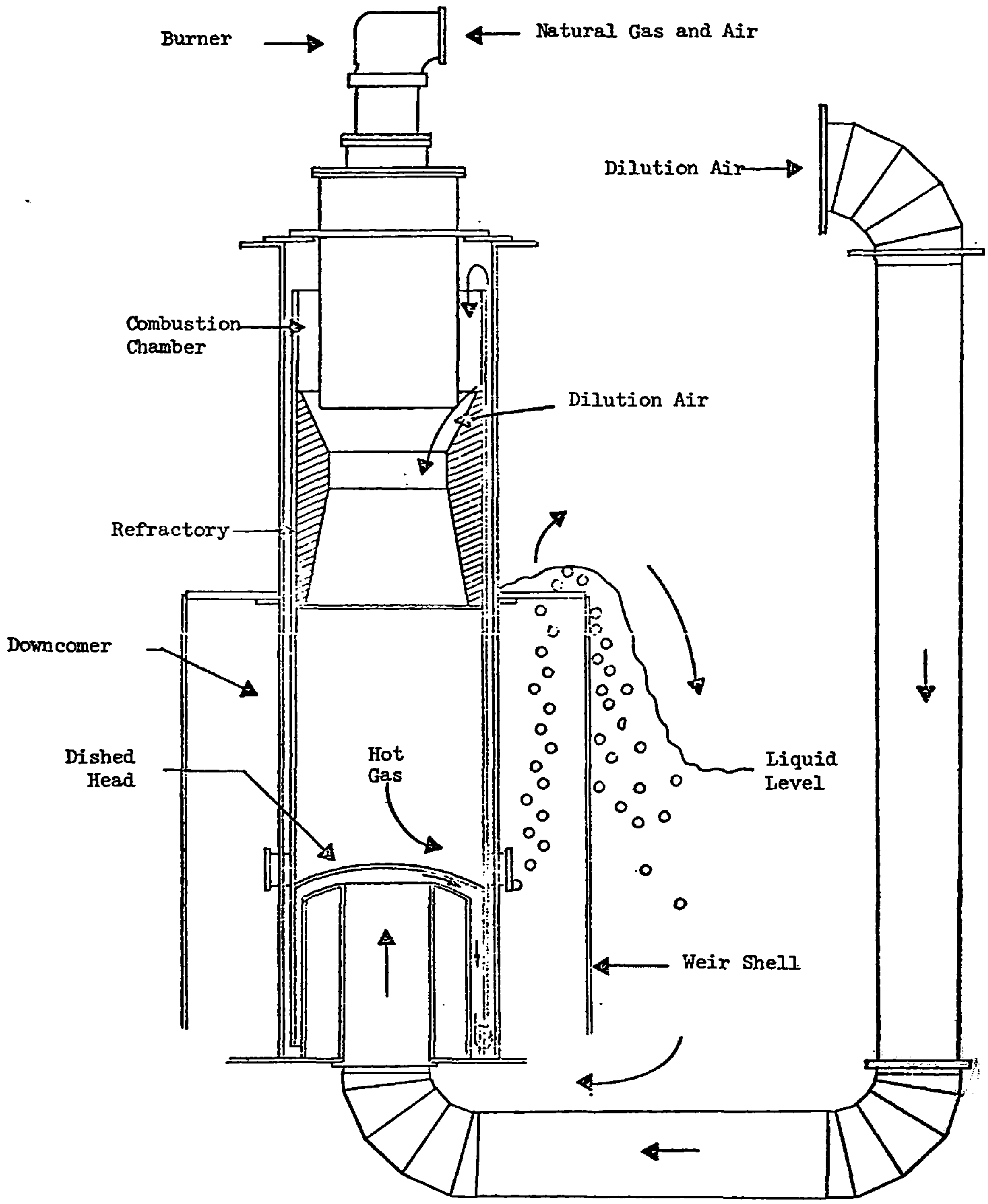


Table 6. EVAPORATOR PERFORMANCE USING JACKETED DOWNCOMER COOLED WITH DILUTION AIR

Parameter	Design[a]	Actual Average
Feed rate, l/sec (gpm)	1.73 (27)	1.55 (24.5)
Evaporation rate, l/sec (gpm)	1.40 (22)	1.32 (21)
Heat input, kg-cal/hr (BTU/hr)	3.2×10^6 (12.5×10^6)	3.2×10^6 (12.5×10^6)
Boiling point, °C (°F)	88.8 (192)	88.2 (191)
Concentration of product, percent	15 - 25	20
Time to reach final concentration, hrs	--	16 - 35

[a]Evaporator operated with only one burner

SECTION VI

DISCUSSION

PROCESS EQUIPMENT

Phase I - Tests Using Water-Cooled Downcomer

Steady state conditions were achieved during this phase which allowed the dry recycle system to be tested. Dried grain was successfully mixed with pressed grain and concentrate (20 percent) and dried.

Analyses of the products of combustion from each burner using an Orsat apparatus indicated near perfect combustion with only negligible excess oxygen. An Orsat apparatus exposes a measured sample of exhaust gases to reagents which absorb carbon dioxide, oxygen, and carbon monoxide; nitrogen is determined by difference. The feed rate was considerably less than design. The heat input required was much higher than expected and a considerable heat loss, largely due to the downcomer cooling system, was discovered. Inspection of the evaporator interior following test runs revealed no build-up of solids on the downcomer jackets or tank surfaces. Minimal charred grain was observed at the burner tip only where the flame directly hits a baffle to divert the hot gases upward and where the inlet feed is injected into the vessel. Small pieces of broken refractory were found at the bottom of the evaporator drain line. After the final test it was discovered that the deflector plate on one downcomer had broken off and fallen to the bottom of the vessel. No cause for this failure was immediately apparent.

Phase II - Tests Using Jacketed Downcomer and Closed Loop Cooling System

Actual tests with this system revealed that a coating of burnt liquor built up on the weir of the downcomer within 31 hours of operation. This coating functioned as an insulator and caused the temperature of the heat transfer oil to reach 171°C (340°F) by the time the test was called off. Inspection of the downcomer deflector plates showed that these had partially broken off from the downcomer. At this time it was also discovered that demister on the evaporator stack had become clogged and a decision was made to remove the demister until a more satisfactory location could be determined. The demister was not in place during the latter phases of the experiment.

Phase III - Tests Using Non-Jacketed Downcomer

The evaporator performed under steady state conditions for 27 hours using this downcomer configuration. Some foaming of the liquor was detected until the 22 percent solids level was reached. During this time, the concentrate from the evaporator was mixed with waste yeast and dried grain and fed to the dryer.

After 57 hours of operation one downcomer failed. The test was terminated and a visual inspection of the interior was made. Fire brick had broken loose on both downcomers due to insufficient support, and the shell on the one downcomer had buckled due to excessive heat.

Data analysis of the first series of tests indicated that the blower was delivering insufficient air for complete combustion of the gas being added, resulting in the poor thermal efficiencies noted. It was determined that an adjustment in the gas flow rate was necessary to establish a proper fuel-air mixture with the blower output, and that a possibility existed that air delivery capacity of the blower might be insufficient for the rate of evaporation desired. It was also discovered that operation of the evaporator without the demister indicated higher than actual evaporation rates, due to significant entrainment of liquor in the stack gases.

Phase IV - Tests Using Inconel Downcomer

Two downcomer designs were evaluated in this test. The non-jacketed downcomer failed after 6 days of operation due to a split of a circumferential weld. The jacketed downcomer remained in operation for 12 days until the test was terminated. A post-test inspection revealed a deflector plate failure on this downcomer.

Performance of the overall system in this test was excellent. All concentrate produced was mixed with dried grain and fed to the dryer with pressed grain and waste yeast. By reducing the firing rate by 25 percent the smoke and odor from the evaporator stack became barely perceptible.

Efficiency checks performed after this series of tests revealed increasing the air to gas ratio did not boost the evaporation rate as had previously been thought. In fact, the evaporation rate dropped off at high air to gas ratios.

Based upon the results of these tests, two similar downcomers were fabricated without gas nozzles on the sides. The evaporator ran for 23 consecutive days in this series of tests. Inspection revealed that the air-cooled downcomer had bulged out in one small area. A large deposit of burnt liquor had formed at the bottom of the downcomer impeding the flow of liquor up inside the weir. Several of the gas outlet holes had started to burn open. The non-jacketed refractory-lined downcomer had burned upon at the lower weld of a metal band which had been welded on to repair a split from a previous test. The deflector plate was in good condition.

Phase V - Evaporator Performance Using Downcomer Cooled with Dilution Air

The redesigned evaporator using a jacketed, cooled downcomer was operated for several extended periods, ranging up to 34 days. Inspection of the downcomer at periodic intervals revealed no build-up of solids or any mechanical damage. At most about 0.6 cm (0.25 in) of "mud" was detected on the downcomer wall and surrounding weir. This material was not caked on and could be easily removed. The final inspection of the evaporator revealed a break in the air piping supplying cooling air to the downcomer.

No further testing or development work was carried out because of gas curtailments which began in late 1972 and carried over into 1973. Gas shortages threatened the ability of the gas supplier to the Houston Brewery to meet its service obligations to its customers. Therefore, the Texas Railroad Commission which regulates gas utilities in that state, authorized the institution of a curtailment plan to assure gas supplies to homes, hospitals, and the like. One curtailment was experienced which lasted several days and shut down all production at the brewery.

EFFLUENT STRENGTH REDUCTION

Initial plans called for a long term study of the brewery effluent both with and without the benefit of the spent liquor evaporator. The decision to use only one burner and downcomer at a time during the latter stages of the development phase restricted the amount of the spent grain liquor which the evaporator could concentrate.

The effects, then, of having an evaporator installation sufficient to concentrate all the spent grain liquor could not be measured. The approximate effect, however, can be determined by deducting the pollutant load from the spent grain liquor, using established data, from the measured pollutant load from the brewery without evaporation of the liquor. This calculation is shown in Table 7 for the Houston Brewery. Projected reductions in B.O.D.$_5$, C.O.D. and suspended solids are all quite significant, ranging from 43.5 percent up to 60.3 percent.

ECONOMICS

Table 8 shows the estimated capital and operating costs of an evaporation system designed for a brewery having a production capacity of 2.35 million hectoliters (2 million barrels) per year. Three situations are illustrated, one using low-cost fuel, assumed to be natural gas at 80¢ per million Kg-cal (20¢ per million BTU), one using fuel at $1.60 per million KG-cal

Table 7. PROJECTED EFFLUENT IMPROVEMENT

Parameter	Flow cu m/day (mgd)	BOD_5 mg/l	BOD_5 Kg/day	BOD_5 (lbs/day)	COD mg/l	COD Kg/day	COD (lbs/day)	S.S. mg/l	S.S. Kg/day	S.S. (lbs/day)
Total effluent with liquor	7400 (1.96)	1,760	13,060	(28,770)	3,040	22,560	(49,690)	850	6,310	(13,890)
Spent grain liquor	300 (0.08)	18,750	5,680	(12,510)	38,150	11,550	(25,450)	12,550	3,800	(8,370)
Total effluent without liquor	7100 (1.88)	1,040	7,360	(16,260)	1,550	11,010	(24,240)	350	2,510	(5,520)
Percent reduction	4.08	40.9	43.5		49.0	51.2		58.8	60.3	

Table 8. ECONOMICS OF ADDING SPENT GRAIN

LIQUOR CONCENTRATOR TO EXISTING DRYING OPERATION

Fuel Cost, $/million Kg-cal	0.80		1.60		3.20	
Evaporator	Submerged Combustion	Multiple-Effect	Submerged Combustion	Multiple-Effect	Submerged Combustion	Multiple-Effect
Capital cost	$425,000	$680,000	$425,000	$680,000	$425,000	$680,000
Annual yield of additional dried grain @ $55.00/metric ton ($50.00/ton)	226,800	226,800	226,800	226,800	226,800	226,800
Incremental costs of operating Concentrator in addition to dryer ($/yr)						
Maintenance @ 5%	21,300	34,000	21,300	34,000	21,300	34,000
Labor	18,000	18,000	18,000	18,000	18,000	18,000
Property tax and insurance	9,500	15,300	9,500	15,300	9,500	15,300
Evaporator fuel (nat. gas)	43,800	--	87,600	--	175,200	--
Evaporator steam	--	28,600	--	45,400	--	78,900
Additional fuel to dry concentrate and screenings/cake	25,200	25,000	50,400	50,400	100,800	100,800
R.O.I., % (assuming 15 yr. life with no salvage value)	15.09	8.09	2.80	2.80	No return on investment	No return on investment

(40¢ per million BTU), and another using relatively high-cost fuel, such as natural gas at \$3.20 per million Kg-cal (80¢ per million BTU), or No. 2 oil at 4¢ per liter (16¢ per gallon). The value assumed for low cost fuel is typical for those areas where natural gas has historically been readily available and there have been few, if any, interruptions to industrial customers. The value assumed for high cost fuel would apply to those areas where natural gas is not available to industrial customers on a year-round basis. This figure allows for an equivalent amount of No. 2 oil to be burned during gas interruption or at all times if necessary.

For each condition two cases are illustrated. The first case utilizes a submerged combustion evaporator system as demonstrated. The second case involves the use of a conventional multiple-effect evaporation with solid bowl centrifuges provided to reduce the suspended solids load and thereby minimize the fouling potential. Three systems such as these have recently become operational in U.S. breweries.

The R.O.I. (Return on Investment) percentages calculated in Table 8 indicate that submerged combustion is the process of choice when fuel at less than \$1.60 per million Kg-cal (40¢ per million BTU) is available. At low fuel cost the return is attractive enough on the investment to suggest its funding irrespective of pollution control consideration. A far different situation is presented for the case of high cost fuel. Here neither submerged combustion nor conventional evaporation can be economically justified on the basis of product recovery alone. In cases where some type of control system is mandatory to reduce waste loadings, conventional evaporation would be far less costly due to its greater efficiency.

SECTION VII

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SECTION VIII

GLOSSARY

$B.O.D._5$ Five-day biochemical oxygen demand. The quantity of oxygen utilized in the biochemical oxidation of organic matter under standard laboratory procedure in five days at 20°C, expressed in milligrams per liter.

Demister - A device for removing entrained liquid from a vapor stream.

Downcomer A cylindrical duct used to direct hot gases from a burner into a liquid from which water is to be evaporated.

Entrainment - The carrying off of a liquid as a fine mist or spray by a vapor rising from a heat exchange surface.

Firebox - Combustion chamber.

Inconel 601 A heat and corrosion resistant nickel-chromium alloy.

Insoluble Solids - Solids removable by laboratory filtering. Suspended solids.

Multiple-Effect Evaporator - A series of evaporative bodies so connected that the vapor from one body is the heating medium for the next body.

Panel Coil - A heat transfer device fabricated from two embossed metal sheets welded to form a series of passes through which a heating or cooling media flows.

Recompression Evaporator - An evaporator in which vapors which have been boiled off the heat exchange surface are compressed to raise the energy level and then fed back inside the heat exchanger where they then condense.

Solid Bowl Centrifuge - A centrifuge which utilizes a spinning cylinder to cause particles to settle out along the wall. Frequently provided with a screw conveyor inside the bowl in order to push collected sediment out of the machine.

Soluble Solids - Total solids less insoluble solids.

Suspended Solids - Insoluble solids.

SWECO® Screen - An eccentric-weighted horizontal disc screen as made by SWECO, Inc.

Total Solids - Residue on evaporation to dryness at 103°C.

SECTION IX

APPENDICES

APPENDIX A - EVAPORATOR TESTS USING

WATER-COOLED DOWNCOMER - SERIES 1

Date Time	Evap. Fuel Valve [illegible]	Levels & Temp. Evap. LI %	Evap. °F	Conc. Tank LI	Conc. Tank °F	Cooling Water Flow Rate 1	Flow Rate 2	Inlet Water Temp.	Out Temp. #1	Out Temp. #2	Temp. Out Evap. Moyno	Set Pt. Feed FCV	Set Pt. Evap. FCV	Set Pt. Conc. Moyno	Specific Gravity Conc.	Set Pt. Dry Recycle	Blower Amps	Pressures Burner Air P 1	Pressures Burner Air P 2
-/21/71 1:05	1 2					92.5	92.5		130	132	121	0	0	0		--			
1:15	1 2					93.5	93.0		132	133	121	0	0	0					
1:25	1 2		184			93.5	93.0		132	133		1.2 psig 14	0	0					
1:35	1 2		184			92.5	93.0		132	134	122	25/18 psig 6	0	0					
1:45	1 2	93	184			93.	92.5		132	134	122	psig 9	0	0					
1:55	1 2	94	184			93.5	93.0		132	133	124	6 psig 5¼	0	0					
2:05	1 2		184			91.0	90.0		135	134	125		0	0			85		
2:17	1 2	98	184			88.	88.		135	134	129	9/11 psig 5½	0	0					
2:25	1 2	98-100	184			87.0	87.5		136	137	130	0 psig 4½	0	0			85		
2:35	1 2	94	184			91.5	91.0		133	134	132	0	0	1/10					
2:45	1 2	92	184			90.5	90.0		133	134	134	8/8 psig 5½	0	2/10			85		
2:55	1 2	94	184			92.5	91.0		132	133	136	7/8 psig 5					85		
3:05	1 2					70.	70.				137								

Date/ Time	Evap. Fuel Valve % Open	Levels & Temp. Evap. LI	°F	LI	°F	Cooling Water Flow Rate 1	2	Inlet Water Temp.	Out #1	Temp. #2	Temp. Out Evap. Moyno	Set Pt. Feed FCV		Set Pt. Evap. FCV	Set Pt. Conc. Moyno	Specific Gravity Conc.	Set Pt. Dry Recycle	Blower Amps	Pressures Burner Air P 1	2
-21-71 3:05	1 2	[illegible]	184			92.0	91.0		131	132	137	6 8	psig 5							
3:15	1 2	[illegible]	184			91.5	90.5		132	133	138	7 8								
3:25	1 2		184			90.5	90.5		132	133	140	10 1.2	psig 5							
3:35	1 2	96	184			92.0	92.0		132	133	140	10 12						65		
3:45	1 2	96				92.5	92.0		131	132	141	10 12		0	2/10					
3:55	1 2	100	184			93.5	92.5		131	132	143	9								
4:10	1 2	100+	184			90.5	90.		131	131	143	2 4	psig 4½							
4:20	1 2	95	184			91.0	91.0		131	132	144	2 4	psig 4½	0	2/10			65		
4:30	1 2	92	184			92.5	91.5		130	132	144	23 25								
4:35	1 2	92									144	10 8-14	psig 5-6							
4:40	1 2	100+	184			92.5	90.0		130	132	144	5 7	psig 5½							
5:00	1 2	[illegible]	184			91.5	92.5		131	132	145	8 10								
5:20	1 2	[illegible]	184			93.0	93.0		130	132	146	14 15	psig 5½							

Date/ Time	Evap. F.C. Valve % Open	Levels & Temp. Evap. LI %	°F	LI	°F	Cooling Water Flow Rate 1	Cooling Water Flow Rate 2	Inlet Water Temp.	Out Temp. #1	Out Temp. #2	Temp. Out Evap. Moyno	Set Pt. Feed FCV	Set Pt. Evap. FCV	Set Pt. Conc. Moyno	Specific Gravity Conc.	Set Pt. Dry Recycle	(Temp.) Blower Amps	Pressures Burner Air F 1	2
4/21/71 5:45	1 2	99	134			90.0	90.5		132	133	146	10 press 11 5¼							
6:15	1 2	100+	134			91.5	91.0		131	132	147	6 psig 6 4 3/4							
6:45	1 2	100+	134			93.0	92.0		130	132	147	10 psig 10 5							
7:15	1 2	100+	134			88.5	88.5		132	133	148	6 psig 7 5					85		
7:45	1 2	100+	134			87.0	87.5		134	133	150	7 psig 8 5							
8:15	1 100 2 100	100+	134			90.	88.		133	133	159				Amps 85		125		
8:45	1 2	100+	134			90.	88.5		131	132	163	0 2			85		125		
9:15	1 2	100+	134			92.5	92.0		130	131	166	10 psig 10-13 4½-5			85		125		
9:45	1 2	100	134			93.0	92.5		130	131	168	10 psig 10 5							
10:15	1 2	100+	134			93.0	92.5		129	130	171	3 psig 4 4½			90				
10:45	1 2	100+	134			[illegible]	92.0		131	130	173	10 psig 10-14 4.5-5.5							
11:15	1 2	100+	134			93.0	93.0		129	130	174	13 psig 15 5.5			90		125		
11:45	1 2	100+	134			93.0	92.0		129	130	175	9 psig 10 5			90		125		

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap. LI %	°F	LI	°F	Cooling Water Flow Rate 1	2	Inlet Water Temp.	Out #1	Temp. #2	Temp. Out Evap. Moyno		Set Pt. Feed FCV	Set Pt. Evap. FCV	Set Pt. Conc. Moyno	Specific Gravity Conc.	Set Pt. Dry Recycle	Blower Amps	Pressures Burner Air P 1	2
1/22/71 12:15 a	1 2	100+	184			93.5	92.5		129	130	176	8 9	press 5					90		
12:45	1 2	100+	184			90.0	89.0		130	131	177	12 14	psig 5					90		
1:15	1 2	100+	184			92.5	92.5		129	130	177	8 8	psig 5					90		
1:45	1 2	100+	184			92.5	91.0		129	130	177	8 9	psig 5					90		
2:15	1 2	100+	184			93.0	91.5		128	129	177	10 12	psig 5.5					90		
2:45	1 2	100+	184			93.0	92.5		128	129	178	10 12	psig 5.5					90		
3:15	1 2	100+	184			93.0	91.5		127	129	177	10 12	psig 5.5					90		
3:45	1 2	100+	184			93.5	92.5		127	128	177	9 10	psig 5					90		
4:15	1 2	100+	184			93.5	92.0		128	129	177	12 14	psig 5					92		
4:45	1 2	100+	184			93.5	92.5		127	129	177	11 12	psig 5.5					90		
5:15	1 2	100+	184			92.5	91.5		126	128	176	10 11	psig 5					90		
5:45	1 2	100+	184			93.0	92.5		126	128	176	10 11	psig 5.5					90		
6:15	1 2	100+	184			93.5	92.0		126	128	176	10 12	psig 5					90		
6:45	1 2	100+	184			93.0	92.0		126	128	176	10 11	psig 5					90		

Date/ Time	Evap. Fuel Valve % Open	Levels & Temp. Evap. LI	°F	LI	°F	Cooling Water Flow Rate 1	Flow Rate 2	Inlet Water Temp.	Out #1	Temp. #2	Temp. Out Evap. Moyno		Set Pt. Feed FCV	Set Pt. Evap. FCV	Set Pt. Conc. Moyno	Specific Gravity Conc.	Set Pt. Dry Recycle	Blower Amps	Pressures Burner Air P 1	2
1/22/71 7:15 a	1 2	100+	184			93.0	92.0		126	128	177	10 11	press 5.5					90		
7:45	1 2	100+	184			93.0	93.0		126	128	178	12 14	psig 6					90		
8:15	1 2	100+	184			89.0	89.0		127	128	178	11 1	psig 15					85		
8:45	1 2	56-58	184			92.5	91.5		126	128	178	13 15	psig 5					90		
9:15	1 2	56-58	184			92.0	92.0		126	128	178	13 15	psig 5.5					91		
9:45	1 2	54-56	184			93.0	92.0		126	128	177	12 14	psig 5.5					92		
10:15	1 2	54	184			89.	85.		127	130	178							93		
10:45	1 2	92	184			90.5	89.	Conc. Tank 30	127	128	178							95		
11:15	1 2	100	184			93.5	94.	40	126	129	178				Feed 20	Air In	Air Burner			
11:45	1 100 2 100	90	184	Temp. Stack 187		93.	92.	56	126	128	178				9	130	3.75	95		
12:15	1 100 2 100	75	176			92.5	92.5	64	118	120	175				0			95		
1:15	1 LF 2 LF	Changed Range	180	137		91.0	92.0	80	79	82	154				0	130	.6	75		
1:30	1 OFF 2 12	16-18	184	180		88.5	89.	78	82	123	153					--	3.75	97		

Date Time	Evap. Feed Valve % Open	Levels & Temp. Evap. LI %	°F	LI	°F	Cooling Water Flow Rate 1	Flow Rate 2	Inlet Water Temp.	Out Temp. #1	Out Temp. #2	Temp. Out Evap. Moyno		Set Pt. Feed FCV	Set Pt. Evap. FCV	Set Pt. Conc. Moyno	Specific Gravity Conc.	Set Pt. Dry Recycle	Pressures Blower Amps	Burner Air F 1	Burner Air F 2
1/22/71 2:15	1 100 2 100	7.	175			92.	92.		119	121	149									
2:45	1 100 2 100	82	185			91.	91.		126	127	147	7 10								
3:15	1 2	79	185	80	158	92.	92.		126	126	144	14 16	psig 5.5				100			
3:45	1 2	87	185	80	157	93.	93.5		125	125	143	10 12	psig 5¼				95			
4:15	1 2	75	185	81	156	92.5	93.0		123	124	142	18 20	psig 6	22						
4:45	1 2	71	185	81	154	93.0	92.5		122	123	141	11 14		21.5			100			
5:15	1 2	71	185	81	154	92.0	92.0		123	124	137	14 16	psig 5.5	--	185		100	125°F	CP 30	
5:45	1 100 2 100	80	185	100	153	92.0	93.0	54	125	124	160			21.5	187			125	2.75	
6:15	1 100 2 100	100+	185	100		88.	90.	58	129	130	167									
6:45	1 100 2 100	100+	185	90	--	90.	88.	66	125	127	177									
7:15	1 100 2 100	100+	185			90.	90.		123	124	180						00			
7:45	1 2	100+	175			92.	90.	74	127	129	170			20						
8:15	1 100 2 100	100+	183			90.	91.	66	127	129	175									

Date/ Time	Evap. Feed Valve % Open		Levels & Temp. Evap. LI 1	°F	LI	°F	Cooling Water Flow Rate 1	2	Inlet Water Temp.	Out #1	Temp. #2	Temp. Out Evap. Moyno		Set Pt. Feed FCV	Set Pt. Evap. FCV	Set. Pt. Conc. Moyno	Specific Gravity Conc.	Set Pt. Dry Recycle	Blower Amps	Pressures Burner Air P 1	2
4/22/71 8:45	1 2	100 100	100+	185	94		90.	91.		129	130	178			32		62%				
9:15	1 2		100+	185	100		90.	90.		130	130	178	22 25	psig 6	30+						
10:15	1 2		100+	185	72-74		90.	90.5		130	130	180	16 18	psig 6	30+						
11:15	1 2		100+	185	38-40		91.5	90.5		130	131	179	7 9	psig 5	30+						
4/23/71 12:15	1 2		100+	185	0		91.0	90.0		129	130	178	0 1	psig 3	30+						
1:15	1 2		78-80	185	30		90.0	90.0		132	133	178	28 30	psig 6.5	24						
2:15	1 2		76-78	185	85		88.5	89.0		134	135	177	18 20	psig 6	24						
3:15	1 2		87-90	185	27		88.0	88.0		135	136	181	22 24	psig 6	27						
4:15	1 2		90-92	185	50	172	89.0	88.5		134	135	181	21 23	psig 6+	28						
5:15	1 2		90-92	185			90.5	90.0		133	134	181	21 23	psig 6+	28						
7:15	1 2		100+	185			90.5	90.0		132	133	180	15 17	psig 6+	29¼						
8:20	1 2		100+	185			91.0	90.0		131	133	177	12 14	psig 5 3/4	30						

APPENDIX B - EVAPORATOR TESTS USING WATER-COOLED DOWNCOMER - SERIES 2

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp.: Evap. LI	Evap. °F	Conc. Tank LI	Stack °F	Cooling Water: Flow Rate 1	Flow Rate 2	Inlet Water Temp.	Out #1	Temp. #2	Temp. Out Evap. Moyno	Flow Controls: Set Pt. Feed FCV		Gas #1	Gas #2	Amp	Gas Press	Pressures: Blower Out P/T	Burner Air P 1	Burner Air P 2
5/14/71 5:05 PM	1 0 2 0	4"/13		0		92	95	78°F			116 113							84-86		
9:20	1 15 2 15	27/87		0		92	95		136	132	143	26/26	psig 4.75	11.25	10.70	100	4.0	84-86		
9:35	1 15 2 15	15/56		0	185	92	96		137/137	134/132	145			12.5	11.90	107	3.9	83-85	22- 29	22- 28
9:55	1 15 2 15	13/42		0		91	95		135	133	147			12.75	12.20	108	3.8- 3.9	83-85		21- 29
10:10	1 15 2 15	17/60		0	190	89	93	76°F	138	135	148			12.25	11.75	105	4.0	83-85	21- 28	21- 29
10:35	1 15 2 15	17/56		0	190	72	95		133	136	148			12.4	12.00	107	3.9	83-86/117	21- 28	21- 29
11:05	1 15 2 15	14.5/50		0	190	91	95		135	131	149	30/30	psig 5.25	12.5	12.1	108- 109	3.9	83-85/115	22- 28	22- 28
11:40	1 15 2 15	1325/43		0	190	93	95		133	130	154			12.25	12.0	109- 110	3.95	83-85/115	22- 30	22- 30
5/15/71 12:15 AM	1 15 2 15	17.0/54		0	189	92	95		135	131	165	35/35	psig 5.75	11.60	11.9	105	3.98	84-85/114	22- 29	21- 29
12:45	1 15 2 15	16.0/51		0	189	90	93.5		137/136	135/134	164	34/34	psig 5.5	11.2	12.1	104	3.9	84-86/115	20- 30	20- 30
1:20	1 15 2 15	14.75/48		0	190	90	94		136/134	133/131	167	37.5/37.5		No Water	12.0	104	3.9+	/113	22- 29	23- 29
2:00	1 15 2 15	14.75/48		0	190	92	95		135/133	132/130	170	31/31	psig 5.5	12.7	12.0	104	3.9+	86-87/111	22- 30	20- 30

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap. LI / °F	Levels & Temp. Conc. Tank LI	Levels & Temp. Stack °F	Cooling Water Flow Rate 1	Cooling Water Flow Rate 2	Cooling Water Inlet Water Temp.	Cooling Water Out Temp. #1	Cooling Water Out Temp. #2	Temp. Out Evap. Moyno	Flow Controls Set Pt.	Flow Controls Feed FCV	Flow Controls Gas #1	Flow Controls Gas #2	Amp	Gas Press	Pressures Blower Out P/T	Pressures Burner Air P 1	Pressures Burner Air P 2
5/14/71 2:35 AM	1 15 2 15	14.25/47	0	190	88	92		135/133	131/130	170	34/34	psig 5.5	12.8	11.9	108	3.9+	85.5-87/111	22-29	20-30
3:00	1 15 2 15	17/55	0		91	94		134	132	171	31/31	psig 5.5	12.8	11.9	108	3.9+	85-86/112		24-29
3:40	1 15 2 15	12/39	0	190	92	94		132/130	130/129	171	40/40	psig 6.0	12.9	11.9	110	3.9+	85-86/110	24-30	24-30
4:15	1 15 2 15	12.75/41	0	191	91	95		132/130	129/127	168	36/36	psig 5.5	12.7	11.9	108	3.9+	85-87/108	23-30	23-31
5:00	1 15 2 15	15.0/50	0	190	91	94		131	128	168	33/33	psig 5.5	12.6	11.9	109	3.9+	85-87/107		24-29
5:45	1 15 2 15	15.5/51	0	190	91	94		131	128	170	31/31	psig 5.5	12.6	11.9	108	3.9+	85-87/107		24-29
6:30	1 2		#1 Burner Out - Coil Burnt																
6:40	1 0 2 15	12.25/40	0	185	91	95		99	125	168	15/15	psig 4.2	--	12.9	89	4.2	91-92/112		24-29
7:25	1 0 2 15	13.0	0	184	91	95		97	124	164	20/20		--	12.8	91	4.2	93/117		23-30
8:00	1 15 2 15		#1 Burner On																
8:00	1 15 2 15	18.0/59	0	191	90	92.5		131	130	162	10/10	psig 4	12.7	11.7	106	3.9+	85-87/118	22-29	20-30
8:55	1 15 2 15	14/46	0	191	82	86		131	130	161	34/34		13.2	12.0	106	3.9+	84-85/122	22-29	22-29
9:35	1 15 2 15	15/50	0	191	85	88	76°F	132	129	163	32/32	psig 5.6	12.75	11.9	106	3.9	84-85/120	22-28	21-27

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap. LI	Evap. °F	Conc. Tank LI	Conc. Tank Stack °F	Cooling Water Flow Rate 1	Flow Rate 2	Inlet Water Temp.	Out #1	Temp. #2	Temp. Out Evap. Moyno	Flow Controls Set Pt. Feed FCV		Gas #1	Gas #2	Amp	Gas Press	Pressures Blower Cut P/T	Burner Air P 1	Burner Air P 2
5/14/71 10:00 AM	1 15 2 15	15/49		0		84	87		132	130	163	34/34	psig 5.7	12.90	12.00	106	2.99	83-85		
10:30	1 15 2 15	15.75/52	190	0	191	85	90	125	132	130	164	33/33	press 5.25	12.75	12.0	106	3.95	83-85/128	22-28	21-29
11:00	1 15 2 15	16.5/55		0	120/146	84	89		132	130	164	31/32-28		12.70	11.9	105	3.98	83-84/127	22-29	22-29
11:35	1 15 2 15	15.75/52	190	0	191	85	88	120	132	129	165	31/30	psig 5.25	12.75	11.9	105	3.95	84-85/127	20-29	22-28
12:00 N	1 15 2 15	15.0/49	189	0	190	83	88	121	132	130	163	31/30	psig 5.5	12.7	12.0	105	4.0	82-83/130	22-27	20-28
12:30	1 15 2 15	12.25/40	190	0	191	84	88	121	128	125	160	33/33	psig 5.75	12.8	12.3	105	4.0	82-83/130	22-27	20-28
1:00 PM	1 15 2 15	10.75/35	190	0	192	84	87	--	127	125	155	35/35	psig 5.75	12.8	12.3	109	4.0	82-84/125	22-28	21-29
1:30	1 15 2 15	10.25/33	190	0	191	82	87	120	127	126	152	37/36	psig 6.0	13.0	12.3	109	4.0	82-83/127	22-28	20-29
2:00	1 15 2 15	10.75/35	190	0	191	85	88	120	127	125	149	37/36	psig 6.0	13.0	12.2	109	4.0	82-83/125	22-28	20-28
2:30	1 15 2 15	11.5/37	--	0	191	87	92	120	125	122	147	35/34	psig 5.75	12.7	12.2	106	4.0	82-83/128	--	22-28
3:30	1 15 2 15	12.0/39	190	0	191	88	92	120	124	122	142	32/32	psig 5.5	12.7	12.1	105	4.0	83-84/128	22-28	22-28
4:30	1 15 2 15	11.0/35	190	0	190	87	92	121	123	121	138	32/31	psig 5.5	12.5	12.2	105	4.0	83-84/130	22-28	22-28
5:30	1 15 2 15	10.5/35	190	0%/7%	190	87	92	120	122	120	153	36/35	psig 6.0	12.6	12.0	105	4.0	82-84/130	22-28	22-28
6:30	1 15 2 15	10.5/35	190	26%	190	87	93	120	122	120	164	36/35	psig 6.0	12.5	12.2	105	4.0	83-84/127	22-28	20-28

Date/Time	Evap. Fuel Valve % Open	Levels & Temp. Evap. LI	Evap. °F	Conc. Tank LI	Stack °F	Cooling Water Flow Rate 1	Flow Rate 2	Inlet Water Temp.	Out #1	Temp. #2	Temp. Out Evap. Moyno	Flow Controls Set Pt. Feed FCV		Gas #1	Gas #2	Amp	Gas Press	Pressures Blower Out P/T	Burner Air P 1	Burner Air P 2
5/15/71 7:30 PM	1 15 / 2 15	10.5/35	190	44%	190	95	90	119	124	122	166	36/35	press 6.0	12.4	12.2	105	4.0	83-84/125	22-28	20-28
8:30	1 15 / 2 15	10.5/35	190	56%	190	95	90	120	121	120	180	36/35	psig 6.0	12.4	12.1	105	4.0	84-85/125	22-28	20-28
9:30	1 15 / 2 15	10.5/35	190	72%	191	92	87	119	121	119	175	36/35	psig 6.0	12.7	12.1	105	4.0	84-85/120	22-28	20-28
10:30	1 15 / 2 15	10.5/35	190	82%	191	90	85	121	125	122	176	36/35	psig 6.0	12.7	12.1	108	4.0	84-85/120	22-28	20-28
11:30	1 15 / 2 15	10.5/35	190	94%	191	90	85	121	125	123	--	36/35	psig 6.0	12.7	11.9	108	4.0	84-85/120	22-28	20-28
5/16/71 12:30 AM	1 15 / 2 15	10.6/35	190	66%/154°F	192	90	86	125	123	122	178	36/36	psig 5.6	12.6	11.8	108	4.0	84-85/117.5	23-28	23-28
1:30	1 15 / 2 15	10.5/35	190	51.0%/153°F	192	90	85	117	112.5	121	166	36/36	psig 5.7	12.5	11.8	108	4.0	85.0/118	22-28	23-28
2:30	1 15 / 2 15	10.5/35.0	190	62%/153	192	91	86	117	123	122	168	36/36	psig 5.8	12.7	11.9	108	4.0	85.0/119	23-28	23-28
3:30	1 15 / 2 15	10.5/35	190		193	90	85	123	122	120	164	36/36		12.5	11.9	108	4.0	85	23-28	23-28
4:30	1 15 / 2 15	10.5/35	190	82%/150	192.5	85	90	121	121	120	161	36/36	psig 5.8	11.7	12.6	108	4.0	85/116	23-28	23-28
5:30	1 15 / 2 15	10.5/35		90%/148	192	85	90	121	122	120	164	36/36	psig 5.8	12.4	11.8	108	4.0	85.5/115°F	23-28	23-28
6:30	1 15 / 2 15	10.5/35	190	98+%/148°F	192	86	90	122	119	120	166	36/36		12.3	11.7	108	3.95	86.0°F/115°F	23-28	23-28
7:25	1 15 / 2 15	10.5/35	190	100%	192	86	91	120	120	119	160	36/36	psig 6.0	12.5	11.9	108	3.95	85.5/115°	23-28	23-28
8:30	1 15 / 2 15	10.5/35	190	100%	192	89	94	120	118	116	168	36/36	psig 6.0	12.5	11.9	108	3.95	85/120	23-28	23-28

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap LI	Evap °F	Conc. Tank LI	Stack °F	Cooling Water Flow Rate 1	Flow Rate 2	Inlet Water Temp.	Out #1	Temp. #2	Temp. Out Evap. Moyno	Flow Controls Set Pt. Feed FCV		Gas #1	Gas #2	Amp	Gas Press	Pressures Blower Out P/T	Burner Air P 1	Burner Air P 2
5/16/71 9:30 AM	1 15 2 15	10.5/35	190	100%	150	85	90	120	118	117	167	36/36	press 5.7	12.5	11.9	106	3.95	84.5/124	22-28	22-28
10:30	1 15 2 15	10.5/35	190	100%	151	85	90	120	119	117	168	36/36	psig 5.8	12.5	11.9	107	3.95	84/127	22-28	22-28
11:30	1 15 2 15	10.5/35	190	100%	153	86	92	130	119	118	168	36/36	psig 5.4	12.6	11.8	105	3.95	83.5/130	22-28	22-28
1:00	1 12 2 12	10.5/33		100%		87	91		120	118		35.5/36		10.5	11.9	105	4.00	83.0		
1:30	1 15 2 15	10.5/35	192	100%		90	95	76	118	116	172	35.5/36		12.75	12.0	105	3.95	82.0/132	22-28	22-28
2:00	1 15 2 15	9.75/32	192	100		88	93	77	119	116	170	35.5/36	psig 5.5	13.0	12.1	107	4.0	83.0/132	22-29	22-28
2:45	1 15 2 15	9.50/31	192			91	96		117	116	178	35.5/36		12.9	11.9	108	3.95	82.0/132	24-28	24-28
3:40	1 15 2 15	9.50/31.5	192			92	97		117	116	172	35.5/36		13.1	12.1	105	3.95	83.0/131	23-28	23-28
4:05	1 15 2 15	31-32/7.5	192			86	90		121	119	173	37.5/38		13.1	12.0	105	3.95	83.0/139	23-28	22-28
5:05	1 15 2 15	32/9.75	192		132	90	94		119	117	173	37.5/38		12.9	12.1	107	3.95	82.0/139	23-28	22-28
5:30	1 15 2 15	31-32/9.6	192			92	96		120	117.5	173	37/38	psig 6.0	12.9	12.2	106	3.95	83/131	22-29	22-29
6:00	1 15 2 15	32/9.75	192	76%		91	95		120	118.0	173	37/39		13.0	12.2	108	3.70	83/128	22-28	19-29
6:30	1 15 2 15	32/9.5	192	70		90	94		119	121	174	37/38		12.9	12.1	108	3.80	83/126	23-29	20-28

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap. LI	Levels & Temp. Evap. °F	Levels & Temp. Conc. Tank LI	Levels & Temp. Stack °F	Cooling Water Flow Rate 1	Cooling Water Flow Rate 2	Cooling Water Inlet Water Temp.	Cooling Water Out Temp. #1	Cooling Water Out Temp. #2	Temp. Out Evap. Moyno	Flow Controls Set Pt. Feed FCV		Flow Controls Gas #1	Flow Controls Gas #2	Amps	Gas Press	Pressures Blower Cut P/T	Pressures Burner Air P 1	Pressures Burner Air P 2
5/16/71 7:00 PM	1 15 2 15	31 9.5	190	62	192	91	95		121	119	173	38 37	press 6.0	12.9	12.1	108	3.90	83 125	29- 29	22- 28
CHANGED LEVEL CONTROLLER TO 10.5 AT 8:45 p.m.																				
9:00	1 15 2 15	35 10.5	191	84	191	91	95		122	120	165	38 37	psig 6.0	12.7	12.0	109	3.9+	84-85 120	24- 29	24- 28
10:10	1 15 2 15	35 10.5			192	91	95		122	120	170	38 38	psig 6	12.7	12.0	110	3.9+	84-85 117	24- 29	24- 28
11:00	1 15 2 15	35 10.5	191	--	192	93	90	120	121	120	165	38 38	psig 6.0	12.7	12.2	110	4.0	84-85 118	24- 29	20- 28
12:00 Mid.	1 15 2 15	35 10.5							119	122		42 42				115		80-81		

APPENDIX C - WATER-COOLED DOWNCOMER TESTS

FEED AND PRODUCT SAMPLES FROM SERIES 1

Date	Sample No.	Sample Description	% T.S.	% S.S.	Ratio SS/IS
4/15/71	1	Composite Sample to Link Belt Screen	8.70		
4/15/71	2	Composite Sample to Link Belt Screen	8.61	Avg.	8.76
4/15/71	3	Composite Sample to Link Belt Screen	8.92		
4/15/71	4	Composite Sample to Link Belt Screen	8.82		
4/15/71	5	Evaporator Feed - Sweco Liq. (Screen Only) 3:30 PM		2.32	.79
4/15/71	6	Evaporator Feed Sweco Liq. (Screen Only) 3:30 PM	5.26		
4/15/71	7	#1 Press Output to Dryer	35.2		
4/15/71	8	#2 Press Output to Dryer	37.9		
4/15/71	9	#3 Press Output to Dryer	42.8		
4/15/71	10	Evaporator Feed Sweco Liq. (Screen & 3 Presses) 6:23 PM	3.09		1.13
4/15/71	12	Evaporator Feed - Sweco Liq. (Screen & 3 Presses) 6:23 PM		1.64	
4/15/71	11	Sample of Initial Liq. in Evap. Taken at Bottom 6:30 PM	4.31		.69
4/15/71	13	Sample of Initial Liq. in Evap. Taken at Bottom 6:30 PM		1.76	
4/16/71	1	Composite Sample to Link Belt Screen	9.02		
4/16/71	2	Composite Sample to Link Belt Screen	8.28	Avg.	8.75
4/16/71	3	Composite Sample to Link Belt Screen	9.22		
4/16/71	4	Composite Sample to Link Belt Screen	8.48		
4/16/71	5	Sample of Initial Liq. in Evap. Taken at Bottom	4.86		.49
4/16/71	6	Sample of Initial Liq. in Evap. Taken at Bottom		1.60	
4/16/71	7	Dust Slurry from Brewhouse	1.77		.362
4/16/71	8	Dust Slurry from Brewhouse		.47	

Date	Sample No.	Sample Description	% T.S.	% S.S.	Ratio SS/IS
4/16/71	9	Composite Sample to Link Belt Screen	8.54		
4/16/71	10	Composite Sample to Line Belt Screen	8.87	Avg.	8.89
4/16/71	11	Composite Sample to Link Belt Screen	9.15		
4/16/71	12	Composite Sample to Link Belt Screen	9.02		
4/16/71	14	Sample from Bottom of Evap. 7:00 PM	3.10		1.14
4/16/71	17	Sample from Bottom of Evap. 7:00 PM		1.65	
4/16/71	15	Sample from Suction Side of Evap. Feed Pump 7:00 PM	2.90		1.00
4/16/71	16	Sample from Suction Side of Evap. Feed Pump 7:00 PM		1.45	
4/16/71	13	Sample of Leakage around Burners	3.06		1.335
4/16/71	18	Sample of Leakage around Burners	1.31	1.75	
4/17/71	1	Sample from Bottom of Evap. Pre Start-Up (11:00 AM)	6.15		
4/17/71	2	Sample from Bottom of Evap. Pre Start-Up (11:00 AM)		1.60	
4/17/71	3	#1 Press - Output to Dryer	40.9		
4/17/71	4	#2 Press Output to Dryer	42.3		
4/17/71	5	#3 Press - Output to Dryer	42.9		
4/17/71	6	Dust Slurry from Brewhouse	1.78		
4/17/71	7	Dust Slurry from Brewhouse		.44	
4/17/71	8	Composite to Link Belt Screen	10.2		
4/17/71	9	Composite to Link Belt Screen	10.2	Avg.	
4/17/71	10	Composite to Link Belt Screen	10.8		
4/17/71	11	Composite to Link Belt Screen	10.6		
4/18/71	1	Thick Material on Floor from Evap.	13.7		
4/18/71	2	Thick Material on Floor from Evap.	13.7		
4/18/71	C-1	Thick Material on Floor from Evap.	13.7		.178
4/18/71	C-2	Thick Material on Floor from Evap.	13.6		
4/19/71	1	Thick Material on Floor from Evap.		2.07	

Date	Sample No.	Sample Description	% T.S.	% S.S.	Ratio SS/IS
4/19/71	2	Composite to Link Belt Screen	7.69		
4/19/71	3	Composite to Link Belt Screen	7.73	Avg.	7.83
4/19/71	4	Composite to Link Belt Screen	7.89		
4/19/71	5	Composite to Link Belt Screen	8.00		
4/19/71	27	Dust Slurry from Brewhouse	1.71		.30
4/19/71	28	Dust Slurry from Brewhouse		.395	
4/19/71	6	Sample to Link Belt Screen Time 2:18	11.90		
4/19/71	7	Sample to Link Belt Screen Time 2:23	11.36		
4/19/71	8	Sample to Link Belt Screen Time 2:28	8.54		
4/19/71	9	Sample to Link Belt Screen Time 2:33	10.90		
4/19/71	10	Sample to Link Belt Screen Time 2:38	11.52		
4/19/71	11	Sample to Link Belt Screen Time 2:43	10.93		
4/19/71	12	Sample to Link Belt Screen - Time 2:48	10.95		
4/19/71	13	Sample to Link Belt Screen Time 2:53	11.81		
4/19/71	14	Sample to Link Belt Screen - Time 2:58	11.55		
4/19/71	15	Sample to Link Belt Screen Time - 3:03	11.20	Avg.	11.53
4/19/71	16	Sample to Link Belt Screen - Time 3:08	11.45		
4/19/71	17	Sample to Link Belt Screen - Time 3:13	11.87		
4/19/71	18	Sample to Link Belt Screen Time - 3:18	12.07		
4/19/71	19	Sample to Link Belt Screen - Time - 3:23	11.65		
4/19/71	20	Sample to Link Belt Screen Time 3:28	11.80		
4/19/71	24	Sample to Link Belt Screen Time 3:33	12.13		
4/19/71	21	Sample to Link Belt Screen Time - 3:38	11.78		
4/19/71	22	Sample to Link Belt Screen Time - 3:43	11.90		
4/19/71	23	Sample to Link Belt Screen - Time - 3:48	12.35		
4/19/71	25	Sample to Link Belt Screen Time - 3:53	12.25		
4/19/71	26	Sample to Link Belt Screen - Time 3:58	12.22		

Date	Sample No.	Sample Description	% T.S.	% S.S.	Ratio SS/IS
4/21/71	1	Liquor to Sewer Brew #6	1.59		
4/21/71	2	Liquor to Sewer - Brew #6		.856	
4/21/71	3	Liquor to Sewer Brew #7	1.29		
4/21/71	4	Liquor to Sewer Brew #7		.713	
4/21/71	5	Evaporator Feed Tank - 9:50 AM	3.40		
4/21/71	6	Evaporator Feed Tank 9:50 AM		1.68	.975
4/21/71	7	Liquor to Sewer - Brew #4 -	.0324		
4/21/71	8	Liquor to Sewer Brew #4		.0188	
4/21/71	9	Sample to Link-Belt Screen Time - 9:30 AM	12.9		
4/21/71	10	Sample to Link-Belt Screen Time 9:35	.06		
4/21/71	11	Sample to Link-Belt Screen - Time 9:40	7.28		
4/21/71	12	Sample to Link-Belt Screen Time - 9:45	14.7		
4/21/71	13	Sample to Link-Belt Screen - Time 9:50	6.94		
4/21/71	14	Sample to Link-Belt Screen - Time - 9:55	9.25		
4/21/71	15	Sample to Link-Belt Screen Time - 10:00	9.78		
4/21/71	16	Sample to Link-Belt Screen - Time 10:05	10.15		
4/21/71	17	Sample to Link-Belt Screen - Time 10:10	11.00		
4/21/71	18	Sample to Link-Belt Screen - Time 10:15	10.40		
4/21/71	19	Sample to Link-Belt Screen Time - 10:20	9.70		
4/21/71	20	Sample to Link-Belt Screen - Time - 10:25	9.8		
4/21/71	21	Sample to Link-Belt Screen Time - 10:30	10.6		
4/21/71	22	Sample to Link-Belt Screen - Time 10:35	11.1		
4/21/71	23	Sample to Link-Belt Screen - Time - 10:40	10.9		
4/21/71	24	Sample to Link-Belt Screen - Time - 10:45	12.2		
4/21/71	29	Sample to Link-Belt Screen - Time - 10:50	12.6		
4/21/71	30	Sample to Link-Belt Screen - Time 10:55	12.5		
4/21/71	31	Sample to Link-Belt Screen - Time - 11:00	12.3		
4/21/71	32	Sample to Link-Belt Screen - Time - 11:05	13.1		
4/21/71	33	Sample to Link-Belt Screen - Time 11:10	12.7		

Date	Sample No.	Sample Description	% T.S.	% S.S.	Ratio SS/IS
4/21/71	27	Liquor to Sewer B.H. D.W. Screen	2.95		
4/21/71	28	Liquor to Sewer B.H. D.W. Screen		1.41	
4/21/71	37	Liquor to Sewer B.H. D.W. Screen	3.93		
4/21/71	38	Liquor to Sewer B.H. D.W. Screen		2.29	
4/21/71	39	Liquor to Sewer B.H. D.W. Screen	3.86		
4/21/71	40	Liquor to Sewer B.H. D.W. Screen		2.04	
4/21/71	34	Evap. Feed 2:00 PM	3.73		.735
4/21/71	36	Evap. Feed - 2:00 PM		1.38	
4/21/71	25	Concentrate 2:00 PM	3.02		
4/21/71	54	Condensate 2:00 PM	1.54		1.07
4/21/71	58	Condensate 2:00 PM		.795	
4/21/71	26	Conc. 3:00 PM	5.22		
4/21/71	42	Evap. Feed - 4:00 PM	3.12		1.30
4/21/71	47	Evap. Feed - 4:00 PM		1.79	
4/21/71	35	Conc. - 4:00 PM	4.85		
4/21/71	44	Conc. - 4:00 PM		1.87	
4/21/71	43	Evap. Feed - 6:00 PM	3.50		1.07
4/21/71	48	Evap. Feed 6:00 PM		1.81	
4/21/71	41	Conc. 6:00 PM	5.83		
4/21/71	45	Conc. - 6:00 PM		2.05	
4/21/71	46	Conc. 7:00 PM	8.05		
4/21/71	50	Conc. - 7:00 PM		2.09	
4/21/71	49	Conc. - 8:00 PM	7.30		
4/21/71	51	Conc. - 8:00 PM		2.84	
4/21/71	53	Evap. Feed - 9:00 PM	3.51		1.14
4/21/71	56	Evap. Feed - 9:00 PM		1.87	
4/21/71	52	Conc. - 9:00 PM	9.4		
4/21/71	57	Conc. - 9:00 PM			

Date	Sample No.	Sample Description	% T.S.	% S.S.	Ratio SS/IS
4/21/71	55	Condensate - 9:00 PM	.39		1.73
4/21/71	59	Condensate - 9:00 PM		.247	
4/21/71	60	Concentrate - 10:00 PM	9.23		
4/21/71	64	Concentrate - 10:00 PM		4.18	
4/21/71	62	Evap. Feed - 11:00 PM			
4/21/71	67	Evap. Feed - 11:00 PM		1.78	
4/21/71	61	Concentrate 11:00 PM	10.9		
4/21/71	65	Concentrate 11:00 PM		4.75	
4/21/71	63	Concentrate - 12:00 MN	11.42		
4/21/71	66	Concentrate - 12:00 MN		5.2	
4/22/71	68	Evap. Feed - 1:00 AM	3.47		.875
4/22/71	69	Evap. Feed - 1:00 AM		1.62	
4/22/71	1	Concentrate - 1:00 AM	12.8		
4/22/71	3	Concentrate - 1:00 AM		5.37	
4/22/71	2	Concentrate 2:00 AM	13.6		
4/22/71	4	Concentrate - 2:00 AM		5.62	
4/22/71	5	Evap. Feed - 3:00 AM	3.42		.78
4/22/71	7	Evap. Feed - 3:00 AM		1.50	
4/22/71	6	Concentrate - 3:00 AM	13.4		
4/22/71	8	Concentrate 3:00 AM		.189	
4/22/71	9	Concentrate - 4:00 AM	15.5		
4/22/71	10	Concentrate - 4:00 AM		5.78	
4/22/71	11	Evap. Feed - 5:00 AM	3.49		.75
4/22/71	13	Evap. Feed - 5:00 AM		1.50	
4/22/71	12	Concentrate - 5:00 AM	13.5		
4/22/71	14	Concentrate - 5:00 AM		6.75	
4/22/71	15	Concentrate - 6:00 AM	14.4		
4/22/71	16	Condensate - 6:40 AM	2.99		
4/22/71	17	Condensate - 6:40 AM		1.64	

Date	Sample No.	Sample Description	% T.S.	% S.S.	Ratio SS/IS
4/22/71	19	Evap. Feed 7:00 AM	3.45		
4/22/71	20	Evap. Feed 7:00 AM		1.47	.74
4/22/71	18	Concentrate 7:00 AM	15.0		
4/22/71	21	Concentrate 8:00 AM	15.7		
4/22/71	23	Evap. Feed - 9:00 AM	3.73		
4/22/71	24	Evap. Feed 9:00 AM		1.59	.74
4/22/71	22	Concentrate 9:00 AM	16.5		
4/22/71	C-3	Concentrate - 10:00 AM	16.9		
4/22/71	C-4	Concentrate - 11:00 AM	17.2		
4/22/71	C-5	Concentrate 12:00 PM	17.9		
4/22/71	25	Evap. Feed 1:00 PM	3.89		
4/22/71	26	Evap. Feed 1:00 PM		1.90	.95
4/22/71	C-6	Concentrate 1:00 PM	14.5		
4/22/71	27	Evap. Feed - 3:00 PM	4.18		
4/22/71	28	Evap. Feed - 3:00 PM		1.90	.83
4/22/71	C-7	Concentrate 3:00 PM	17.3		
4/22/71	C-8	Concentrate - 4:00 PM	17.4		
4/22/71	29	Evap. Feed - 5:00 PM	3.19		
4/22/71	30	Evap. Feed - 5:00 PM		1.80	1.39
4/22/71	C-9	Concentrate 5:00 PM	17.0		
4/22/71	C-10	Concentrate - 6:00 PM	19.8		
4/22/71	C-11	Concentrate - 7:00 PM	21.7		
4/22/71	C-13	Concentrate - 8:00 PM	17.0		
4/22/71	C-14	Concentrate 10:00 PM	14.8		
4/23/71	C-15	Concentrate - 12:15 AM	13.8		
4/23/71	C-16	Concentrate 2:00 AM	14.6		
4/23/71	C-17	Concentrate - 4:00 AM	13.7		
4/23/71	31	Evap. Feed - 6:00 AM	3.35		
4/23/71	32	Evap. Feed - 6:00 AM		1.87	1.26

Date	Sample No.	Sample Description	% T.S.	% S.S.	Ratio SS/IS
4/23/71	C-12	Concentrate 6:00 AM	13.1		
4/23/71	C-18	Concentrate 8:00 AM	13.25		

APPENDIX D WATER-COOLED DOWNCOMER TESTS

FEED AND PRODUCT SAMPLES FROM SERIES 2

Date	Time	Sample No.	Sample Description	% T.S.	% S.S.	Ratio SS/TS
5/14/71	5:00 PM	1	Evap. Feed Tank Bottoms	3.71		1.12
5/14/71	5:00	2	Evap. Feed Tank Bottoms		1.96	
5/14/71	5:30	3	Evap. Bottom Prior to Startup	5.30		.64
5/14/71	5:30	4	Evap. Bottom Prior to Startup		2.07	
5/14/71	5:30	5	Evap. Feed	3.71		1.02
5/14/71	5:30	6	Evap. Feed		1.85	
5/14/71	7:30	7	Evap. Concentrate	4.17		
5/14/71	8:30	8	Evap. Concentrate	4.55		
5/14/71	9:30	9	Evap. Concentrate	4.76		
5/14/71	9:30	10	Evap. Feed	3.68		1.11
5/14/71	9:30	11	Evap. Feed		1.94	
5/14/71	10:30	12	Evap. Concentrate	5.13		
5/14/71	11:30	15	Evap. Concentrate	5.70		
5/14/71	11:30	13	Evap. Feed	3.68		1.13
5/14/71	11:30	14	Evap. Feed		1.95	
5/15/71	1:30 AM	16	Evap. Feed	3.60		1.05
5/15/71	1:30	18	Evap. Feed		1.84	
5/15/71	1:30	19	Stack Condensate	.214		
5/15/71	2:30	20	Evap. Concentrate	10.29		
5/15/71	2:30	21	Evap. Concentrate - Cenco	10.99		
5/15/71	3:30	22	Evap. Feed	3.56		1.035
5/15/71	3:30	23	Evap. Feed		1.81	
5/15/71	3:30	24	Evap. Concentrate	11.10		
5/15/71	4:30	25	Evap. Concentrate	11.62		
5/15/71	5:30	28	Evap. Feed	3.69		.995
5/15/71	5:30	29	Evap. Feed		1.84	

Date	Time	Sample No.	Sample Description	% T.S.	% S.S.	Ratio SS/IS
5/15/71	5:30 AM	30	Evap. Concentrate	12.75		
5/15/71	6:15	31	Evap. Concentrate	14.92		
5/15/71	:15	27	Evap. Concentrate	13.00		
5/15/71	7:30	33	Evap. Feed	3.47		1.44
5/15/71	7:30	35	Evap. Feed		2.05	
5/15/71	7:30	34	Evap. Concentrate	13.62		
5/15/71	•7:30	32	Evap. Concentrate Cenco	11.65		
5/15/71	8:30	36	Evap. Concentrate	14.15		
5/15/71	9:30	40	Evap. Feed	3.71		1.12
5/15/71	9:30	41	Evap. Feed		1.96	
5/15/71	9:30	37	Evap. Concentrate	14.90		
5/15/71	9:30	39	Stack Condensate	.1043		
5/15/71	10:30	38	Evap. Concentrate	16.60		
5/15/71	11:30	43	Evap. Concentrate	16.3		
5/15/71	11:30	44	Evap. Feed	3.52		1.17
5/15/71	11:30	45	Evap. Feed		1.90	
5/15/71	12:00 PM	42	Evap. Concentrate - Cenco	17.9		
5/15/71	12:30	47	Evap. Concentrate	16.8		
5/15/71	1:30	50	Evap. Feed	3.54		1.17
5/15/71	1:30	51	Evap. Feed		1.91	
5/15/71	1:30	49	Evap. Concentrate	16.7		
5/15/71	2:30	48	Evap. Concentrate	19.1		
5/15/71	2:30	46	Evap. Concentrate - Cenco	16.15		
5/15/71	3:30	1	Evap. Concentrate	16.6		
5/15/71	4:00	52	Evap. Concentrate - Cenco	17.6		
5/15/71	3:30	3	Evap. Feed	3.34		1.21
5/15/71	3:30	4	Evap. Feed		1.83	

Date	Time	Sample No.	Sample Description		% T.S.	% S.S.	Ratio SS/IS
5/15/71	4:15 PM	5	Stack Condensate		.173		
5/15/71	4:30	2	Evap. Concentrate		16.6		
5/15/71		6	Evap. Concentrate		16.7		
5/15/71	5:30	7	Evap. Feed		3.26		
5/15/71	5:30	8	Evap. Feed			1.85	1.31
5/15/71	6:30	9	Evap. Concentrate		19.7		
5/15/71	6:30	10	Evap. Concentrate	Cenco	19.2		
5/15/71	7:30	11	Evap. Feed		3.27		
5/15/71	7:30	14	Evap. Feed			1.87	1.335
5/15/71	7:30	12	Evap. Concentrate		23.2		
5/15/71	7:30	13	Evap. Concentrate	Cenco	19.5		
5/15/71	8:30	16	Evap. Concentrate		21.2		
5/15/71	8:30	15	Evap. Concentrate	Cenco	22.3		
5/15/71	9:30	18	Evap. Concentrate		20.2		
5/15/71	9:30	17	Evap. Concentrate -	Cenco	18.8		
5/15/71	10:30	19	Evap. Feed		3.07		
5/15/71	10:30	22	Evap. Feed			1.72	1.275
5/15/71	10:30	20	Evap. Concentrate		20.0		
5/15/71	10:30	21	Evap. Concentrate	Cenco	19.7		
5/15/71	11:30	23	Evap. Concentrate		23.0		
5/15/71	11:30	24	Evap. Concentrate -	Cenco	22.3		
5/16/71	12:30 AM	25	Evap. Concentrate		20.8		
5/16/71	12:30	26	Evap. Concentrate -	Cenco	21.4		
5/16/71	1:30	27	Evap. Feed		2.99		
5/16/71	1:30	30	Evap. Feed			1.59	1.135
5/16/71	1:30	28	Evap. Concentrate		24.0		
5/16/71	1:30	29	Evap. Concentrate -	Cenco	22.0		

Date	Time	Sample No.	Sample Description	% T.S.	% S.S.	Ratio SS/IS
5/16/71	2:30 AM	31	Evap. Concentrate	20.9		
5/16/71	2:30	32	Evap. Concentrate - Cenco	22.3		
5/16/71	3:30	33	Evap. Concentrate	22.0		
5/16/71	3:30	34	Evap. Concentrate Cenco	21.4		
5/16/71	4:30	37	Evap. Feed	3.47		1.27
5/16/71	4:30	38	Evap. Feed		1.94	
5/16/71	4:30	35	Evap. Concentrate	21.8		
5/16/71	4:30	36	Evap. Concentrate - Cenco	22.0		
5/16/71	5:30	39	Evap. Concentrate	24.8		
5/16/71	5:30	40	Evap. Concentrate Cenco	22.8		
5/16/71	6:30	41	Evap. Concentrate	21.8		
5/16/71	6:30	42	Evap. Concentrate Cenco	22.8		
5/16/71	7:30	43	Evap. Feed	3.58		1.22
5/16/71	7:30	44	Evap. Feed		1.97	
5/16/71	7:30	46	Evap. Concentrate	23.1		
5/16/71	7:30	45	Stack Condensate	.343		
5/16/71	8:30	47	Evap. Concentrate	24.8		
5/16/71	9:30	49	Evap. Concentrate	24.6		
5/16/71	10:30	50	Evap. Feed	3.75		2.15
5/16/71	10:30	51	Evap. Feed		2.56	
5/16/71	10:30	52	Evap. Concentrate	25.0		
5/16/71	11:30	53	Evap. Concentrate	24.9		
5/16/71	1:30 PM	54	Evap. Concentrate	28.2		
5/16/71	1:30	56	Evap. Feed	3.94		1.77
5/16/71	1:30	58	Evap. Feed		2.52	
5/16/71	2:30	55	Evap. Concentrate	27.9		
5/16/71	3:30	59	Evap. Concentrate	28.2		

Date	Time	Sample No.	Sample Description		% T.S.	% S.S.	Ratio SS/IS
5/16/71	4:00 PM	57	Evap. Concentrate	Cenco	26.9		
5/16/71	4:30	62	Evap. Feed		4.20		
5/16/71	4:30	61	Evap. Feed			2.42	1.36
5/16/71	4:30	60	Evap. Concentrate		28.2		
5/16/71	5:30	63	Evap. Concentrate		27.8		
5/16/71	6:30	2	Evap. Concentrate		26.0		
5/16/71	6:30	3	Evap. Concentrate	Cenco	27.3		
5/16/71	7:30	64	Evap. Feed		3.71		
5/16/71	7:30	1	Evap. Feed			2.35	1.73
5/16/71	7:30	4	Evap. Concentrate		26.7		
5/16/71	7:30	5	Evap. Concentrate	Cenco	26.8		
5/16/71	8:30	6	Evap. Concentrate		24.6		
5/16/71	8:30	7	Evap. Concentrate	Cenco	23.2		
5/16/71	9:30	8	Evap. Concentrate		26.4		
5/16/71	9:30	9	Evap. Concentrate	Cenco	26.2		
5/16/71	10:30	10	Evap. Feed		3.69		
5/16/71	10:30	13	Evp. Feed			2.09	1.31
5/16/71	10:30	11	Evap. Concentrate		25.5		
5/16/71	10:30	12	Evap. Concentrate	Cenco	21.5		
5/16/71	11:30	14	Evap. Concentrate		25.2		
5/16/71	11:30	15	Evap. Concentrate -	Cenco	26.8		
5/17/71	12:30 AM	16	Evp. Concentrate		25.3		
5/17/71	12:30	17	Evap. Concentrate -	Cenco	27.8		
5/17/71	1:30	19	Evap. Concentrate		26.1		
5/17/71	1:30	18	Evap. Concentrate	Cenco	25.9		
5/17/71	1:30	20	Evap. Feed		3.58		
5/17/71	1:30	21	Evap. Feed			2.03	1.31

Date	Time	Sample No.	Sample Description		% T.S.	% S.S.	Ratio SS/IS
5/17/71	2:30 AM	22	Evap. Concentrate		24.6		
5/17/71	2:30	23	Evap. Concentrate	Cenco	25.6		
5/17/71	3:30	24	Evap. Concentrate		22.8		
5/17/71	3:30	25	Evap. Concentrate	Cenco	22.0		

APPENDIX E EVAPORATOR TESTS USING

WATER-COOLED DOWNCOMER ORSAT ANALYSES

Date	Time	Sample Point	% CO_2	% O_2	% CO	% Diff. (% N_2) + (% Other)
5/11/71	4:30 PM	Stack	5.4	6.7	0.0	87.9
5/11/71	8:30 PM	Stack	7.0	3.4	0.0	89.6
5/11/71	9:45 PM	Stack	6.4	2.4	0.0	91.2
5/11/71	10:30 PM	Stack	6.6	4.2	0.0	89.2
5/12/71	4:45 PM	Stack	7.0	3.2	0.0	89.2
5/13/71	1:30 PM	Burner #2	10.4	0.0	0.0	89.6
5/13/71	2:30 p.m.	Burner #1	8.8	0.2	0.0	91.0
5/13/71	3:00 PM	Burner #1	9.4	0.2	0.0	90.4
5/13/71	4:00 PM	5 ft. Into Stack	7.8	1.2	0.0	91.0
5/13/71	4:30 PM	3 ft. Into Stack	8.3	.9	0.0	90.8
5/15/71	12:30 AM	Burner #1	10.0	0.4	0.0	89.6
5/15/71	1:15 AM	Burner #2	10.8	0.2	0.0	89.0
5/15/71	1:45 AM	Stack	5.9	2.5	0.0	91.6

APPENDIX F - EVAPORATOR TESTS USING

JACKETED DOWNCOMER AND CLOSED LOOP

COOLING SYSTEM

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap. LI	Levels & Temp. Evap. °F	Levels & Temp. Therminol LI	Levels & Temp. Therminol Psig	Therminol In Temp. #1	Therminol In Temp. #2	Therminol Out Temp. #1	Therminol Out Temp. #2	Stack Temp.	Temp. Out Evap. Moyno	Burners Gas Orifice ΔP #1	Burners Gas Orifice ΔP #2	Burners Gas Press Psig	Burners Burner Air ΔP #1	Burners Burner Air ΔP #2	Blower Output Amps	Blower Output Flow Feed	Press	Drex	Unit Press
9/2/71 11:15 A	1 1 2 1	24/7.5	122					150	170		122	2.3	2.2	4.2			64	0	88		
11:30	1 6 2 6	45/14	123	11	7.5/7.8	230	165	245	220	186	123	5.6	5.1	4.1	10-15	5-25	94		84.25		
11:45	1 9 2 9	43/13	12		8.0/7.8	230	240	265	240	192	122	9.25	9.30	4.05	15-25	20-30	110		78		
12:00 N	1 9 2 9	37/11.5	122					265	245		122	9.40	9.70	4.00			110	40	76.5		
12:15	1 9 2 9	38/12.0	176	12.0	7.7/7.8	235	245	270	245	192	176	11.80	9.50	3.95	15-20	15-30	109	50	77.0		
12:30	1 9 2 9	47/14.5						270	250		183	11.50	9.10	4.05			108		78.0		
1:00 P	1 9.0 2 9.2	57/17.5	191	12.0	7.8/8.0	245	240	270	250	193	191	10.6	8.8	4.00	15-20	15-30	104	39	78.0		
1:15	1 9.0 2 9.2	70/21.5						275	250			10.25	8.8	4.05			102	38	79.5		
1:30	1 8.9 2 9.1	64/19.5	192		8.0/8.0	245	235	275	250	194	192	10.75	8.7	4.05	13-20	18-20	104	39	79.0		
1:45	1 8.8 2 9.1	60/	193					275			193	10.8	9.1	4.0			106	42	79.0		
2:00	1 9.0 2 9.2	59/18	192	12+	8.0/8.0	245	235	275	250	193	192	11.9	8.8	4.05	15-22	20-30	107	41/42	80		

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap. LI	Evap. °F	Therminol LI	Therminol Psig	Therminol In Temp. #1	Therminol In Temp. #2	Therminol Out Temp. #1	Therminol Out Temp. #2	Stack Temp.	Temp. Out Evap. Moyno	Burners Gas Orifice ΔP #1	Burners Gas Orifice ΔP #2	Burners Gas Press Psig	Burners Burner Air ΔP #1	Burners Burner Air ΔP #2	Blower Output Amps	Blower Output Flow Feed	Press	Drex	Unit Press
9/2/71 2:15 P	1 9.9 2 9.1	57/17	192					275			192	10.75	8.9	4.00			108		79.5		
3:45	1 9 2 9	43/13	168		6.2/8.4	245	230	270	250	192	168	11.5	9.6	4.0	15-25	15-35	112	60	77		
4:15	1 9 2 9	42/12.8	170	14	8.3/7.8	245	232	273	250	192	170	11.35	10.0	4.0	15-25	15-35	106	60	78		
4:45	1 9.25 2 9.75	52/16.5	179	14	8.5/7.9	249	232	275	252	193	179	11.3	9.6	4.0	14-25	15-32	108	50	78.5		
5:15	1 9.25 2 9.75	58/18.2	188	14	8.4/8.0	250	234	278	252	193	188	11.1	9.4	4.0	10-20	15-35	104	50	78.5		
5:45	1 4.0 2 9.75	60/18	189	14	8.0		235		250	187	189		10.3	4.2		15-40	96	24	84		
6:15	1 2 9.75	57/17.5	182	10.5	7.2		235		250	186	182		10.4	4.2		15-35	88	28	86		
6:45	1 9.0 2 9.8	64/20	186		7.5/5.5	247	230	275	250	194	186	10.5	9.4	4.0	15-20	20-25	104	45	80		
7:15	1 9.0 2 9.2	69/16.5	185	11.0	9.0/9.0	250	230	275	250	194	185	10.25	8.5	4.0	15-20	20-30	104	45	80		
7:45	1 9.0 2 9.2	66/20.5	187		9.0/9.0	250	230	275	250	194	187	10.35	8.4	4.05	15-20	20-25	103	47	81		
8:15	1 9.0 2 9.4	81/25.5	190					275	250		190	9.75	8.4	4.05			102	39	82		
8:45	1 9.0 2 9.4	87/23.5	191		9.2/9.0	250	235	275	250	194	189	9.90	9.0	4.00	15-20	50-25	102	39	81.75		
9:15	1 9.0 2 9.4	86/26	190					275	250		160	9.5	8.6	4.0			100	37	82.5		

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap LI	Evap °F	Therminol LI	Therminol Psig	Therminol In Temp. #1	Therminol In Temp. #2	Therminol Out Temp. #1	Therminol Out Temp. #2	Stack Temp.	Temp. Out Evap. Moyno	Burners: Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press Psig	Burner Air ΔP #1	Burner Air ΔP #2	Blower Output Amps	Flow Feed	Press	Drex	Unit Press
9/2/71 9:45 P	1 9.0 2 9.4	77/23	191	12"	9.2/9.0	250	230	275	250	194	191	9.9	9.0	4.1	15-20	15-25	103.4	42	81.5		
10:15	1 9.0 2 9.5	78/23.5	188					275	250		188	9.8	8.8	4.0			102	42	81.0		
10:45	1 9.0 2 9.6	79/24	187	12"	9.5/9.0	250	232	280	255	194	187	9.7	8.8	4.0	10-20	10-30	100	40	82		
11:15	1 9.0 2 9.6	75/23	187					280	255		187	9.9	9.0	4.0			102	41	81.5		
11:45	1 9.0 2 9.6	73/22.5	185	14"	9.2/9.3	255	235	280	255	194	185	9.9	8.7	4.0	12-20	15-30	104	42	82.0		
9/3/71 12:15 A	1 9.0 2 9.6	74.5/23	184					280	258		184	9.8	8.8	4.0			100	42	81.5		
12:45	1 9.0 2 9.6	75/23	183		9.2/8.9	250	235	280	258	194	183	9.65	8.6	4.0	13-20	20-25	100	42	81.5		
1:15 A	1 9.0 2 9.6	75/23	183					280	258		183	9.7	8.6	4.0			100	42	81.5		
1:45	1 9.0 2 9.6																				
2:15	1 9.0 2 9.6	78/24	182		9.4/9.0	260	238	282	260	195	182	9.3	8.5	4.0	15-20	18-25	102	42	81.5		
3:15	1 9.0 2 9.6	80.5/24.75	182		9.2/8.9	260	240	288	261	195	182	9.15	8.3	4.05	13-21	17-24	100	41	82		
4:15	1 9.0 2 9.6	81/24.8	181		9.3/9.1	270	242	292	265	195	181	9.0	8.2	4.05	15-20	16-24	99	40	82.5		
5:15	1 9.0 2 9.6	81/24.75	181		9.4/9.0	270	243	290	265	195	181	9.0	8.15	4.05	15-20	20-25	100	40	82.0		

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap. LI	Evap. °F	Therminol LI	Therminol Psig	Therminol In Temp. #1	In Temp. #2	Out Temp. #1	Out Temp. #2	Stack Temp.	Temp. Out Evap. Moyno	Burners Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press Psig	Burner Air ΔP #1	Burner Air ΔP #2	Amps	Blower Output Flow Feed	Press	Drex	Unit Press
9/3/71 6:15 A	1 9.0 2 9.6	77 / 23.5	176		9.0 / 8.7	280	255	302	268	195	176	9.0	8.4	4.05	13-23	18-26	98	44	82		
8:15	1 9.0 2 OFF	55 / 16.75	171		9.0 / 0.5	295	185	311	165	185	171	10.6	0.1	4.2	20-25	206		20.5	87		
9:15	1 9.0 1 9.45	77 / CUT	173					315	268		173	9.0	8.0	4.0				46			
9:45	1 9.0 2 9.4	77 / 23.5		0	8.8 / 9.8	295	250	320	270	195	177	9.0	8.1	4.1	10-20	15-25	97	44	83		
10:15	1 92 2 92	77 / 23.5						320	270		179	9.3	8.0	4.1			97	47	82		
11:15	1 9.1 2 9.1	77 / 23.5			8.4 / 8.6	300	255	320	270	195	178	9.25	8.0	4.0	10-20	15-25	98	50	82		
12:15 P	1 9.1 2 9.1	78 / 23.5	179		8.8 / 9.2	300	255	320	270	195	179	9.50	8.1	4.05	10-20	15-25	100	50	82		
1:15	1 9.1 2 9.1	77 / 23.5			8.8 / 8.5	300	255	315	270	195	181	9.50	8.6	4.05	10-20	15-25	102	50	81.25		
2:15	1 9.1 2 9.3	78 / 23.5			8.0 / 8.5	300	260	315	270	195	183	9.60	8.8	4.05	10-20	15-25	100	47	81		
3:15	1 9.0 2 9.1	72 / 21.5			8.0 / 8.0	290	260	240	275	195	176	9.70	8.7	4.1	12-18	15-25	100	48	81		
3:45	1 9.0 2 9.3	79 / 23.25						315	275		178	9.5	8.4	4.1			100	48	81.5		
4:15	1 9.0 2 9.3	77 / 23.25	18"	10"	8.00 / 8.25	300	260	320	275	195	180	9.5	8.6	4.1	15-20	15-20	100	48	81.5		
5:15	1 9.1 2 9.3	77 / 23.50	16"		8.0 / 8.0	300	260	320	275	195	181	9.4	8.5	4.05	10-18	15-25	100	48	81.0		

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap. LI	Levels & Temp. Evap. °F	Levels & Temp. Therminol LI	Levels & Temp. Therminol Psig	Therminol In Temp. #1	Therminol In Temp. #2	Therminol Out Temp. #1	Therminol Out Temp. #2	Stack Temp.	Temp. Out Evap. Moyno	Burners Gas Orifice ΔP #1	Burners Gas Orifice ΔP #2	Burners Gas Press Psig	Burners Burner Air ΔP #1	Burners Burner Air ΔP #2	Blower Output Amps	Blower Output Flow Feed	Press	Drex	Unit Press
9/3/71 6:15 P	1 9.0 2 9.35	78 23.5	19.4	10"	8.3 8.3	310	265	325	280	195	178	9.4	8.4	4.05	10-20	10-30	100	45	81.5		
7:15	1 9.5 2 9.4	78 23.5	19.5	10.5	8.0 8.3	310	265	325		195	178	9.7	8.4	4.0	10-20	10-30	98	45	81.5		
9/8/71 5:50 P	1 6 2 6	14 43		24+"	7.50 7.25	240	280	240	225	190	165	7.3	6.0	4.1	15-20	20-25	94	20	83.5	30	2.4
6:20	1 9.2 2 8.8	16 50						255	250		170	10.10	9.1	4.05			100	80	80.0	86	
6:50	1 8.9 2 9.3	15.5 51		24+"	7.7 7.6	250	213	278	255	192	191	10.6	9.0	4.0	13-25	15-30	102	50	79	88	10.8
7:20	1 8.9 2 9.3	22.5 70						279	255		191	9.7	8.6	4.05			100	48	81	86	
7:50	1 8.8 2 9.3	25.5 96		24+	7.8 7.7	250	215	279	255	193	191	9.2	8.2	4.05	12-20	10-28	99	38	82	86	
8:20	1 8.85 2 9.3	20.5 69						279	257		192	9.8	8.6	4.05			101	40	81	86	
8:50	1 8.8 2 9.3	19.5 63		24+	7.7 7.7	252	215	280	257	192	192	9.9	8.8	4.0	12-30	12-23	102	42	81	87	11.8
9:50	1 9.2 2 9.4	23.0 75		24-	6.2 5.7	220	215	280	258	195	191	9.7	8.7	4.05	15-25	12-20	106	42	81.5	88	10.0
10:30	1 2				7.5 7.7	249	215			192						12-20	10-25				13.0
10:50	1 9.25 2 9.65	23.0 73		24+	7.5 7.5	255	216	280	259	193	190	9.9	8.8	4.0	12-20	15-27	102	42	81.0	91	11.0

Date/Time	Evap. Fuel Valve to Open	Levels & Temp. Evap. LI	Levels & Temp. Evap. °F	Levels & Temp. Therminol LI	Levels & Temp. Therminol Psig	Therminol In Temp. #1	Therminol In Temp. #2	Therminol Out Temp. #1	Therminol Out Temp. #2	Stack Temp.	Evap. Out Evap. Moyno	Burners Gas Orifice ΔP #1	Burners Gas Orifice ΔP #2	Burners Gas Press Psig	Burners Burner Air ΔP #1	Burners Burner Air ΔP #2	Blower Output Amps	Blower Output Flow Feed	Press	Drex	Unit Press
9/8/71 11:50 P	1 9.25 2 9.7	26.0	83	24	8.6 9.0	235	218	272	259	190	190	9.7	8.7	4.05	10-20	15-25	104	39	81.5	88	13±
9/9/71 12:50 A	1 9.4 2 9.75	24.5	77	24+	8.3 8.3	255	219	272	259	192	191	9.8	8.8	4.05	12-20	15-30	101	40	81.5	91	10.0
1:20	1 9.3 2 9.75	25	81					282	260		192	9.6	8.8	4.05			102	40	82	91	
1:50	1 9.4 2 9.8	27	88	24+	8.3 8.2	258	219	272	261	193	191	9.4	8.6	4.05	12-20	10-25	100	39	82	92	10.0
2:50	1 9.4 2 9.75	24	89	24+	8.3 8.2	260	220	275	262	193	190	9.3	8.5	4.05	15-25	10-20	100	38	82	93	12.0
3:50	1 9.5 2 9.8	26	86	24+	8.2 8.0	260	220	279	262	192	189	8.9	8.6	4.0	15-25	10-20	100	40	82	94	
4:50	1 9.5 2 10.1	28.5	97	24+	8.2 8.0	260	220	260	265	192	187	8.7	8.6	4.15	15-25	10-20	100	39	82	95	
5:50	1 0 2 9.0	20.5	66	24-	7.8 8.0	230	218	190	260	190	184		9.0	4.15	20-30	0-10	84	24	89	88	
6:50	1 0 2 9.0	21	69.5	23-	7.6 8.0	200	215	189	260	187	180		8.9	4.15	20-30	0-10	84	22	90	90	
7:50	1 0 2 9.0	25.5	80	23-	7.6 8.0	190	215	188	262	187	180		8.6	4.2	20-30	0-10	84	21	89.5	90	
8:50	1 9.0 2 9.0	30+	100+	24	8.2 8.0	260	220	282	265	192	180	8.6	7.7	4.05	10-20	20-30		0	84	94	
9:50	1 9.9 2 10.1	30+	100+	24	8.2 8.0	270	230	288	273	192	182	7.9	8.0	4.05	15-20	20-30		35	87	94	
10:50	1 9.1 2 9.9	18	59	24	8.2 7.9	275	235	298	278	192	180	10.0	9.6	4.0	15-20	20-30		51	80.5	92	

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap. LI / °F	Levels & Temp. Therminol LI	Levels & Temp. Therminol Psig	Therminol In Temp. #1	Therminol In Temp. #2	Therminol Out Temp. #1	Therminol Out Temp. #2	Stack Temp.	Temp. Out Evap. Moyno	Burners Gas Orifice ΔP #1	Burners Gas Orifice ΔP #2	Burners Gas Press Psig	Burners Burner Air ΔP #1	Burners Burner Air ΔP #2	Blower Output Amps	Blower Output Flow Feed	Press	Drex	Unit Press
9/9/71 11:50 A	1 10.3 2 10.25	30+ / 100+	23	8.0 / 7.8	270	240	290	280	193	183	9.3	9.4	4.0	10-20	15-25		40	85	95	
12:50 A	1 10.1 2 10.2	21 / 68	23	9.0 / 5.5	255	240	240	282	192	183	9.8	9.0	4.05	15-20	18-22	104	44	82	73	
1:50	1 OFF 2 10.25	18.25 / 60	16.25	515 / 7.7	220	240	190	280	188	179	0	10.6	4.2	0	0	86	28	89	55	
2:50	1 10.30 2 11	90 / 27.5	12.00	7.6 / 7.0	260	240	300	290	192	183	9.4	9.3	4.05	15-20	18-23	96	40	84	86	
3:50	1 10.2 2 11	28.5 / 93	12	8.8 / 8.8	285	245	305	285	193	183	9.2	9.2	4.00	15-20	18-23	96	40	83.5	93	
4:50	1 11.6 2 11.4	28.5 / 94	12.25	8.5 / 8.8	285	255	305	290	192	182	9.9	9.6	4.00	15-20	18-23	96	40	84	86	
5:50	1 11.7 2 11.6	28.5 / 93	12.00	8.6 / 8.8	290	260	310	295	192	181	10.1	9.7	4.0	15-20	20-22	94	40	84	68	
6:50	1 11.8 2 11.7	28.5 / 95	11.75	8.5 / 8.8	295	260	313	278	192	178	10.1	9.5	4.0	15-22	20-22	95	40	85	68	
7:50	1 11.7 2 11.8	28.5 / 92	11.25	8.2 / 8.6	300	267	315	302	192	179	9.9	9.6	4.05	15-25	20-22	94	40	85.5	72	
8:50	1 11.7 2 11.8	28.5 / 93	11.00	8.5 / 8.6	300	272	320	307	192	179	10.2	9.4	4.05	15-25	20-22	94	40	86	69	
9:50	1 11.6 2 11.75	28 / 93	11"	8.5 / 8.8		280	322	312	192	178	9.9	9.6	4.0	15-25	18-25	94	40	85	72	
10:50	1 11.6 2 11.75	28.5 / 93	11"	8.7 / 9.0	312	288	327	318	192	178	9.9	9.8	4.0	15-22	18-25	95	40	84.5	69	3.5

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap LI °F	Levels & Temp. Therminol LI	Levels & Temp. Therminol Psig	Therminol In Temp. #1	Therminol In Temp. #2	Therminol Out Temp. #1	Therminol Out Temp. #2	Stack Temp.	Temp. Out Evap. Moyno	Burners Gas Orifice ΔP #1	Burners Gas Orifice ΔP #2	Burners Gas Press Psig	Burners Burner Air ΔP #1	Burners Burner Air ΔP #2	Blower Output Amps	Blower Output Flow Feed	Press	Drex	Unit Press
9/9/71 11:50 P	1 11.6 2 11.75	28.5/94	11"	8.4/8.7	319	291	331	322	192	178	10.0	9.9	4.0	15-23	18-25	95	40	84.5	70.5	2.3
9/10/71 12:50 A	1 11.6 2 11.75	28.25/94	10"	8.3/8.7	318	293	331	330	192	177	10.7	10.0	4.05	12-22	18-22	95	40	84.5	67	2.3
1:50	1 11.6 2 11.75	28.5/94	9.5"	8.4/8.5	321	297	336	330	191	177	9.8	9.9	4.05	16-23	18-25	94	40	85	69	1.9
2:50	1 11.6 2 11.75	28.5/93	9.0"	8.2/8.5	326	300	337	334	192	180	10.0	10.0	4.0	15-23	15-25	94	42	84	79	2.7
3:50	1 11.6 2 11.75	28.5/93	8.5"	8.2/8.5	328	300	339	339	191	180	10.1	10.1	4.0	17-23	15-23	94	42	83.5	93	3.3

APPENDIX G JACKETED DOWNCOMER TESTS

FEED AND PRODUCT SAMPLES

Date	Time	Sample No.	Sample Description	% TS	% SS	SS/IS	
9/2/71	9:30 AM	10 & 11	Feed	3.08	1.67	1.18	
	11:25	12 & 13	Feed	3.47	2.26	1.87	Start-Up
	1:20 PM	16 & 18	Feed	2.90	1.44	0.99	
	3:45	24 & 25	Feed	2.32	1.24	1.15	
	6:45	28 & 29	Feed	2.31	1.26	1.22	
	7:45	32 & 33	Feed	2.98	1.72	1.37	
	10:45	36 & 37	Feed	3.28	1.94	1.45	
9/3/71	1:45 AM	42 & 43	Feed	3.26	1.97	1.53	
	4:45	47 & 48	Feed	3.19	1.74	1.20	
	7:45	52 & 53	Feed	2.97	1.57	1.12	
	10:45	57 & 58	Feed	2.76	1.50	1.19	
	1:45 PM	5 & 6	Feed	3.18	1.58	0.99	
	2:45	7	Conc.	18.15			
	3:45	8	Conc.	17.43			
	4:45	9	Conc.	18.16			
	4:45	10 & 11	Feed	3.41	2.26	1.96	
	5:45	12	Conc.	18.06			
	6:45	13	Conc.	16.55			
9/8/71	6:30 AM	1 & 2	Feed	2.29	1.40	1.75	Fill
	7:00	3 & 4	Feed	2.73	1.42	1.08	
	5:50 PM	5 & 6	Feed	2.65	1.52	1.34	Start-Up
	6:50	7	Conc.	4.23			
	7:50	8	Conc.	5.12			
	8:50	10	Conc.	6.53			
	8:50	11 & 12	Feed	2.94	1.48	1.01	

Date	Time	Sample No.	Sample Description	% TS	% SS	SS/IS
9/8/71	9:50 PM	13	Conc.	7.30		
	10:50	14	Conc.	7.79		
	11:50	15	Conc.	8.56		
9/9/71	12:50 AM	18	Conc.	8.96		
	1:50	19	Conc.	9.62		
	1:50	20 & 21	Feed	3.03	1.48	0.96
	2:50	22	Conc.	10.95		
	3:50	23	Conc.	11.65		
	4:50	27	Conc.	12.38		
	4:50	25 & 26	Feed	2.88	1.48	1.05
	5:50	28	Conc.	13.31		
	6:50	29	Conc.	13.26		
	7:50	32	Conc.	14.15		
	7:50	30 & 31	Feed	3.04	1.58	1.08
	8:50	34	Conc.	14.55		
	9:50	35	Conc.	15.60		
	10:50	38	Conc.	17.05		
	10:50	36 & 37	Feed	2.92	1.61	1.23
	11:50	39	Conc.	17.05		
	12:50 PM	41	Conc.	18.20		
	1:50	42	Conc.	18.35		
	1:50	43 & 44	Feed	2.74	1.55	1.30
	2:50	47	Conc.	18.33		
	3:50	48	Conc.	18.67		
	4:50	3	Conc.	19.72		
	4:50	4 & 5	Feed	2.86	1.53	1.14
	5:50	6	Conc.	19.58		
	6:50	7	Conc.	19.72		

Date	Time	Sample No.	Sample Description	% TS	% SS	SS/IS
9/9/71	7:50 PM	8	Conc.	19.75		
	8:50	9	Conc.	20.00		
	9:20	10 & 11	Feed	2.90	1.55	1.15
	9:50	12	Conc.	19.98		
	10:50	13	Conc.	20.30		
	11:50	14	Conc.	20.30		
9/10/71	12:20 AM	15 & 16	Feed	2.22	1.18	1.13
	12:50	17	Conc.	20.57		
	1:50	18	Conc.	20.28		
	2:50	19	Conc.	19.75		
	3:20	20 & 21	Feed	2.04	0.98	0.925
	3:50	22	Conc.	19.55		

Stack Condensate

Date	Time	Sample No.	Sample Description	% TS	% SS	SS/IS
9/3/71	Noon	1 & 2	Conc.	0.48	0.03	
9/8/71	7:50 PM	9	Conc.	3.99		
9/9/71	4:15 AM	24	Conc.	2.97		
	8:00	33	Conc.	0.10		
	Noon	40	Conc.	3.67		
	2:00 PM	45 & 46	Conc.	0.095	0.092	30.6
	4:00	1 & 2	Conc.	0.68	0.34	2.00

APPENDIX H - EVAPORATOR TESTS USING

NON-JACKETED DOWNCOMER

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap. Board LI	LIC	Drex LI	Drex PSIG	Therminol Gas Meter	Stack Temp.	Temp. Out Evap. Moyno	Burners: Gas Orifice ΔP ΔP #1	ΔP #2	Gas Press PSIG	Burner Air ΔP #1	#2	Blower Output: Amps	Temp. Feed Tank	Feed Rate	Conc.
10/5/71 12:30 P	1 2																
1:00	1 15 2 15	41	12	32		4584733 2300-2350	186	114	6.7	6.6	4.0	15-25	15-30	92	94	30/20-40	0
2:00	1 15 2 15	43	13	27	29	24,500	192	186	7.5	7.4	4.05	18-24	15-25	92	94	30/30-40	0
3:00	1 15 2 15	44 45	13	25	24		193	192	7.5	7.6	4.05	18-24	15-28	104	80	30/0	0
4:00	1 15 2 15	62	18	68		4598604 23500-24000	193	192	7.1	6.9	4.10	15-25	15-25	98	70	30/0	0
5:00	1 15 2 15	63 65	16.5	65			192	192	6.9	6.6	4.10	15-25	15-25	96	91	30/100	0
6:00	1 15 2 15	52	14.0	63		22500-24000	191	191	7.2	6.8	4.1	15-22	15-25	94	94	30/0	0
7:00	1 15 2 15	81	25.0	61			194	190	6.4	6.2	4.1	13-23	10-25	98	88	30/0	0
8:00	1 15 2 15	50	16.0	59		4617630 2150-2250	194	190	6.7	6.7	4.1	13-22	8-25	92	93	30/100	0
9:00	1 15 2 15	100+	30+	61					5.2	5.4	4.15			93	92	30/41	0
	1 2	9:10 BURNERS OFF 9:55 BURNERS ON															
11:00	1 15 2 15	48	14.0				192	163	5.5	5.6	4.15	5-16	0-22	78	46	30/40	0

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap. Board LI	LIC	Drex LI	Drex PSIG	Therminol Gas Meter	Stack Temp.	Temp. Out Evap. Moyno	Burners: Gas Orifice ΔP #1	ΔP #2	Gas Press PSIG	Burner Air ΔP #1	#2	Blower Output: Amps	Temp. Feed Tank	Feed Rate	Conc.
10/6/71 1:00 A	1 15 2 15	80	23.5	--		23.2(4633888)	192	159	6.7	6.5	4.1	15-25	15-25	88	92	30/0	0
2:00	1 15 2 15	79	23.5	--			193	188	6.5	6.1	4.1	15-25	15-25	92	93	30/66	0
3:00	1 15 2 15	66	19.0	52		23.4(4640666)	193	188	6.6	6.3	4.1	15-25	17-27	91	95	30/0	0
4:00	1 15 2 15	67	21.0	50			193	188	6.7	6.3	4.1	15-25	17-27	93	95	30/62	0
5:00	1 15 2 15	74	23.0	51		23.2(4649666)	192	188	6.7	6.3	4.1	15-25	17-27	98	89	30/63	0
6:00	1 15 2 15	82	25.5	53			193	187	6.5	6.1	4.1	15-25	15-25	95	95	30/0	0
7:00	1 15 2 15	70	20.5	49		22.3(4658822)	194	187	6.5	6.3	4.1	15-25	10-25	96	88	30/62	0
8:00	1 15 2 15	78	23.0	50			194	186	5.9	6.1	4.1	10-22	10-25	92	86	30/0	0
9:00	1 15 2 15	69	22.0	54		23.0(4667305)	192	185	6.4	6.4	4.1	10-20	15-25	93	90	30/60	0
10:00	1 15 2 15	61	18.5	53		(4674292) 2150-2250	192	186	6.0	6.6	4.1	10-20	15-25	96	70	30/60	0
11:00	1 15 2 15	84	24.0	68		(4678705) 2125-2375	193	186	5.6	6.2	4.1	10-17	15-22	86	58	30/80	0
12:00 N	1 2	70	24.0	69			194	186	5.9	6.3	4.15	10-15	10-20	94	58	30/0	0
1:00 P	1 15 2 15	76	24.5	60		22,000-23,000 4686924	193.5	186	6.5	5.9	4.15	15-22	10-20	92	66	30/0	30

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap. Board LI	LIC	Drex LI	Drex PSIG	Therminol Gas Meter	Stack Temp.	Temp. Out Evap. Moyno	Burners: Gas Orifice ΔP #1	ΔP #2	Gas Press PSIG	Burner Air ΔP #1	#2	Blower Output: Amps	Temp. Feed Tank	Feed Rate	Conc.
10/6/71 2:00 P	1 15 2 15	80	24.0	62			192.0	185	6.5	5.8	4.10	15-22	10-20	102	66	30/0	32
3:00	1 15 2 15	80	24.0	63		22,000-23,000 4695556	193	186	6.5	6.0	4.10	15-22	10-20	98	76	30/0	16
4:00	1 15 2 15	71	21.5	63			192	187	6.75	6.0	4.15	15-20	8-18	102	82	30/80	28
5:00	1 15 2 15	73	21.0	60		22,000-23,000 4704287	192	186	6.6	6.1	4.15	17-22	10-22	100	90	30/80	43
6:00	1 15 2 15	71	21.0	42			192	185		6.0	4.1	15-20	10-22	102	89	30/80	0
7:00	1 15 2 15	77	23.0			2200-2300 4712359	193	182	7.2	5.9	4.1	17-22	10-25	95	90	30/82	0
8:00	1 15 2 15	74	21.5				192	186	7.1	6.0	4.15	13-23	8-25	92	90	30/50	0
9:00	1 15 2 15	67	20.5	52		2200 4721999	192	177	6.5	6.1	4.15	15-23	10-25	96	80	30/65-75	0
10:00	1 15 2 15	59	18.0	58			192	182	6.6	6.2	4.1	15-23	10-23	100	75	30/79	8
11:00	1 15 2 15	56	17.0	42		2100-2200 4730739	191	179	5.9	6.3	4.15	20	10-25	80	90	30/0-6	0
12:00 M	1 15 2 15	56	17.0	41			192	181	5.9	6.2	4.15	14-23	10-25	92	90	32/32	0
10/7/71 1:00 A	1 15 2 15	46	14.0	20		2150-2200 4739549	191	177	5.9	6.3	4.15	15-25	10-25	102	92	42/42	0
2:00	1 15 2 15	48	14.5	21			192	185	5.2	6.6	4.15	16-20	12-18	92	90	42/42	0

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap. Board LI	LIC	Drex LI	PSIG	Therminol Gas Meter	Stack Temp.	Temp. Out Evap. Moyno	Burners: Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press PSIG	Burner Air ΔP #1	#2	Blower Output: Amps	Feed Tank	Feed Rate	Conc.
10/7/71 3:00 A	1 15 2 14.75	44	13.5	23		2300-2400 4748627	193	18[illegible]	7.3	7.0	4.1	8-20	13-20	86	92	38/38	0
4:00	1 14.3 2 14.8	46	14.0	24			193	180	7.2	6.9	4.1	15-20	13-20	91	94	39/40	0
5:00	1 14.8 2 14.8	47	14.0	26		23.2(4757134)	193	170	6.9	6.9	4.1	16-20	13-20	84	95	37/38	0
6:00	1 14.8 2 14.8	42	13.0	27			193	167	6.9	7.0	4.1	15-20	13-22	88	95	36/37	0
7:00	1 14.8 2 14.8	42	12.8	27		23.0(4766100)	193	166	6.9	6.9	4.1	15-20	14-23	85	95	37/38	0
8:00	1 14.8 2 14.8	46	14.0	29			193	173	6.8	6.9	4.1	16-21	17-23	86	95	40/41	0
9:00	1 14.8 2 14.8	46	14.0	29		23.2(4775762)	193	174	7.0	6.9	4.1	17-22	15-22	85	95	40/41	0
10:00	1 14.8 2 14.8	46	14.0	31			193	174	6.9	6.9	4.1	15-20	13-20	81	95	38/39	14
11:00	1 14.8 2 14.8	46	14.0	33		23.0(4785232)	193	176	6.9	6.9	4.1	15-19	13-20	96	91	38/40	30
12:00 N	1 14.8 2 14.8	46	14.0	33			193	176	6.9	7.0	4.1	15-19	15-20	95	90	38/40	46
1:00 P	1 14.8 2 14.8	46	14.0	34		23500-22500 4794022	193	176	6.8	7.0	4.15	17-16	13-18	98	82	38/39.5	62
2:00	1 14.8 2 14.8	46	14.0	34			193	176	7.2	7.0	4.10	17-18	12-18	98	68	38/39	65
3:00	1 14.8 2 14.8	46	14	33		23500-24000 4804217	193	171	7.7	6.9	4.1	19-20	13-17	98	50	38/39.5	76

Date/ Time	Evap. Fuel Valve to Open	Levels & Temp. Evap. Board LI	LIC	Drex LI	PSIG	Therminol Gas Meter	Stack Temp.	Temp. Out Evap. Moyno	Burners: Gas Orifice/ΔP ΔP #1	ΔP #2	Gas Press PSIG	Burner Air ΔP #1	#2	Blower Output: Amps	Temp. Feed Tank	Feed Rate	Conc.
10/-/-1 4:00 P	1 14.8 2 14.8	36	11	30			193	180	8.0	7.0	4.05	22	12-18	100	58	38/39	76
5:00	1 14.8 2 14.8	29	8.5	27		24000 4812004	193	178	7.6	7.4	4.10	23-24	15-20	106	70	38/39.5	71
6:00	1 14.8 2 14.8	31	9.0	28			193	176	7.50	7.3	4.10	22-24	15-20	106	84	42/43	45
7:00	1 14.8 2 14.8	29	9.0	30		24000-24500 4822614	192.5	177	7.70	7.30	4.10	23-25	15-20	102	87	42/43	38
8:00	1 14.8 2 14.8	30	9.0	32			193	178	7.70	7.30	4.15	24-25	15-20	104	88	44/45	34
9:00	1 14.8 2 14.9	30	9.0	32		24000-24500 4833005	193		8.10	7.40	4.05	27.5	15-20	106	88	44/45	36

10:45 SHUTDOWN

APPENDIX I - NON JACKETED DOWNCOMER TESTS

FEED AND PRODUCT SAMPLES

Date	Time	Sample No.	Sample Description	% T.S.	% S.S.
10/4/71	4:00 PM	1	Feed	1.56	.745
10/4/71	6:00 PM	3	Feed	1.505	.69
10/5/71	12:20 PM	1	Feed	1.97	1.025
10/5/71	12:35 PM	2	Feed	2.08	1.01
10/5/71	2:00 PM	5	Conc.	3.2	
10/5/71	3:00 PM	6	Conc.	4.5	
10/5/71	3:00 PM	7	Feed	2.10	1.02
10/5/71	4:00 PM	9	Conc.	4.79	
10/5/71	5:00 PM	10	Conc.	5.32	
10/5/71	6:00 PM	11	Conc.	5.96	
10/5/71	6:00 PM	12	Feed	2.13	1.07
10/5/71	7:00 PM	14	Conc.	6.83	
10/5/71	8:00 PM	15	Conc.	7.21	
10/5/71	9:00 PM	16	Conc.	7.79	
10/5/71	9:00 PM	17	Feed	2.40	1.39
10/5/71	11:00 PM	19	Conc.	8.33	
10/6/71	12:15 AM	20	Feed	2.66	1.41
10/6/71	1:00 AM	22	Conc.	8.60	
10/6/71	1:15 AM	23	Sight Glass Foam	8.97	
10/6/71	2:00 AM	24	Conc.	9.1	
10/6/71	3:00 AM	25	Conc.	10.05	

Date	Time	Sample No.	Sample Description	% T.S.	% S.S.
10/6/71	3:15 AM	26	Feed	2.35	1.11
10/6/71	4:00 AM	28	Conc.	11.0	
10/6/71	5:00 AM	29	Conc.	11.6	
10/6/71	5:15 AM	30	Stack Condensate	1.08	.65
10/6/71	6:00 AM	32	Conc.	11.90	
10/6/71	6:15 AM	33	Feed	2.22	.965
10/6/71	7:00 AM	35	Conc.	12.4	
10/6/71	8:00 AM	36	Conc.	13.1	
10/6/71	9:00 AM	37	Conc.	14.6	
10/6/71	9:15 AM	38	Feed	2.40	1.12
10/6/71	10:00 AM	40	Conc.	14.7	
10/6/71	11:00 AM	41	Conc.	15.3	
10/6/71	12:00 N	42	Conc.	16.0	
10/6/71	12:00 N	43	Feed	2.59	1.19
10/6/71	1:00 PM	45	Conc.		
10/6/71	2:00 PM	46	Conc.	17.27	
10/6/71	3:00 PM	47	Feed	2.23	1.06
10/6/71	4:00 PM	49	Conc.	15.06	
10/6/71	5:00 PM	50	Conc.	19.07	
10/6/71	6:00 PM	1	Conc.	19.36	
10/6/71	6:00 PM	2	Feed	2.59	1.30
10/6/71	7:00 PM	4	Conc.	20.02	
10/6/71	8:00 PM	5	Conc.	19.83	
10/6/71	9:00 PM	6	Conc.	19.58	

Date	Time	Sample No.	Sample Description	% T.S.	% S.S.
10/6/71	9:00 PM	7	Feed	2.59	1.34
10/6/71	10:00 PM	9	Conc.	18.32	
10/6/71	11:00 PM	10	Conc.	18.70	
10/7/71	12:00 M	11	Conc.	17.83	
10/7/71	12:00 M	12	Feed	2.75	1.50
10/7/71	1:00 AM	14	Conc.	18.60	
10/7/71	2:00 AM	15	Conc.	16.12	
10/7/71	3:00 AM	16	Conc.	16.93	
10/7/71	3:15 AM	17	Feed	2.70	1.53
10/7/71	4:00 AM	19	Conc.	15.62	
10/7/71	5:00 AM	20	Conc.	15.00	
10/7/71	6:00 AM	21	Conc.	19.52	
10/7/71	6:15 AM	22	Feed	2.90	1.63
10/7/71	7:00 AM	24	Conc.	20.2	
10/7/71	8:00 AM	25	Conc.	20.1	
10/7/71	8:30 AM	26	Stack Condensate	.73	.37
10/7/71	9:00 AM	28	Conc.	20.25	
10/7/71	9:15 AM	29	Feed	2.52	1.39
10/7/71	10:00 AM	31	Conc.	20.75	
10/7/71	11:00 AM	32	Conc.	20.75	
10/7/71	12:00 N	33	Conc.	20.75	
10/7/71	11:45 AM	34	Feed	2.36	1.30
10/7/71	1:00 PM	36	Conc.	20.00	
10/7/71	2:00 PM	37	Conc.	20.22	

Date	Time	Sample No.	Sample Description	% T.S.	% S.S.
10/7/71	2:53 PM	38	Feed	2.17	1.14
10/7/71	3:00 PM	40	Conc.	22.00	
10/7/71	4:00 PM	42	Conc.	21.02	
10/7/71	5:00 PM	43	Conc.	21.68	
10/7/71	6:00 PM	44	Conc.	22.22	
10/7/71	6:00 PM	45	Feed	2.42	1.24
10/7/71	7:00 PM	1	Conc.	22.30	
10/7/71	8:00 PM	2	Conc.	23.12	
10/7/71	9:00 PM	3	Conc.	22.55	
10/7/71	9:00 PM	4	Feed	2.89	1.50
10/8/71	1:00 PM	6	Sweco Overflow	6.69	
10/8/71		7	Sweco Overflow	6.36	
10/8/71		8	Sweco Overflow	6.65	

APPENDIX J - EVAPORATOR TESTS USING

INCONEL 601 DOWNCOMERS - SERIES 1

Date/ Time	HIC #1/#2	Panel LI	Fox LIC	Drexel Brook	Gas Rec. Flow	Stack Temp.	Temp. Out of Moyno	Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press Psig	Burner Air ΔP #1	Burner Air ΔP #2	Blower Amps	Feed Tank Level	Feed Rate	Conc. Tank Level	Conc. % T.S.	Tank Press	Blower Output
12/2/71 5:15 A		START-UP																	
5:45	6.0/15.0	60.0	18.0	58				1.9	4.3	4.2									
6:45	14.8/15.0	67.0	20.5	56		192	184	3.5	2.7	4.2	13-14	6-7	70	92	30-40	0			
12/4/71 8:30 A					0 4883882		START-UP												
9:00	9.8/6.9	63	19.25	100+		190.5	120	4.1	4.1	4.15	13-15	10-20	89-90	78	4-7	100	3.3		
10:00	9.8/6.8	64	19.5	100+		192.5	187	3.5	3.6	4.2	10-11	12-15	83	85	30-40	100			
11:00	9.7/6.7	65	20	100+	13,000 4893466	191.5	187	2.2	2.4	4.2	4	10-20	60	86	16	0	3.8		
12:00 N	9.7/6.5	64	19.75	100+		189	183	2.1	2.3	4.2	1-3	0-10	53	82	6	0			
1:00 P	9.8/6.4	65	19.75	100+	13,000 4900410	189	181	2.0	2.2	4.2	1-3	0-10	54	78	10	0	4.5		
2:00	9.8/6.4	63	19.00	100+		188	183	2.0	2-3/8	4.0 4.2	2-8	0-10	54 46					psig 2.0	6.75 6.50
3:30		OPENED UP & DRAINED CONDENSATE STACK											75 Amps 65						
4:30		LOWERED LEVEL IN EVAPORATOR PERFORMANCE INCREASED																	

Date/ Time	HIC #1 / #2	Panel LI	Fox LI	Drexel Brook	Gas Rec. Flow	Stack Temp.	Temp. Out of Moyno	Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press Psig	Burner Air ΔP #1	Burner Air ΔP #2	Blower Amps	Feed Tank Level	Feed Rate	Conc. Tank Level	Conc. % T.S.	Tank Press	Blower Output
12/4/71 5:00 P	9.3 / 6.3	54	17.00	100+		192	187	3.75	3.75	4.2	15	15	86		30-40	0		.7	7-1/8
6:00	10.2 / 6.9	57	17.50	100+	19-17000 4915992	192	190	3.90	4.25	4.2	15	16	88		18-26		5.2	.7	7-1/8
7:00	10.1 / 6.9	56	17.0	86-100+		193	191	4.10	4-3/8	4.2	14-16	27 17	88-90	Full	26-30	26		.4	7-1/8
8:00	10.1 / 6.9	56	17	80-90	17-20,000 4924282	191.5	190	4.1	4-3/8	4.2	15	26 18-19	90	Full	0	20	6.2	0	7-1/16
9:00	10.1 / 6.9	55	17.5	70-80	18-19,500 4929912	192.0	190	4.3	4-5/8	4.2	13-15	29 17-18	93	92	0	16	8.00	0	7-1/16
10:00	10.1 / 6.9	56	17.75	70-80	18-19,500 4929912	192.0	190	4.3	4-5/8	4.1	12-14	29 16-19	92	83	0	14		0	7-1/16
11:00	10.1 / 6.9	58	18.0	50-60	18-20,000 4935753	193.5	189	4.25	4-7/16	4.2	13-15	31 15-20	91	82	0	24	9.9	0	7-1/8
12/5/71 12:00 M	10.1 / 6.9	60	18.5	50-66		193	187	4.10	4-5/8	4.2	13-15	30 18	91					0	7-1/8
1:00 A	10.1 / 6.9	64	19.0	40	18-20,000 4943190	193	187	4.2	4.6	4.15	14	37 18	91	Full	0	19		0	7.1
2:00	10.1 / 6.9	64	19.5	--		193	186	4.2	4.7	4.15	14	30 18	92	Full	0	16	10.4	0	7.05
3:00	10.1 / 6.9	69	17.0	--	18-20,000 4950938	191	184	4.4	4.9	4.15	14	25 20	91	Full	0	16		0	7.05
4:00	10.1 / 6.9	63	18.5	--		193	183	4.3	4.9	4.15	14	26 20	92	Full	100+	28	11.9	0	7.0
5:00	10.1 / 6.9	56	16.5	56	19,500 4959075	190	183	4.3	4.9	4.15	14	30 18	92	Full	0	36	12.8	0	7.0
6:00	10.1 / 6.9	61	20.0	--		192	182	4.15	4.8	4.15	13	31 18	92	96	0	43	14.0	0	7.0

Date/ Time	HIC #1/#2	Panel LI	Fox LIC	Drexel Brock	Gas Rec. Flow	Stack Temp.	Temp. Out of Moyno	Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press Psig	Burner Air ΔP #1	Burner Air ΔP #2	Blower Amps	Feed Tank Level	Feed Rate	Conc. Tank Level	Conc. % T.S.	Tank Press	Blower Output
12/5/71 7:00 A	10.1/6.9	55	18.5	--	18-20,500 4967037	191	180	4.2	4.8	4.15	13	35 18-19	93	98	0	50		0	7.0
8:00	10.1/6.9	60	17.5	--		192	178	4.2	4.9	4.15	12-13	33 17-19	92	96	100+	58		0	7.0
9:00	10.1/6.9	63	19.5	--	19,000 4975035	193	177	4.2	4.8	4.15	13	30 17-19	91	97	100+	64	15.7	0	7.0
10:00	10.2/6.9	60	17.5	--		193	176	4.2	4.7	4.15	10-15	15-20	92	92	0	70	17.3	0	6.9
11:00	10.2/6.9	57	18.5	--		192.5	174	4.2	4.6	4.15	10-12	15-20	91	84	100+	69	17.4	0	6.9
12:00 N	10.1/6.9	60	18	--	18,500 4987594	192	173	4.2	4.7	4.15	13-15	15-20	92	71	0	69	17.8	0	6.9
1:00 P	10.1/6.9	69	17.75	--		192	171	4.1	4.7	4.15	15	15-20	90	59	0	69		0	6.9
3:00	10.2/6.9	56	17.25	--		192	171	4.2	4.1	4.15	12-15	15-20	91	71	30	56	19.2	0	6.9
4:00	10.1/6.9	57	17.25	--	18,500 5003160	192	170	4.1	4.2	4.15	10-12	13-19	90	61	28-34	43		0	6.9
5:00	10.1/6.9	56	17.25	--		192	169	4.1	4.1	4.15	10-13	15-20	90	52	28-34	34	20.0	0	6.9
6:00	10.1/6.9	57	17.50	--	17500-19000 5011090	192	170	4.2	4.0	4.15	10-12	15-20	90	68	40	32	20.2	0	7.0
7:00	10.1/6.9	56	17.0	--		192		4.1	4-1/16	4.15	10-13	15-20	91	84	35	40	21.0	0	7.0
8:00	10.1/6.9	55	17.0	--		192	174	4.1	4.15	4.15	10-12	15-20	92	92	35	55	20.0	0	7.1
9:00	10.1/6.9	55	17.0	--		192	174	4.1	4.15	4.15	10-13	15-20	92	82	35	65	20.5	0	7.1

Date/ Time	HIC #1 / #2	Panel LI	Fox LIC	Drexel Brook	Gas Rec. Flow	Stack Temp.	Temp. Out of Moyno	Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press Psig	Burner Air ΔP #1	Burner Air ΔP #2	Blower Amps	Feed Tank Level	Feed Rate	Conc. Tank Level	Conc. % T.S.	Tank Press	Blower Output
12/5/71 10:00 P	10.1 / 6.9	56	17.0	--	17500-19000 5026110	192	175	4.1	4.15	4.15	10-12	15-20	92	76	35.5	78	21.0	0	7.0
11:00	10.1 / 6.9	56	17.0	--	18500-17500 5029950	192	175	4.1	3.75	4.15	10-12	15-22	90	92	35.5	88	20.4	0	7.0
12/6/71 12:00M	10.1 / 6.9	56	17.0	--		192	176	4.1	3.80	4.15	10-12	12-20	91	94	35.5	96	19.7	0	7.0
1:00 A	10.1 / 6.9	56	17.0	--	18500-18000 5038076	192	176	4.1	3.85	4.15	10-12	15-20	91	94	35.5	100+	19.0	0	7.0
2:00	10.1 / 6.9	56	17.0	--		192	176	4.1	3.85	4.15	10-12	15-20	91	94	35.5	100+	20.4	0	7.0
3:00	10.1 / 6.9	55	16.5	--	19-17,000 504536	192	174	3.8	4.15	4.15	10-12	15-20	90	94	35.5	100+	20.4	0	7.0
4:00	10.1 / 6.9	56	16.5	--		192	173	3.8	4.15	4.15	10-12	15-20	90	95	35.5	100+	18.5	0	7.0
5:00	10.1 / 6.9	56	17.0	--	18,000 5052919	192	175	3.8	4.15	4.15	12	18	90	93	35.5	100+	18.5	0	7.0
7:00	10.1 / 6.9	56	17.0	--	18-19,000 5060770	192	173	4.1	4.15	4.15	12	17-19	90	95	35.5	100+	19.1	0	7.0
8:00	10.1 / 6.9	56	17.0			192	173	4.1	4.15	4.15	12	17-19	92	94	35.5	100+	19.1	0	7.0
9:00	10.1 / 6.9	56	17.0		18-19,500 5068762	192	172	4.1	4.15	4.15	12	17-19	91	85	35.5	100+	19.0	0	7.0
10:00	10.1 / 6.9	56	17.0			192	172	4.1	4.15	4.15	10-11	17-19	91	90	34	100+	20.00	0	7.0
11:00	10.1 / 6.9	56	17.0		18-19,500 5076669	192	173	4.1	4.15	4.15	10-11	17-19	91	96	34	91	19.5	0	7.05
12:00 N	10.2 / 6.9	56	17.0			192	172	4.0	4.15	4.15	10-11	15-20	90	94	34	76	18.9	0	7.0

Date/ Time	HIC #1 / #2	Panel LI	Fox LIC	Drexel Brook	Gas Rec. Flow	Stack Temp.	Temp. Out of Moyno	Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press Psig	Burner Air ΔP #1	Burner Air ΔP #2	Blower Amps	Feed Tank Level	Feed Rate	Conc. Tank Level	Conc. % T.S.	Tank Press	Blower Output
12/6/71 1:00 P	10.2 / 6.9	56	16.5			192	172	4.1	3.75	4.15	10-12	15-20	91	94	33	54	18.7	0	7.0
2:00	10.2 / 6.9	56	17.0		18,000 5091400	192	172	4.1	3.7	4.15	10-11	16-19	90	95	33	36	18.2	0	7.0
3:00	10.2 / 6.9	55	16.75			192	172	4.0	4.2	4.15	10-12	15-20	91	96	33	27	18.3	0	7.0
5:00	10.1 / 6.9	55	16.75			192	173	4.0	4.15	4.15	10-12	15-20	91	97	33	29	19.7	0	7.0
6:00	10.2 / 6.9	55	16.75		19,000 5106042	192	172	4.0	4.2	4.15	10-12	15-20	90	97	33	32	19.6	0	7.0
7:00	10.1 / 6.9	55	17.0			195	172	4.0	4.15	4.15	10-13	14-19	91		33	32	19.7	0	7.0
8:00	10.1 / 6.9	56	17.0		18,500 5111640	192	172	4.0	4.1	4.15	10-12	15-20	90	64	33	31	20.2	0	7.1
9:00	10.1 / 5.9	56	17.0			192	170	3.9	4.1	4.15	10-12	15-22	91	70	33	33	20.0	0	7.1
10:00	10.1 / 6.9	56	17.0		18,500 5119437	192	172	3.95	4.1	4.15	10-12	15-20	91	72	33	32	21.0	0	7.1
11:00	10.1 / 6.9	56	17.0			192	172	3.90	4.0	4.15	10-12	13-21	91	84	33	34	21.5	0	7.1
12/7/71 12:00 M	10.1 / 6.9	56	17.0		17000-18500 5126880	192	172	4.0	4.0	4.15	10-12	13-20	91	90	34	40	20.8	0	7.15
1:00 A	10.1 / 6.9	55	17.0			192	172	4.05	4.1	4.15	10-12	10-25	91	96	34	50	21.8	0	7.15
2:00	10.1 / 6.9	56	17.0		18,000	192	172	4.00	4.1	4.15	9-11	10-25	91	96	34	62	22.0	0	7.20
3:00	10.1 / 6.9	56	17.0			192	172	4.00	4.1	4.15	9-11	10-25	92	96	35	75	22.0	0	7.20

Date/ Time	HIC #1 / #2	Panel LI	Fox LIC	Drexel Brook	Gas Rec. Flow	Stack Temp.	Temp. Out of Moyno	Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press Psig	Burner Air ΔP #1	Burner Air ΔP #2	Blower Amps	Feed Tank Level	Feed Rate	Conc. Tank Level	Conc. % T.S.	Tank Press	Blower Output
12/7/71 4:00 A	10.1 / 6.9	56	17.0		18,000 5142000	191.5	172	4.00	4.05	4.15	9-11	10-25	92	96	35	86	22.0	0	7.20
5:00	10.1 / 6.9	56	17.0			191.5	171	4.05	4.10	4.15	9-11	10-25	93	96	35	95	20.0	0	7.25
6:00	10.1 / 6.9	56	17.0		17-18,500 5149772	192	169	4.05	4.10	4.15	9-11	10-25	93	96	35	95	20.7	0	7.20
7:00	10.1 / 6.9	56	17.0			191.5	169	4.00	4.10	4.15	9-11	15-25	91	94	35	92	21.0	0	7.25
8:00	10.1 / 6.9	55	16.5		18,000 5157525	192	170	4.00	4.15	4.15	9-11	15-25	91	94	35	88	21.0	0	7.25
9:00	10.1 / 6.9	57	17.5			192	173	4.05	4.10	4.15	8-10	15-25	91	94	35	86	21.0	0	7.20
10:00	10.1 / 6.9	56	17.0		5164707	192	173	4.05	4.10	4.15	8-10	15-22	91	92	35	86	20.8	0	7.0
11:00	10.0 / 6.9	56	17.0			192	173	4.05	4.1	4.15	7-10	15-22	90	92	35	92	18.8	0	7.0
12:00 N	10.0 / 6.9	56	17.0		17-18,500 5172469	192	173	4.1	4.25	4.15	7-10	15-23	90	86	35	92	19.6	0	6.95
1:00 P	10.0 / 6.9	55	16.5		17-18,500 5176020	192	176	4.1	4.25	4.15	7-9	15-20	90	61	35	88	19.2	0	7.0
2:00	10.0 / 6.9	55	17.0		17-19,000 5180188	192	174	4.1	4.30	4.15	6-9	14-19	90	66	35	78	19.3	0	6.9
3:00	10.0 / 6.9	56	17.0			192	174	4.1	4.3	4.15	7-9	15-20	90	75	34	66	18.7	0	6.9
4:00	10.0 / 7.1	56	17.0		18000-19000 5187917	192	174	4.1	4.35	4.15	7-9	14-19	91	80	34	66	18.9	0	6.9
5:00	10.0 / 7.1	55	17.0			192	174	4.1	4.35	4.2	6-9	14-19	91	83	34	58	18.0	0	6.9

Date/ Time	HIC #1 / #2	Panel LI	Fox LIC	Drexel Brook	Gas Rec. Flow	Stack Temp.	Temp. Out of Moyno	Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press Psig	Burner Air ΔP #1	Burner Air ΔP #2	Blower Amps	Feed Tank Level	Feed Rate	Conc. Tank Level	Conc. % T.S.	Tank Press	Blower Output
12/7/71 6:00 P	9.3 / 7.1	54	16.75		17500-19000 5195742	192	173	4.1	4.4	4.15	7-9	15-20	91.5	90	32.5	45	18.5	0	6.9
7:00	9.9 / 7.1	56	17.0			192	170	4.1	4.35	4.15	7-9	14-19	91	95	33.5	26	18.8	0	6.9
8:00	9.9 / 7.1	54	16.75		17500-19000 5203440	192	169	4.1	4.35	4.15	8-10	16-20	91	97	33	14	19.2	0	6.9
9:00	10.1 / 7.0	55	16.75			192	170	4.1	4.35	4.15	8-10	15-20	91	96	33	15	19.6	0	6.9
10:00	10.1 / 7.0	55	16.25		17500-19000 5210972	192	171	4.1	4.35	4.15	7-10	15-20	91	95	33	16		0	6.9
11:00	10.0 / 7.0	56	17.0			192	170	4.1	4.35	4.15	8-10	14-19	91	93	33	15	20.7	0	6.9
12/8/71 12:00 M	10.0 / 7.0	56	17.0		17500-19000 5219165	192	170	4.1	4.35	4.15	7-9	15-20	90.5	93	33	15	20.7	0	6.9
1:00 A	10.0 / 7.0	56	17.0			192	171	4.1	4.30	4.15	7-9	15-22	92	93	33	22		0	6.95
2:00	10.0 / 7.0	56	17.0	--	17500-19000 5226863	192	172	4.1	4.3	4.15	7-9	13-22	92	93	33	24	20.9	0	6.95
3:00	10.0 / 7.0	56	17.0	--		192	174	4.0	4.25	4.15	7-9	13-22	91	93	33	24	20.8	0	6.95
4:00	10.0 / 7.0	56	17	--	17500-19000 5234725	192	174	3.95	4.30	4.15	7-9	13-22	91	92	33	24	20.2	0	6.95
5:00	10.0 / 7.0	54	16.25	--		192	173	4.0	4.30	4.15	7-9	18-22	91	92	33	26	21.4	0	6.95
6:00	9.5 / 7.0	56	16.75	--	18750-17250 5242617	192	174	3.90	4.30	4.15	7-9	37	91	92	33	19	21.7	0	6.95
7:00	9.5 / 7.0	55	16.75	--		192	171	3.85	4.30	4.15	7-9	19-22	91	91	33	16	21.7	0	6.95

Date/ Time	HIC #1/#2	Panel LI	Fox LIC	Drexel Brook	Gas Rec. Flow	Stack Temp.	Temp. Out of Moyno	Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press Psig	Burner Air ΔP #1	Burner Air ΔP #2	Blower Amps	Feed Tank Level	Feed Rate	Conc. Tank Level	Conc. % T.S.	Tank Press	Blower Output
12/9/71 8:00	9.7/7.0	57	17.25		19000-16750 5250981	192	173	3.95	4.20	4.15	7-9	17-25	91	91	33	19	21.7	0	6.95
9:00	9.9/7.0	56	17.00			192	171	3.75	4.20	4.15	7-8	10-25	90	92	33	17	21.0	0	6.90
10:00	9.9/7.0	56	17.0		19,250-16250 5258896	192	172	3.95	4.15	4.15	7-8	15-20	88	92	33	39	21.0	0	6.90
11:00	9.9/7.0	56	17.0			192	172	4.0	4.20	4.15	7-10	15-23	88	89	33	60	21.3	0	6.90
12:00 N	9.9/7.0	56	17.0		17000-18500 5266940	192	173	4.0	4.20	4.15	6-8	10-25	88	93	33	80	21.1	0	6.80
1:00 P	9.9/7.0	56	17.0			192	173	4.0	4.20	4.15	6-8	10-25	88	46	33	80	21.2	0	6.80
2:00	9.9/7.0	56	17.0		19000-16250 5274118	192	173	3.95	4.20	4.15	6-8	10-25	89	56	33	77	21.1	0	6.80
3:00	9.9/7.0	55	17.0			192	173	4.05	4.20	4.15	6-9	10-25	88	67	33	75	20.8	0	6.80
4:00	10.0/7.0	56	17.0			192	173	4.05	4.25	4.15	6-7	10-25	89	82	33	66	20.9	0	6.8
5:00	10.0/7.0	56	17.0		16000-19000 5285773	192	172	4.0	4.2	4.15	7-9	15-20	89	92	33	62	20.5	0	6.8
6:00	10.0/7.0	55	16.75			192	169	4.0	4.25	4.15	7-9	15-20	89	93	33.5	63	20.8	0	6.8
7:00	10.0/7.0	56	17.0			192	169	3.9	4.25	4.15	7-9	15-20	89	92	33.5	56	20.9	0	6.85
8:00	10.0/7.0	56	17.0			192	169	3.9	4.25	4.15	8-10	15-20	89	80	33.5	50	20.2	0	6.8
9:00	10.0/7.0	56	17.0		17000-19000 5302480	192	173	3.9	4.2	4.15	7-9	15-20	89	66	33.5	40		0	6.8

Date/ Time	HIC #1 / #2	Panel LI	Fox LIC	Drexel Brook	Gas Rec. Flow	Stack Temp.	Temp. Out of Moyno	Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press Psig	Burner Air ΔP #1	Burner Air ΔP #2	Blower Amps	Feed Tank Level	Feed Rate	Conc. Tank Level	Conc. % T.S.	Tank Press	Blower Output
12/8/71 10:00 P	9.7 / 7.0	56	17.0			192	173	3.9	4.25	4.15	7-9	15-20	88	72	33.5	31	19.8	0	6.8
11:00	9.8 / 7.0	55	16.75			192	173	3.9	4.25	4.15	6-10	16-19	88	77	33.5	29	19.7	0	6.8
12/9/71 12:00 M	9.8 / 7.0	56	16.75			192	172	3.9	4.25	4.15	7-9	15-20	88	85	33.5	22		0	6.8
1:00 A	9.8 / 7.0	55	16.75		17500-18500 5314420	192	174	3.9	4.25	4.15	7-9	15-20	87.5	88	33.5	20	19.9	0	6.8
2:00	10.0 / 7.0	56	17.0			192	174	3.9	4.25	4.15	7-9	15-20	87.5	88	33.5	23		0	6.8
3:00	10.0 / 7.0	55	17.0		17000-18500 5323160	192	174	3.95	4.25	4.15	7-9	15-20	87.5	88	33.5	17	20.0	0	6.8
4:00	10.0 / 7.0	56	17.0			192	176	4.10	4.30	4.15	6-8	15-18	87	88	33.0	19	19.5	0	6.75
5:00	10.0 / 7.0	56	17.0		17000-19000 5333055	192	176	4.15	4.30	4.20	7-8	14-20	88	88	33	24		0	6.70
6:00	10.0 / 7.0	56	17.0			192	177	4.15	4.30	4.20	6-8	15-18	88	89	33	39		0	6.70
7:00	10.0 / 7.0	56	17			192	176	4.20	4.30	4.20	6-8	15-18	88	88	33	42		0	6.70
8:00	10.0 / 7.0	56	17	--	17000-18750 5345486	192	176	4.1	4.3	4.15	14-18	6-8	88	88	33	42	20.3	0	6.75
9:00	10.0 / 7.0	55	17	--		192	174	4.15	4.3	4.20	14-18	6-8	89	88	33	52	15.6	0	6.65

APPENDIX K - INCONEL 601 DOWNCOMER

TESTS - SERIES 1

FEED AND PRODUCT SAMPLES

Date	Time	Sample No.	Sample Description	% T.S	% S.S	Ratio SS/IS
12/2	5:45 AM	#1	Evaporator Bottoms	2.72		
		#2	Midnight		1.22	.82
12/2	6:15 AM	#3	Evap. Feed	2.56		
		#4			.817	.468
12/2	Noon	#4	Evap. Feed	2.60		
		#5			1.125	.75
			Second Startup After Repairs			
12/4	7:45 AM	#7	Evap. Feed During Startup	2.53		.975
		#8			1.25	
12/4	11:30 AM	#9	Feed	2.36		.905
		#10			1.12	
12/4	5:30 PM	#11	Feed	2.53		
		#12			1.25	.98
12/4	8:30 PM	#13	Feed	2.78		
		#14			1.42	.96
12/4	11:30 PM	#15	Feed	2.80		
		#16			1.44	.94
12/5	2:30 AM	#17	Feed	2.87		
		#18			1.40	.95
12/5	5:30 AM	#19	Feed	2.67		

Date	Time	Sample No.	Sample Description	% T.S	% S.S	Ratio SS/IS
12/5	5:30 AM	#20	Feed		1.22	.84
12/5	7:30 AM	#21		2.63		
		#22			1.19	.82
12/5	11:30 AM	#23		2.31		
		#24			1.06	.85
12/5	4:30 PM	#25	Conc.	21.4		
12/5	5:20 PM	#26	Conc.	21.8		
12/5	5:45 PM	#27		2.60	1.20	.85
		#28				
12/5	8:30 PM	#29	Feed	2.73		
		#30	Feed		1.35	.98
12/5	9:30 PM	#31	Conc.	20.5		
12/6	3:00 AM	#32	Feed	2.57		
		#33	Feed		1.29	1.02
12/6	7:30 AM	#34	Conc.	19.72		
12/6	7:45 AM	#35	Feed	2.29		
		#36	Feed		1.11	.94
12/6	10:30 AM	#37	Conc.	18.88		
12/6	10:45 AM	#38	Feed	2.38		1.05
		#39	Feed		1.22	
12/6	5:30 PM	#40	Feed	3.00		
		#41	Feed		1.59	1.13
12/6	9:45 PM	#42	Feed	3.40		
		#43			1.70	1.00

Date	Time	Sample No.	Sample Description	% T.S	% S.S	Ratio SS/IS
12/7	2:45 AM	#1	Feed	3.45		
		#2	Feed		1.88	1.20
12/7	8:45 AM	#3	Feed	3.35		
		#4			1.84	1.22
12/7	12:45 PM	#5	Feed	3.94		
		#6			1.81	.85
12/7	2:35 PM	#7	Conc.	20.31		
12/7	5:00 PM	#8	Feed	2.97		
		#9			1.44	.94
12/7	10:00 PM	#10	Feed	3.22		
		#11			1.61	1.00
12/8	2:00 AM	#12	Feed	3.32		
		#13			1.75	1.12
12/8	5:45 AM	#14	Conc. to Recycle	20.0		
12/8	5:45 AM	#15	Press Output	30.3		
12/8	5:45 AM	#16	Recycle to Dryer	51.8		
12/8	5:45 AM	#17	Dry Grain to Recycle	83.8		
12/8	6:30 AM	#18	Feed	3.42		
		#19			1.73	1.02
12/8	7:50 AM	#20	Recycle	61.0		
		#21	Conc. to Recycle	19.3		
		#22	Dry Grain	91.5		
		#23	Press Grain	34.8		
12/8	10:40 AM	#24	Feed	3.20		

Date	Time	Sample No.	Sample Description	% T.S	% S.S	Ratio SS/IS
12/8	10:40 AM	#25			1.63	1.04
12/8	4:35 PM	#27	Brewhouse D.W.S.[a] H_2O	2.06		
		#28			.96	.87
12/8	5:15 PM	#29	Conc. to Recycle	23.0		
12/8	5:15 PM	#30	Press Grain 2 Presses	43.5		
12/8	5:15 PM	#31	Recycle to Dryer	55.0		
12/8	5:15 PM	#32	Dry Grain	90.4		
12/8	6:20 PM	#33	Brewhouse D.W.S.	2.73		
		#34			1.51	1.23
12/8	7:50 PM	#35	Brewhouse D.W.S.	1.95		
		#36	6 Min. 12 Min. Total		.85	.77
12/8	8:45 PM	#37	Feed	3.13		
		#38			1.44	.85
12/8	9:45 PM	#39	Brewhouse D.W.S.	2.00		
		#40	6 Min. - 11 Min. Total		1.05	
12/8	10:30 PM	#41	Press #1	41.8		
12/8	10:30 PM	#42	Press #2	41.8		
12/8	10:30 PM	#43	Recycle to Dryer	55.7		
12/8	10:30 PM	#44	Dry Grain	89.4		
12/8	10:30 PM	#45	Conc. to Recycle	20.8		
12/8	11:40 PM	#46	Brewhouse D.W.S.	1.56		
		#47	4 Min. - 10 Min. Total		.73	.88
12/9	1:35 AM	#48	Brewhouse D.W.S.	1.72		
		#49	4 Min. - 9 Min. Total		.82	.91

[a] Dewatering Screen

Date	Time	Sample No.	Sample Description	% T.S	% S.S	Ratio SS/IS
12/9	2:30 AM	#50	Feed	3.22		
		#51			1.50	.875
12/9	3:35 AM	#52	Brewhouse D.W.S.	1.32		
		#53	4 Min. - 10 Min. Total		.63	.915
12/9	3:40 AM	#1	Recycle to Dryer	63.4		
	3:40 AM	#2	Dry Grain	90.5		
	3:40 AM	#3	Conc. to Recycle	19.6		
	3:40 AM	#4	Press 1	39.3		
	3:40 AM	#5	Press 2	38.7		
12/9	6:15 AM	#6	Feed	3.12		
		#7			1.55	.99
12/9	7:40 AM	#8	Conc. to Recycle	20.2		
		#9	Recycle to Dryer	62.0		
		#10	Dry Grain	89.8		
		#11	Press #1	40.4		
		#12	Press #2	40.1		
12/9	12:45 PM	#13	Recycle to Dryer	60.0		
	12:45 PM	#14	Press Grain	42.7		
	12:45 PM	#15	Dry Grain	91.5		
12/9	1:40 PM	#16	Brewhouse D.W.S.#1	2.01		
		#17			.99	
	1:40 PM	#18	Brewhouse D.W.S.#2	1.74		
		#19			1.08	
12/9	3:40 PM	#20	Brewhouse D.W.S.	2.43		

Date	Time	Sample No.	Sample Description	% T.S	% S.S	Ratio SS/IS
12/9	3:40 PM	#1	Comp. #1 7-14 Min.		.63	
	3:40 PM	#2	Brewhouse D.W.S.	1.05		
		#3	Comp. #2 14-15 Min.		.43	

APPENDIX L - EVAPORATOR TESTS USING

INCONEL 601 DOWNCOMERS - SERIES 2

Date/ Time	HIC #1 / #2	Panel LI	Fcx LIC	Drexel Brook	Gas Rec. Flow	Stack Temp.	Temp. Out of Moyno	Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press Psig	Burner Air ΔP #1	Burner Air ΔP #2	Blower Amps	Feed Tank Level	Feed Rate	Conc. Tank Level	Air Temp.	Blower P/T	Tank Press
1/3/72 10:50 A	EVAP. FULL 10:50 a.m READY FOR START UP																		
10/4/72 5:00 P	.4 / 2.9	39	11.5	38		188	114	1.1	1.6	3.9	4.0	8.0	68					7.3 / 39	0
6:00	9.9 / 11	41	12.0	41	16,000 6264250	186	179	3.0	3.20	3.9	10-15	17	99	-				7.1 / 39	0
7:20	11 / 9.8	40	12.0	37		186	182	3.1	3.20	3.9	10-15	17	99					7.1 / 39	0
1/5/72 8:30 A	9.6 / .8	52	16.5	30	15,500 6322600	190	150	2.85	2.00	3.9	17-21	7.0	86					7.55 / 32	0
10:30	2.2 / .8	42	12.5	32		192	168	1.35	2.10	4.0	8.0	8.0	66					7.60 / 30	0
11:30	9.1 / 4.1	60	18.0	4	14,000 6335123	187	151	2.10	2.00	3.95	15.0	9.0	90					7.40 / 38	0
1:00 P	10.0 / 4.1	61	18.0		13,750 6344952	187.5	156	2.50	2.00	3.95	15-20	9.0	88					7.50 / 44	0
2:00	10.1 / 4.1	61	18.0			188	164	2.55	1.90	3.95	15-20	9.0	87					7.30 / 44	0
3:00	10.0 / 4.1	60	18.5	100+		190	169	2.60	2.50	3.95	15-20	9.0	87					7.25 / 47	0
4:00	10.0 / 4.1	60	18.75	100+		190	173	2.60	2.55	3.95	15-20	9.0	88					7.3 / 48	0
6:30	10.0 / 4.1	60	18.5	100+	14,500 6361075	190	166	2.55	2.50	3.95	15-20	9.0	86					7.3 / 46	0

Date/ Time	HIC #1 / #2	Panel LI	Fox LIC	Drexel Brock	Gas Rec. Flow	Stack Temp.	Temp. Out of Moyno	Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press Psig	Burner Air ΔP #1	Burner Air ΔP #2	Blower Amps	Feed Tank Level	Feed Rate	Conc. Tank Level	Air Temp.	Blower P/T	Tank Press
1/5/72 8:00 P	10.0 / 4.1	60	18.0	100+		190	168	2.55	2.50	3.95	17-21	9.0	87					7.4 / 43	0
1/6/72 8:45 A	10.0 / 4.1	60	18.0	0	14,500 6415630	189	145	2.60	2.50	3.95	17-22	9.0	89	100	28	100+		7.5 / 34	0
9:45	10.0 / 4.1	62	18.75	0		189	112	2.60	2.50	3.95	17-22	10.0	89	100	25.5	100		7.45 / 36	0
11:00	9.8 / 4.0	62	18.50	0	14,500 6424036	190	136	2.60	2.55	3.95	18-23	9.0	88	100	255	100		7.40 / 40	0
11:45	10.0 / 3.95	62	18.75	0	14,500	190	138	2.60	2.55	3.95	18-24	9.0	87	100	24.0	89		7.35 / 43	0
1:15 P	9.75 / 3.50	62	18.50	0	6432116	190.5	96	2.55	2.40	4.00	18-24	7-10	85	100	24.0	66	425	4.30 / 47	0
3:30	9.9 / 4.10	59	17.75	0		189	147	2.65	2.55	4.00	18-24	8.0	88	100	28.0	100	335	7.20 / 52.0	0
4:45	9.9 / 4.0	64	19.75	0	14,500 6447334	190	161	2.55	2.55	3.95	18-24	8.5	87	94	26.5	100		7.25 / 51.0	0
5:50	9.5 / 3.75	62	19.0	0		190	170	2.50	2.55	3.95	18-24	8.0	86	100	25.0	100	410	7.25 / 46	0
6:45	9.75 / 4.20	62	19.25	0	14,500 6454440	190	169	2.55	2.55	3.95	18-24	8.0	88	100	25.0	100		7.30 / 44	0
1/7/72 8:45	10.00 / 4.25	62	18.75	100+	14,500 6506062	189.5	170	2.55	2.60	4.00	20-27	10-11	91	100	28	74	375	7.40 / 40	0
9:45	10.15 / 4.25	62	19.0	100+		189.5	171	2.60	2.70	4.00	20-25	9-10	90	100	28	71	375	7.30 / 46	0
10:45	10.20 / 4.30	61	19.0	100+	14,500 6513599	190	172	2.60	2.70	4.00	20-26	9-10	90	100+	28	70	385	7.20 / 50	0
11:45	9.9 / 4.15	63	19.5	100+		190	167	2.50	2.55	4.0	20-26	8.0	87	100	28	72	380	7.20 / 53	0

Date/ Time	HIC #1 / #2	Panel LI	Fox LIC	Drexel Brook	Gas Rec. Flow	Stack Temp.	Temp. Out of Moyno	Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press Psig	Burner Air ΔP #1	Burner Air ΔP #2	Blower Amps	Feed Tank Level	Feed Rate	Conc. Tank Level	Air Temp.	Blower P/T	Tank Press
1/7/72 1:45	10.0 / 4.15	62	19.0	100+	14,500 6524605	190	173	2.55	2.55	4.0	19-25	8.5	87	96	28	72	395	7.10 / 56	0
2:45	10.25 / 4.15	62	19.0	100+		190	172	2.60	2.55	4.0	20-25	8-9	87	88	28	72	400	7.10 / 57	0
3:45	10.20 / 4.15	62	19.0	100+		190	168	2.60	2.60	4.0	19-25	8-10	87	88	28	71	400	7.10 / 56	0
4:45	10.25 / 4.15	62	19.25	100+	15250-14750 6535638	190	168	2.55	2.60	4.0	19-25	8.5	88	86	27	66	400	7.15 / 56	0
5:45	10.25 / 4.20	63	19.0	100+		190	167	2.60	2.60	4.0	19-26	8.5	88	90	27	60	395	7.20 / 52	0
6:45	10.25 / 4.20	63	19.0	100+		190	169	2.60	2.65	4.0	19-27	8.5	88				390	7.20 / 50	0
1/8/72 9:00 A	10.10 / 4.15	63	19.25	100+	15500-13500 6596456	190	172	2.55	.265	4.0	19-24	9.0	88	92	27	66	405	7.10 / 58	0
10:00	10.20 / 4.20	63	19.0	100+		190.25	172	2.55	2.60	3.95	18-27	7-10	86	94	27	64	410	7.00 / 62	0
11:00	10.00 / 4.20	63	19.25	100+		190.25	172	2.55	2.65	4.00	19-24	8.5	85	94	27	62	410	6.95 / 64	0
12:00 N	10.00 / 4.20	63	19.00	0		190.25	173	2.55	2.70	4.00	18-25	8.5	85.	93	27	62	410	6.95 / 64	0
1:00 P	10.00 / 4.20	63	19.25	0	14500-14000 6611550	190.25	172	2.55	2.70	4.00	18-24	7-9	85	86	27	62	415	6.90 / 66	0
2:00	10.15 / 4.20	63	19.25	--		190	172	2.60	2.70	4.00	18-25	8-10	86	74	27	60	410	6.90 / 66	0
3:00	10.20 / 4.20	63	19.25	--		190	173	2.55	2.70	3.95	17-23	7-9	85	74	27	56	410	6.90 / 68	0
4:00	9.85 / 4.15	63	19.25	--		190	173	2.55	2.70	4.00	17-24	8-9	85	64	27	56	410	6.85 / 70	0

Date/ Time	HIC #1 / #2	Panel LI	Fox LIC	Drexel Brook	Gas Rec. Flow	Stack Temp.	Temp. Out of Moyno	Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press Psig	Burner Air ΔP #1	Burner Air ΔP #2	Blower Amps	Feed Tank Level	Feed Rate	Conc. Tank Level	Air Temp.	Blower P/T	Tank Press
1/8/72 5:00 P	9.8 / 4.15	63	19.0	--	14000-14500 6627028	190	172	2.55	2.70	4.0	17-24	7.5-9	84	68	27	62	410	6.85 / 68	0
1/9/72 9:00 A	10.10 / 4.20	63	19.25	--	13250-15000 6692530	190.25	173	2.55	2.70	4.0	14-21	7-9	85	88	26	68	425	6.80 / 70	0
10:00	10.10 / 4.15	63	19.00	--		190.5	174	2.55	2.65	4.0	15-22	7-10	84	90	26	60	438	6.80 / 71	0
11:00	10.10 / 4.15	63	19.25	--		190.5	176	2.60	2.70	3.95	14-22	7-8	84	87	25	52	430	6.75 / 74	0
12:00 N	10.10 / 4.15	63	19.25	--		190.5	177	2.55	2.65	4.00	15-21	6.5-7.5	84	90	25	42	430	6.75 / 76	0
1:00 P	10.10 / 4.15	63	19.25	--		190.5	177	2.60	2.65	4.00	14-21	6-9	84	88	25	32	435	6.75 / 77	0
2:00	10.10 / 4.15	63	19.0	--	13750-14500 6717196	190.5	176	2.60	2.65	4.00	14-21	6-9	83	89	26	30	435	6.70 / 76	0
3:00	10.10 / 4.20	63	19.25	--		190.5	177	2.55	2.65	4.00	14-21	6-9	84	88	26	26	435	6.70 / 76	0
4:00	9.9 / 4.15	63	19.0	--		190.5	177	2.60	2.65	3.95	14-21	6-9	82	88	26	24	435	6.70 / 74	0
5:00	10.15 / 4.20	63	19.25	--		190.5	177	2.55	2.65	4.00	14-21	7-8	82	83	26	22	435	6.70 / 76	0
1/10/72 8:20 A	9.85 / 4.15	63	19.25	--	14750-13000 6797715	190.5	175	2.55	2.65	4.00	14-21	7-9	84	88	27	66	430	6.80 / 70	0
9:00	9.70 / 4.15	63	19.0	--		190.5	175	2.50	2.65	4.00	14-22	6-9	84				437	6.80 / 70	0
10:00	10.00 / 4.20	63	19.25	--		190.5	174	2.55	2.65	4.00	14-22	7-10	85	88	27	66	435	6.80 / 72	0
11:00	10.00 / 4.20	63	19.25	--		190.5	173	2.60	2.65	4.00	14-20	7-9	85	90	26.5	68	432	6.80 / 72	0

Date/ Time	HIC #1 / #2	Panel LI	Fox LIC	Drexel Brook	Gas Rec. Flow	Stack Temp.	Temp. Out of Moyno	Gas Orifice ΔP #1	Gas Orifice ΔP #2	Gas Press Psig	Burner Air ΔP #1	Burner Air ΔP #2	Blower Amps	Feed Tank Level	Feed Rate	Conc. Tank Level	Air Temp.	Blower P/T	Tank Press
1/10/72 12:00 N	10.0 / 4.15	63	19.25	--		190.5		2.60	2.65	4.00	14-20	6-8	84				430	6.80 / 73	0
1:00 P	10.00 / 4.15	63	19.25	--		190	174	2.60	2.65	4.00	14-20	7-9	84	88	27	76	429	6.75 / 72	
2:00	10.00 / 4.15	63	19.00	--		190	175	2.60	2.65	4.00	13-18	6-8	84	90	27	64	425	6.75 / 74	
3:00	10.00 / 4.15	63	19.00	--		190	175	2.60	2.65	4.00	13-20	6-8	85	88	27	64	420	6.75 / 72	
4:00	10.00 / 4.15	63	19.00	--		190	173	2.60	2.65	4.00	14-18	7-8	85	90	27	72	420	6.80 / 70	

APPENDIX M - INCONEL 601 DOWNCOMER TESTS -

SERIES 2

FEED AND PRODUCT SAMPLES

Date (1972)	Time	Sample No.	Sample Description	% T.S.	% S.S.	Ratio SS/IS
1/4	10:10 AM	1	Feed	3.87		
		2	Feed		1.85	.905
1/4	10:50 AM	3	Feed	3.83		
		4	Feed		1.99	1.07
1/4	7:30 PM	5	Feed	4.15		
		6	Feed		1.85	.805
1/5	9:00 AM	7	Feed	3.89		
		8	Feed		1.90	.95
1/5	1:00 PM	9	Feed	4.00		
		10	Feed		2.13	1.15
1/5	6:30 PM	11	Feed	3.75		
		12	Feed		2.01	1.16
1/6	9:00 AM	13	Feed	3.46		
		14	Feed		1.72	.99
1/6	11:30 PM	15	Feed	3.36		
		16	Feed		1.84	1.41
1/6	5:00 PM	17	Feed	3.25		
		18	Feed		1.50	.85
1/7	9:00 AM	19	Feed	3.38		
		20	Feed		1.74	1.13

Date	Time	Sample No.	Sample Description	% .S	% S.S	Ratio SS/IS
1/7	11:25 AM		Press #1	40.3		
	11:25 AM		Press #2	41.4		
	11:25 AM		Recycle	66.0		
	11:25 AM		Dry Grain	90.0		
	11:25 AM		Conc.	23.1		
	11:25 AM		Yeast	15.6		
					2.32	
1/7	1:40 PM	28	Feed	2.79		
		29	Feed		1.42	1.037
1/7	3:00 PM	32	Press #1	41.4		
		31	Press #2	41.1		
		30	Recycle	68.5		
		33	Dry Grain	88.0		
		34	Conc.	21.6		
		35	Yeast	15.1		
1/7	5:30 PM	36	Feed	2.91		
		37	Feed		1.29	.797
1/7	7:00 PM	3	Press #1	42.9		
		2	Press #2	43.1		
		4	Recycle	67.25		
		1	Dry Grain	88.0		
		5	Conc.	19.95		
		6	Yeast	15.10		
1/8	9:00 AM	7	Yeast	3.56		

Date	Time	Sample No.	Sample Description	% T.S.	% S.S.	Ratio SS/IS
1/8	9:00 AM	8	Feed	3.32		
		9	Feed		1.68	1.02
1/8	9:30 AM	14	Press #1	34.5		
		11	Press #2	40.7		
		10	Recycle	61.8		
		12	Dry Grain	90.0		
		13	Conc.	22.3		
		14	Yeast	3.73		
1/8	1:00 PM	16	Feed	2.54		
		17			1.28	1.015
	1:30 PM	23	Press #1	38.1		
		20	Press #2	39.8		
		22	Recycle	69.0		
		21	Dry Grain	91.5		
		19	Conc.	22.5		
		18	Yeast	2.91		
1/8	5:00 PM	30	Feed	2.43		
	5:00 PM	31	Feed		1.14	.885
	5:00 PM	26	Press #1	40.8		
		28	Press #2	38.3		
		29	Recycle	74.25		
		27	Dry Grain	92.3		
		25	Conc.	19.95		
			Yeast			

Date	Time	Sample No.	Sample Description	% T.S.	% S.S.	Ratio SS/IS
1/9	9:00 AM	34	Press #1	41.8		
		33	Recycle	75.0		
		35	Dry Grain	91.25		
		32	Conc.	19.6		
1/9	9:00 AM	36	Feed	2.83		
		37			1.29	.837
1/9	1:00 PM	42	Feed	2.46		
		43			1.11	.82
		39	Press #1	40.3		
		38	Recycle	75.5		
		40	Dry Grain	89.2		
		41	Conc.	19.05		
1/9	5:00 PM	5	Feed	2.75		
		6			1.25	.83
		2	Press #1	40.3		
		3	Recycle	73.75		
		1	Dry Grain	90.5		
		4	Conc.	19.50		
1/10	9:00 AM	13	Feed	3.37		
		14	Feed		1.72	1.04
		7	Press #1	36.1		
		8	Press #2	35.75		
		10	Recycle	68.4		
		11	Conc.	21.2		

Date	Time	Sample No.	Sample Description	% T.S.	% S.S.	Ratio SS/IS
1/10	9:00 AM	12	Yeast	12.5		
1/10	1:00 PM	21	Feed	2.76		
		22			1.51	1.20
		16	Press #1	43.0		
		18	Press #2	33.6		
		15	Recycle	67.2		
		17	Dry Grain	90.5		
		20	Conc.	--		
		19	Yeast	17.25		

APPENDIX N - EVAPORATOR TESTS

USING JACKETED DOWNCOMER COOLED

WITH DILUTION AIR

Time & Date	Flow Rates Evap. Feed (GPM)	Conc. Pump (Set)	Firing Rate (Million BTU/Hr.)	Stack Temp. °F	Concentrate (% T.S.)
10/19/72					
12:00 M			12.3		
1:00 AM			12.3		
2:00 AM			12.3		
3:00 AM			12.3		
4:00 AM			12.3		
5:00 AM			12.3		
6:00 AM			12.3		
7:00 AM			12.3		
8:00 AM			12.3		
9:00 AM			12.3		
10:00 AM			12.3		
11:00 AM			12.3		
12:00 N			12.3		
1:00 PM			12.3		
2:00 PM			12.3		
3:00 PM			12.3		
4:00 PM	16	--	12.3		9.0
5:00 PM	0		12.3		10.0
6:00 PM	0		12.3		

Time & Date	Flow Rates Evap. Feed (GPM)	Conc. Pump (Set)	Firing Rate (Million BTU/Hr.)	Stack Temp. °F	Concentrate (% T.S.)
10/19/72					
7:00 PM	50		12.3		11.4
8:00 PM	0		12.3		
9:00 PM	0		12.3		14
10:00 PM	0		12.3		
11:00 PM			12.3		16.4
10/20/72					
12:00 M			12.3		16.8
1:00 AM			12.3		17.6
2:00 AM			12.3		18.4
3:00 AM			12.3		20.0
4:00 AM			12.3		20.0
5:00 AM	26		12.3		21.4
6:00 AM	26	--	12.3		21.2
7:00 AM	26	--	12.3		20.2
8:00 AM	27	--	12.3		19.4
9:00 AM	27	--	12.3		20.0
10:00 AM	27	--	12.3		20.4
11:00 AM	27	--	12.3		19.4
12:00 N			12.3		
1:00 PM	27	--	12.3		
2:00 PM	27	--	12.3		17.0
3:00 PM	26	--	12.3		17.0
4:00 PM	26	4.0	12.3		17.0

Time & Date	Flow Rates Evap. Feed (GPM)	Conc. Pump. (Set)	Firing Rate (Million BTU/Hr.)	Stack Temp. °F	Concentrate (% T.S.)
10/20/72					
5:00 PM	25	4.5	12.3		17.4
6:00 PM	24	4.5	12.3		17.0
7:00 PM	23	4.5	12.3		17.0
8:00 PM	24	4.5	12.3		18.0
9:00 PM	24	4.5	12.3		--
10:00 PM	24	4.5	12.3		--
11:00 PM	24	5.0	12.3		17.9
10/21/72					
12:00 M	24	5.0	12.3		18.2
1:00 AM	24	5.0	12.3		18.6
2:00 AM	24	5.0	12.3		18.4
3:00 AM	24	5.0	12.3		18.6
4:00 AM	24	5.0	12.3		18.6
5:00 AM	24	5.0	12.3		18.2
6:00 AM	24	5.0	12.3		18.4
7:00 AM	24	5.0	12.3		19.0
8:00 AM	24	5.0	12.3		19.2
9:00 AM	24	5.0	12.3		19.0
10:00 AM	24	5.0	12.3		20.
11:00 AM	24	5.0	12.3		20.0
12:00 N	24	5.0	12.3		20.4
1:00 PM	24	4.0	12.3		19.8
2:00 PM	24	3.0	12.3		18.0

Time & Date	Flow Rates Evap. Feed (GPM)	Conc. Pump (Set)	Firing Rate (Million BTU/Hr.)	Stack Temp. ^oF	Concentrate (% T.S.)
10/21/72 3:00 PM	24	--	12.3		21.6
4:00 PM	25	2.5	12.3		22.0
5:00 PM	26	3.5	12.3		22.0
6:00 PM	26	4.0	12.3		22.0
7:00 PM	27	4.0	12.3		22.0
8:00 PM	28	4.5	12.3		
10/25/72			12.5		
10/26/72	23		12.5	184	19.
10/30/72			12.5		
11/8/72	24		12.5	184	3.

APPENDIX O

EFFLUENT SAMPLING WITH EVAPORATOR

OPERATING

12/8/71	12/9/71	12/13/71*	12/14/71*
NA	860	876	NA
6,120	3,100	1,950	2,320
835	800	852	676
800	740	708	600
3,268	1,894	2,560	1,800
NA	63.0	12.1	NA
NA	0.01	0.08	NA
NA	0.43	0.20	NA
NA	0.16	0.00	NA

NA = No Analysis

* One burner in service

APPENDIX P

EFFLUENT SAMPLING WITH EVAPORATOR NOT OPERATING

Date of Sample	BOD_5, mg/l	COD, mg/l	Total Suspended Solids mg/l	Volatile Suspended Solids mg/l	Total Solids mg/l	Total Kjeldahl Nitrogen, mg/l	Nitrite mg/l	Nitrate, mg/l	Total Phosphorus, mg/l
10/11/71	1,534	NA	716	NA	1,660	NA	NA	NA	NA
10/13/71	1,566	NA	808	NA	1,990	NA	NA	NA	NA
10/19/71	1,870	1,750	1,300	1,240	1,660	97.3	LT 0101	0.40	5.2
10/20/71	NA	c,910	940	912	1,850	NA	NA	NA	NA
10/25/71	1,590	2,160	860	840	1,820	88.0	LT 0.01	0.62	5.2
10/26/71	NA	1,920	1,160	1,120	1,620	NA	NA	NA	NA
11/9/71	1,580	2,160	940	932	910	14.	LT 0.01	0.10	0.05
11/10/71	NA	2,070	980	928	1,770	NA	NA	NA	NA
11/17/71	NA	2,570	860	844	2,010	NA	NA	NA	NA
11/18/71	2,140	2,720	810	790	1,870	14.	LT 0.01	0.08	3.5
11/19/71	1.060	3.740	1,340	1,280	2,300	16.	LT 0.01	0.10	0.92
11/20/71	NA	4,580	1,960	1,890	3,160	NA	NA	NA	NA
11/21/71	1,270	3,510	1,160	1,010	2,850	18.	0.33	0.06	6.0

Date of Sample	BOD_5, mg/1	COD, mg/1	Total Suspended Solids mg/1	Volatile Suspended Solids mg/1	Total Solids mg/1	Total Kjeldahl Nitrogen, mg/1	Nitrite mg/1	Nitrate, mg/1	Total Phosphorus, mg/1
11/22/71	NA	,2840	900	836	2,000	NA	NA	NA	NA
11/30/71	NA	2,600	535	505	1,664	NA	NA	NA	NA
12/1/71	410	2,110	560	510	1,876	13.3	0.01	0.32	0.20
12/18/71	1,284	1,173	612	536	1,266	3.9	LT .1	0.18	3.8
12/19/71	NA	1,440	436	208	1,496	NA	NA	NA	NA
12/20/71	1,992	2,860	1,160	1,120	2,180	5.9	LT .1	0.18	2.0
12/21/71	NA	3,169	1,012	932	2,320	NA	NA	NA	NA
12/29/71	NA	1,543	680	582	1,350	NA	NA	NA	NA
12/30/71	1,752	1,646	744	704	1,454	5.1	ND	ND	0.5

NA = No Analysis

ND = Not Detectable

LT = Less Than

SELECTED WATER RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

1. *Report No.*

2.

3. *Accession No.*

W

4. *Title* SUBMERGED COMBUSTION EVAPORATOR FOR CONCENTRATION OF BREWERY SPENT GRAIN LIQUOR

5. *Report Date*

6.

8. *Performing Organization Report No.*

7. *Author(s)*

Stein, J. L.

10. *Project No.*

12060 HCW

9. *Organization*

Anheuser-Busch, Inc., St. Louis, Missouri, Engineering Department

11. *Contract/Grant No.*

13. *Type of Report and Period Covered*

12. *Sponsoring Organization*

15. *Supplementary Notes*

Environmental Protection Agency report number, EPA-660/2-74-059, June 1974

16. *Abstract*

A major waste stream in many breweries is the liquor resulting from spent grains dewatering prior to drying. This liquor may account for a third or more of the $B.O.D._5$ and suspended solids generated by a typical brewery.

Initial studies of the spent grain liquor problem indicated that recovery rather than treatment was the best approach. A number of evaporators were evaluated to determine which design was most satisfactory for concentrating the liquor. A submerged combustion evaporator was selected on the basis of engineering analyses and pilot scale tests.

A full scale unit was installed at the Houston Brewery of Anheuser-Busch, Inc., in 1970. This evaporator was modified several times to overcome failures of the burner downcomers brought about by high temperatures. Before a final solution to these problems could be demonstrated, the project was terminated. Fuel costs above $1.60 per million kg-cal (40¢ per million BTU) coupled with thermal efficiencies approximately 3.5 times better for conventional four-effect evaporators indicated that a conventional evaporator would be more economical at these fuel price levels.

17a. *Descriptors*

*Evaporators, *Industrial Wastes, Water Pollution Control, Water Pollution Sources, Waste Disposal, Wastes

17b. *Identifiers*

*Submerged Combustion Evaporators, *Spent Grain, *Brewing Wastes, Beer, Food Processing, Multiple-Effect Evaporators, Resource Recovery

17c. *COWRR Field & Group* 05E, 05D

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