NATIONAL RENEWABLE ENERGY LABORATORY
GOLDEN, COLORADO

SUBCONTRACT ACO-9-29067-01
PROCESS DESIGN AND COST ESTIMATE
OF CRITICAL EQUIPMENT IN THE
BIOMASS TO ETHANOL PROCESS

REPORT 99-10600/17
CONTINUOUS ACID HYDROLYSIS REACTOR

JANUARY 22, 2001
REV WEB

Harris Group Inc.
1000 Denny Way, Suite 800
Seattle, Washington 98109

REPORT 99-10600/17

CONTINUOUS ACID HYDROLYSIS REACTOR

SUBCONTRACT ACO-9-29067-01
PROCESS DESIGN AND COST ESTIMATE OF CRITICAL EQUIPMENT IN THE BIOMASS TO ETHANOL PROCESS

NATIONAL RENEWABLE ENERGY LABORATORY
GOLDEN, COLORADO

JANUARY 22, 2001

TABLE OF CONTENTS

ARS/mlm
10600rpt17

REPORT 99-10600/17

CONTINUOUS ACID HYDROLYSIS REACTOR

SUBCONTRACT ACO-9-29067-01
PROCESS DESIGN AND COST ESTIMATE OF CRITICAL EQUIPMENT IN THE BIOMASS TO ETHANOL PROCESS

NATIONAL RENEWABLE ENERGY LABORATORY
GOLDEN, COLORADO

JANUARY 22, 2001

1. SUMMARY

National Renewable Energy Laboratory (NREL) has requested that Harris Group Inc. (HGI) help determine the commercial pricing of the presteaming vessels and continuous acid hydrolysis reactors for three different processes. All the processes convert wood chips to sugars in high temperature, dilute sulfuric acid concentration reactors. The sugar is then converted to ethanol in the remaining process equipment. Each of the processes has different temperatures, pressures, residence times, and acid concentrations. The purpose of this report is to compare the pricing from vendor bids and recommend which bids should be used in a capital cost estimate. Also included is an installation cost for each option. Of the two vendors, HGI recommends using the Andritz quotes. Although their pricing is higher, HGI feels Andritz's experience and thoughtful approach taken to the metallurgy and physical process are the most comprehensive. On a price-per-reactor basis the Andritz bid is competitive.

Future work should include a determination of how full the reactors must be for adequate mixing and consistent cooking. The results of this study may reduce the number of reactor vessels and subsequent cost.

2. INTRODUCTION

HGI has been working with NREL to estimate pricing for the acid hydrolysis reactors for various processes. The work has involved corrosion testing to determine appropriate reactor metallurgy for the proposed process operating parameters. It has also included a vendor analysis to choose appropriate vendors for pricing the reactors (see Appendix A). Two vendors, Andritz and Anco-Eaglin, were chosen for their previous experience with acid hydrolysis and an acid hydrolysis reactor specification was sent to them. The vendors provided pricing on three different processes: Process 100, Process 200 Stage 1, and Process 300 Stages 1 and 2. This report summarizes the information and pricing supplied by the vendors and respective installation costs.

3. DESCRIPTION

3.1 Process Summaries

NREL under the direction of the Office of Fuels Development at the U.S. Department of Energy has, over the years, developed a process for converting cellulosic biomass to fuel ethanol based on NREL and subcontracted research and standard engineering practices. Three specific variations of the process were considered for the work in this subcontract:

- Pretreatment with Enzymatic Hydrolysis (P100)
- Two-Stage Countercurrent Acid Hydrolysis (P200)
- Two-Stage Dilute Acid Hydrolysis (P300)

In Process 100, biomass feedstock in chip form is introduced to the plant and screened. . The chips are passed to a scalper screen to remove very large materials, then onto a chip thickness sizing screen. We assume that approximately 20% of the incoming material will be oversized and will require processing through a single-disc refiner system. The disc refiner reduces oversized material to less than 19 mm, suitable for the pretreatment reactors. The biomass is pretreated to make it more susceptible to acid penetration. During pretreatment, much of the hemicellulosic portion of the biomass is hydrolyzed into soluble sugars in a continuous hydrolysis reactor. This reactor uses steam and dilute sulfuric acid to initiate hydrolysis. Afterwards, the liquid portion of the pretreated slurry must be separated from the solids to facilitate conditioning of the liquid portion to remove compounds, such as acetic acid, that may be toxic to downstream fermentative organisms. Once the liquid stream is conditioned properly (most likely via ion exchange and overliming), it is recombined with the solids and sent to fermentation.

This process uses simultaneous saccharification and cofermentation (SSCF) to hydrolyze cellulose and ferment the resulting glucose and other sugars present to ethanol in the same vessel. As this design currently stands, a portion of the pretreated hydrolyzate is drawn off and used to produce cellulase enzyme. The enzyme is then added to the fermentation vessels. A recombinant ethanologen is used to ferment multiple sugars to ethanol. The resulting beer is then sent to distillation and dehydration to purify and concentrate the ethanol. The lignin portion of the original biomass gets carried through the system and exits with the distillation bottoms. This lignin is used as fuel for the burner/boiler system in the plant. As a result it must be dewatered sufficiently to achieve proper combustion.

Process 200 uses no acid in the first stage and a countercurrent reactor design in the second stage of hydrolysis to convert the hemicellulose and a large portion of the cellulose in the biomass to soluble sugars. The second-stage reactor separates the solids and liquor containing dissolved sugars. The solids are sent to the boiler and the liquid is sent to the oligomeric reactor and flash tank. The liquor is then neutralized and sent to fermentation. The back end of the process is the same as Process 100, but the process stream is liquid only.

Process 300 differs from Process 100 in that no enzymes are used. All hydrolysis is accomplished thermochemically. In the first stage of hydrolysis, the hemicellulosic portion of the biomass is hydrolyzed to soluble sugars. These sugars must then be washed from the slurry prior to the second stage of hydrolysis or else they will be degraded at the more severe conditions. The soluble sugar stream is neutralized (with stoichiometric amounts of lime) and sent to fermentation. The solids stream, primarily cellulose and lignin, is sent to the second stage of hydrolysis to further hydrolyze cellulose to glucose. After hydrolysis this stream is also sent to fermentation. The back end of the process is the same as Process 100.

A comparison of the differences in the presteaming and reactor operating conditions can be found in Table 1.

Table 1
Process Conditions

Description	Unit	Conditions
WOOD CHIP TYPES		yellow poplar, Douglas fir, or ponderosa pine
Average size	in.	3.4 x 3.4 x 1.4 in.
Feed stock rate	metric tpd	2000
Average wood density	g/ml	1.217
Moisture	%	47.9
Bulk density	lb/cu ft	8-10
PROCESS 100		
Process Flow Diagram	Revision E	PFD-P100-A201
Equipment Number		M –202
Chip Presteamer Vessel		
Operating temperature	^{o}C	100
Operating pressure	atm	1
Steam pressure	atm	4.42
Steam flow	kg/hr	17,115
Residence time	minutes	20
Chip flow into vessel	kg/hr	159,948
Metallurgy		316 L SS
Hydrolysis Reactor		
Operating temperature	^{o}C	180
Operating pressure	atm	9.75
Acid concentration (% liquid)	%	0.7
Acid flow (2.133% sulfuric)	kg/hr	60,521
Steam pressure	atm	13
Steam flow	kg/hr	32,638
Reactor residence time	minutes	10
Total flow from reactor	kg/hr	271,313
Metallurgy		Alloy 825
PROCESS 200 STAGE 1		
Process Flow Diagram	Revision A	PFD-P202-A201
Equipment Number		M-202

Table 1
Process Conditions (continued)

Description	Unit	Conditions
Chip Presteamer Vessel		
Operating temperature	°C	100
Operating pressure	atm	1
Steam pressure	atm	4.42
Steam flow	kg/hr	10,929
Residence time	minutes	20
Chip flow into vessel	kg/hr	159,948
Metallurgy		316 L SS
Hydrolysis Reactor		
Acid concentration	%	0
Operating temperature	°C	183
Operating pressure	atm	10.5
Steam pressure	atm	25
Steam flow	kg/hr	10,929
Water flow	kg/hr	76,679
Reactor residence time	minutes	9
Total flow from reactor	kg/hr	277,931
Metallurgy		316 L SS
PROCESS 300 STAGE 1		
Process Flow Diagram	Revision E	PFD- P300-A201
Equipment Number		M-201
Chip Presteamer Vessel		
Operating temperature	°C	100
Operating pressure	atm	1
Steam pressure	atm	4.42
Low pressure steam flow	kg/hr	16,967
Chip flow into vessel	kg/hr	159,948
Residence time	minutes	20
Metallurgy		316 L SS

Table 1
Process Conditions (continued)

Description	Unit	Conditions
Hydrolysis Reactor		
Operating temperature	°C	190
Operating pressure	atm	12.12
Acid concentration (% liquid)	%	0.5
Acid flow (1.9 % sulfuric)	kg/hr	48,495
Steam pressure	atm	13
Steam flow	kg/hr	44,617
Reactor residence time	minutes	4
Total flow out of the reactor	kg/hr	270,027
Metallurgy		Alloy 825
PROCESS 300 STAGE 2		
Process Flow Diagram	Revision E	PFD-P300-A204
Equipment Number		R-202
Chip Presteamer Vessel		
Operating temperature	°C	100
Operating pressure	atm	1
Acid concentration (% liquid)	%	0.03
Feed flow to presteamer	kg/hr	123,032
Feed (% insoluble solids)	%	45.6
Steam pressure	atm	4.42
Steam flow	kg/hr	5,811
Residence time	minutes	20
Metallurgy		317L SS
Hydrolysis Reactor		
Operating temperature	°C	210
Operating pressure	atm	18.39
Acid concentration (% liquid)	%	1.7
Acid flow (20% sulfuric)	kg/hr	8,476
Steam pressure	atm	23
Steam flow	kg/hr	25,053
Total flow out of reactor	kg/hr	162,372
Reactor residence time	minutes	3
Metallurgy		zirconium clad

3.2 Vendor Equipment

Andritz's industrial background is in the pulp and paper industry. Anco-Eaglin's industrial experience is with animal rendering and acid hydrolysis of chicken feathers. They both took approaches to the acid hydrolysis based on their experience. The results of their approaches led to fairly large disparities in the bids they provided. Both vendors suggested horizontal reactor vessels. Material in the reactors is moved through the reactor by internal paddles or screws.

3.2.1 Andritz

The equipment trains proposed by Andritz largely consisted of a presteaming bin, integral metering conveyor, chute, plug screw feeder, and horizontal reactor(s) (digesters) with an internal screw and blowback valve. The plug screw feeder was used between equipment to increase the pressure of the feedstock to the reactor vessel. A blowback valve is used as material is blown out of the reactor to prevent loss in vessel pressure. Integral instruments were included. Chesterton mechanical seals and motors were included. No structural support, ladders, or catwalks were included in the pricing. All the major equipment provided has been used in the pulp and paper industry. The same size of reactor was provided for each process with the numbers of reactors and reactor trains changing with different residence times. For longer residence times there were two reactors back to back per train. Metallurgy changed according to the process conditions (see Appendix B).

3.2.2 Anco-Eaglin

The equipment trains provided by Anco-Eaglin were basically the same except for the metallurgy required for the different processes. Differences in residence time between the processes were considered with smaller reactors.

The presteamer is fed by a set of screw conveyors with variable frequency drives to adjust and vary the feed as the process may dictate. The presteamer is a horizontal vessel with a paddle type device within to move the chips. The discharge from the presteamer is a variable-frequency screw conveyor leading to a blow tank. The blow tank was used to act as a seal between the presteamer and the reactor. The blow tank has a live bottom screw to feed the material to the reactor. The live bottom with multiple tightly flighted screws feeds into a pipe. Steam is injected into the screw to pressurize it on the way to the reactor. Anco described the steam injection as a venturi-like arrangement. The steam acts as a motive force to pull the chips into the reactor. They have done this with powders, but have no experience with materials similar to wood chips. The blow tank will be supplied with a relief valve. In Anco-Eaglin's experience with other materials, a plug is formed in the screw and this keeps the difference in pressure between vessels. The reactor vessel also has a paddle-type device within to keep the material flowing through it. The pitched flight reactor discharge conveyors are also variable-frequency drive. Anco-Eaglin felt that the close pitched flights would allow the material to act as a seal coming out of the vessel. (In other designs they have blown the material into a flash chamber or blow pot with a 4-in. gate valve that opens and closes with pressure.) Integral instrumentation, oil-cooling system, and motors were provided. High-pressure stuffing boxes, multiple packing rings, lantern rings, and water flush sealing were used to minimize leakage. Any leakage would be carried into the vessel rather than into the atmosphere. (NREL confirmed that this would not be a problem.) Catwalks, presteamer support steel, and handrails are provided. HGI has reservations as to how the Anco-Eaglin design gets up to pressure in the reactor and how pressure is sealed between the stages.

4. DISCUSSION

The results of the bids for the presteamer and reactor vessel packages for each process are listed in Table 2. There are substantial disparities in price between Andritz and Anco-Eaglin for the same process operating conditions. Breaking the information down further helps clarify the differences. The largest single contributor to the price difference was the assumption of percent full volume in the reactor vessels. In horizontal pulping digesters, Andritz has historically used 40% to 50% full for the chip level. Andritz' experience has indicated that the chips flow better and there is a more even distribution of acid and steam. HGI's experience has indicated that the chips can flow backwards over the top of the reactor screw if the level is too high. The result can be uneven cooking. Other digester (pulping reactor) vendors use as high as 75% full for horizontal vessels. Andritz used the same basic reactor size, varying the number of reactors and trains for the residence time required.

Anco-Eaglin has designed the reactor vessels for 95% full at 10 minutes of residence time (see Table 3). Anco's experience with materials other than chips is that a full vessel is adequate for proper mixing and cooking. The Anco design includes a paddle arrangement to keep a plug moving rather than a screw. Anco has not experienced quality problems from materials flowing backwards.

Please note that the same density was used for Stage 1 and Stage 2 of Process 300 for both vendor quotes. A difference in the Process 300 Stage 2 density would affect the reactor volume.

In Table 2 the total horsepower is listed for each of the processes. The Andritz equipment is nearly double the required horsepower of the Anco-Eaglin quote. The plug screw feeders used in the Andritz design are the reason for this difference. The plug screw feeders range between 600 and 700 hp. The pressure for the next stage is created in the plug screw feeder. This is consistent with pulp and paper industry experience. Note that Process 300 Stages 1 and 2 have lower individual horsepowers due to the reduced number of trains. The main horsepower consumption in the Anco-Eaglin quote is in the presteamer and reactor paddles. The paddles are used to move a solid plug of the feedstock from one end of the vessel to the other. Each of the paddles has a motor estimated at 250 hp. In contrast, the screws in the Andritz quote require 25 hp at partial loading.

The metallurgy for the reactors is the same for all the quotes. The associated equipment varies in its metallurgy. Andritz took greater care in keeping the metallurgy exposed to severe process conditions consistent. If the reactor required Alloy 825, the reactor screw in and the plug screw feeder housing were also clad in the same metallurgy. For the zirconium-clad vessel in Process 300 Stage 2, Andritz provided alternative pricing for a 316L stainless steel screw. It may be cost effective to keep replacing this equipment as it corrodes rather than paying the price for the metallurgy. (Both prices are found in Table 3.) Anco-Eaglin did not provide in-kind metallurgy for equipment that would be exposed to the reactor conditions. More corrosion testing would be required to make a risk assessment for lesser metallurgies.

Table 2
Vendor Quote Comparison

Process	Vendor	Equipment Price	Trains	Presteamer	Reactor	Presteamer Feeder	Reactor Feeder	Reactor Discharge	Seals	Valves	Miscellaneous	Horsepower
Process 100 -- 10 minute residence time	Ancho Eaglin		Three	(3) horizontal 316L SS presteaming bins 11'Dx26'TT 75.9 cuM each, 227.6 cuM total volume. 316L SS rotator & Paddle	(3) horizontal Alloy 825 reactors 8'Dx26'TT 38.9 cuM each, 116.7 cuM total volume, 316LSS rotator & paddle	(3) 24" 316LSS Screw	(3) 24" 316L SS Screw w/ headbox and gear box	24" 316LSS Screw	High pressure stuffing boxes, multiple packing rings, lantern rings and water flush sealing	PRV's, PSV's, Steam Control valves, Reactor Blow Valves	316L SS Blow Tank w/ live bottom, Instruments, Catwalks, structural steel for Presteamer Oil cooling system	1741 HP
	Andritz		Five	(5) 316L SS presteaming bins, 85% fill, 50 cuM each, 250 cuM total	(10) horizontal Alloy 825 reactors 72"Dx 45'-10"TT, 36.7 cuM each, 367cuM total, w/ Alloy 825 screw		(5 each) 316L SS twin agitator feeder, Plug Screw Feeder w/ ALLoy 825 Housing		Chesterton special Mechanical w/lubrication system	(5) Alloy 825 Blow Back Valve	Instruments, motors, gear boxes	3512.5 HP
Process 200 Stage 1 -- 9 minute residence time	Ancho Eaglin		Three	(3) horizontal 316L SS presteaming bins 11'Dx26'TT 75.9 cuM each, 227.6 cuM total volume. 316L SS rotator & Paddle	(3) horizontal 316L SS reactors 8'Dx26'TT 38.9 cuM each, 116.7 cuM total volume, 316LSS rotator & paddle	(3) 24" 316LSS Screw	(3) 24" 316L SS Screw w/ headbox and gear box	(3) 24" 316LSS Screw	High pressure stuffing boxes, multiple packing rings, lantern rings and water flush sealing	PRV's, PSV's, Steam Control valves, Reactor Blow Valves	316L SS Blow Tank w/ live bottom, Instruments, Catwalks, structural steel for Presteamer Oil cooling system	1741 HP
	Andritz		Five	(5) 316L SS presteaming bins, 85% fill, 50 cuM each, 250 cuM total	(10) horizontal 316L SS reactors 72"Dx 45'-10"TT, 36.7 cuM each, 367cuM total, w/ 316L SS screw		(5 each) 316L SS twin agitator feeder, 316L SS Plug Screw Feeder		Chesterton special Mechanical w/lubrication system	(5) 316L SS Blow Back Valve	Instruments, motors, gear boxes	3512.5 HP
Process 300 Stage 1 -- 4 minute residence time	Ancho Eaglin		Three	(3) horizontal 316L SS presteaming bins 11'Dx26'TT 75.9 cuM each, 227.6 cuM total volume. 316L SS rotator & Paddle	(3) horizontal Alloy 825 SS reactors 5'Dx26'TT 15.2 cuM each, 45.6 cuM total volume, 316LSS rotator & paddle	(3) 24" 316LSS Screw	(3) 24" 316L SS Screw w/ headbox and gear box	(3) 24" 316LSS Screw	High pressure stuffing boxes, multiple packing rings, lantern rings and water flush sealing	PRV's, PSV's, Steam Control valves, Reactor Blow Valves	316L SS Blow Tank w/ live bottom, Instruments, Catwalks, structural steel for Presteamer Oil cooling system	1741 HP
	Andritz		Four	(4) 316L SS presteaming bins, 85% fill, 70 cuM each, 280 cuM total	(4) horizontal Alloy 825 reactors 72"Dx 45'-10"TT, 36.7 cuM each, 367cuM total, w/ Alloy 825 screw		(4 each) 316L SS twin agitator feeder, Plug Screw Feeder w/ ALLoy 825 Housing		Chesterton special Mechanical w/lubrication system	(4) Alloy 825 Blow Back Valve	Instruments, motors, gear boxes	3170 HP
Process 300 Stage 2 -- 3 minute residence time	Ancho Eaglin		Three	(3) horizontal 317L SS presteaming bins 11'Dx26'TT 75.9 cuM each, 227.6 cuM total volume. 317L SS rotator & 316L SS Paddles	(3) horizontal Zirconium Clad SS reactors 5'Dx26'TT 15.2 cuM each, 45.6 cuM total volume, 317LSS rotator &316L SS paddles	(3) 24" 316LSS Screw	(3) 24" 316L SS Screw w/ headbox and gear box	(3) 24" 316LSS Screw	High pressure stuffing boxes, multiple packing rings, lantern rings and water flush sealing	PRV's, PSV's, Steam Control valves, Reactor Blow Valves	316L SS Blow Tank w/ live bottom, Instruments, Catwalks, structural steel for Presteamer Oil cooling system	1741 HP
	Andritz		Four	(4) 317L SS presteaming bins, 85% fill, 70 cuM each, 280 cuM total	(4) horizontal Zirconium clad 72"Dx 45'-10"TT, 36.7 cuM each,146. 8 cuM total, w/ zirconium Clad screw		(4 each) 317L SS twin agitator feeder, Plug Screw Feeder w/ 317L SS Housing		Chesterton special Mechanical w/lubrication system	(4) 317L SS Blow Back Valve	Instruments, motors, gear boxes	3170 HP

Table 3
Vendor Pricing Comparison Based on Similar Assumptions

Vendor	Process	Equipment Price/Reactor (million $)	Metallurgy	% Full	Number of Reactors
Anco-Eaglin	100		Alloy 825 w/316L paddles	95%	3
Andritz	(10 minutes)		Alloy 825 w/825 screw	40% to 50%	10
Anco-Eaglin	200 Stage 2		316L SS	85.5%	3
Andritz	(9 minutes)		316L SS	40% to 50%	10
Anco-Eaglin	300 Stage 1		Alloy 825 w/316 paddles	95%	3
Andritz	(4 minutes)		Alloy 825 w/825 screw	40% to 50%	4
Anco-Eaglin	300 Stage 2		Zirconium-clad reactor w/316 paddles	95%	3
Andritz	(3 minutes)		Zirconium-clad reactor w/ zirconium-clad screw w/ 316 screw	40% to 50%	4

Comparing the price per reactor for each process with other sundry equipment equally divided, the digester prices are more in line with each other. Note that the differences in price per reactor decreases as the number of digesters approach each other. The reason for this is twofold: (1) The engineering is divided between the same number of reactors. (2) The associated equipment is distributed differently. For example in the Andritz quotes, Process 100 and Process 300 Stage 1 have the same metallurgy. One would assume that the price per reactor would be close to the same for the Andritz quotes. This is not the case. The reason is that the trains in Process 100 contain two piggybacked reactors with one plug screw feeder and the Process 300 train has one plug screw feeder for each reactor. The plug screw feeders are an expensive piece of equipment because they are Alloy 825 clad. An additional difference for the Process 300 reactors is a higher design pressure. This makes the vessel more expensive as well.

In terms of metallurgy, the cost factor between Alloy 825 and 316L stainless steel ranges from a factor of 1.19 to 1.3 per reactor. (These factors were derived from Table 3 for Anco-Eaglin 2.36/ 1.98 = 1.19 and for Andritz 1.633/1.266 = 1.3.) The cost factor between zirconium clad and 316L stainless steel ranges by a factor of 1.75 to 1.81 per reactor. (See corrosion study, Appendix B.)

4.1 Installation Pricing

The installed cost factor for Process 200 Stage 1 was based on HGI experience on a previous job with similar operating conditions and 316L stainless steel piping (see Table 4). Installation costs for the Andritz and Anco-Eaglin equipment were based on the respective equipment costs. The other installed cost options were adjusted to reflect the differences from the Process 200 Stage 1 equipment. For example, most of the equipment involves 316L stainless steel piping. There should be no difference between the process stages for the piping if the throughput, piping, and pieces of equipment are the same. Therefore, the same installed piping cost should be used. Installation does not include engineering, contingency, field engineering, or start-up.

Table 4
Reactor Equipment and Installed Cost

	Andritz			Anco-Eaglin		
Process	**Equipment Price**	**Total Installed Cost**	**Installed Direct Cost Factor**	**Equipment Price**	**Total Installed Cost**	**Installed Direct Cost Factor**
Process 100		$35,856,000			$16,249,000	
Process 200 Stage 1		$32,190,000			$15,101,000	
Process 300 Stage 1		$24,698,000			$15,959,000	
Process 300 Stage 2		$33,514,000			$21,907,000	

For the Andritz pricing, Processes 100 and 200 contain five trains. Both contain 316L stainless steel piping. The difference in metallurgy between Process 100 and Process 200 Stage 1 is reflected in the equipment pricing. Process 300 Stage 1 also has 316L stainless steel piping. However, Process 300 Stages 1 and 2 both have four trains. The installed cost for Process 300 was factored down for four stages. The piping metallurgy for Process 300 Stage 2 reflects 317L stainless steel. So, the installation costs of the piping increased for this option over Process 300 Stage 1. (The details for installation pricing can be found in

Appendix C.) Installed costs for Andritz include catwalks and handrails, etc., This is reflected in the higher equipment installation dollars for Andritz (see Appendix C).

The installation costs for the Anco-Eaglin quote are the same for Stage 1 of the process options. All three have 316L stainless steel piping. For all the Anco-Eaglin options the number of trains is the same and the throughput is the same even though the reactor sizes vary somewhat. Therefore, other than metallurgy changes the installation costs are very similar. Process 300 Stage 2 installation cost reflects 317L stainless steel piping.

Because Andritz paid more attention to keeping the metallurgy consistent with the agitators and feed screws, HGI believes that the Andritz quotes are a better indication of the differences between the different types of process. Note that Process 200 Stage 1 is basically a metallurgy of 316L stainless steel. There are five trains in the Andritz quote for the residence time indicated. The price per reactor as evidenced in Table 3 is the lowest for Process 200 Stage 1. In comparison to Process 300 Stage 1, the residence time makes it more expensive due to the number of trains. Although not reflected here, Process 200 Stage 1 also has an additional stage. Process 100 has only one reactor stage. Thus for both the Andritz and Anco-Eaglin quotes, the Process 100 with the longer residence time and the Alloy 825 metallurgy is the least expensive when considering installed reactor equipment only for the different processes. Process 200 Stage 2 will be more than $4 million, which is the difference between the installed cost for Process 100 and Process 200 Stage 1.

4.2 Scaling

The Andritz equipment cost will be used for scaling. If the production is to be scaled down by 20%, the installation cost can be adjusted by reducing the number of trains for Process 100 or 200 from five to four. A reasonably accurate price could be attained by multiplying the installed cost by 0.8. Likewise, an additional 20% increase in production would result in the 1.2 times price of either of these two process options. Taking the price to ±40% would be slightly less accurate due to the engineering costs associated with the equipment design, but this would still give a relatively good number based on this degree of accuracy. Likewise, Process 300 Stages 1 and 2 could be estimated relatively accurately at ±25% by adding or subtracting an additional train and multiplying the cost by ±25%.

5. CONCLUSION

There is a significant difference between the process options in terms of pricing. Process 100 has only one stage of reactors. Process 200 has two stages; therefore, the installed reactor cost for both Process 200 stages will be more than for Process 100. Process 300, which will include both Stage 1 and 2, is significantly greater in price with the zirconium-clad metallurgy.

Of the two vendors, Andritz is much more experienced in handling wood chips, and reactors identical to the ones quoted have been used in the pulp and paper industry since 1984. The Andritz equipment was based on a reactor level that was 40% to 50% full versus 95% full for Anco-Eaglin. Therefore, the Andritz reactors were larger in volume and in quantity. As a result, Andritz quoted more equipment and the resulting equipment cost estimate is higher. The resulting installation estimate, which is factored off the equipment, is higher as well. Andritz was more thoughtful in choosing the appropriate metallurgy for the mixers and feeders. This also added to the cost.

6. RECOMMENDATION

HGI recommends using the type of equipment proposed in the Andritz quote (i.e., plug screw feeders and process-appropriate metallurgy). The horizontal reactors should be tested for varying feed stock fill to determine if cooking is affected by percent full. The number of reactor trains and reactor sizing should then be based on experimental data for the chosen process. In addition, Process 300 Stage 2 density should be confirmed.

APPENDIX A
VENDOR COMPARISON REPORT

REPORT NO. 10600/1

ACID HYDROLYSIS REACTOR VENDOR COMPARISON

TASK 1: DESIGN AND COST ESTIMATE OF DILUTE ACID HYDROLYSIS REACTOR SYSTEM

DELIVERABLE 1.1 **Summary of existing manufacturers and their equipment offerings that might be able to be utilized for the first and/or second dilute acid hydrolyzer.**

1. OVERVIEW

A web search was done to supplement the list of vendors supplied by NREL who could design equipment for an acid hydrolysis system. Of those vendor surveyed, the ones most likely to provide viable equipment and a system design are shown in Table I. Vendors who did not do process design were not included in the table. Five vendors were interviewed about equipment they provide. Some were quoted to NREL in previous studies. Four of the vendors had cooked wood for the pulp and paper industry. Beloit and Stake Technology have "ethanol-like" experience. Sunds and Ahlstrom's ethanol experience was through TVA and NREL. Stake Technology did not feel they could produce economically viable equipment for an acid hydrolysis to ethanol plant. Andrew Richard felt the Co-axial feeder would become too expensive.

From discussions with the vendors, the consensus was that although vertical digesters were fine for chips, horizontal or sloped digesters were better for non-wood feed stocks.

Anco-Eaglin had the most experience with high temperatures, high pressures and exotic metallurgy. They are capable of process design for unusual processes and have their own fabrication shop. They seemed quite interested in pursuing a wood to ethanol process.

Both Beloit's Pandia digester and Sunds' vertical and horizontal digesters are old technology. Ahlstom's vertical digester is proven, but "newer" technology (20 years old). For chips, a digester with less internal moving parts would be better, (i.e.: Ahlstrom's Kamyr digester has the least moving parts) and therefore, less maintenance.

All of the vendors were anxious about when a facility might be built. Jack Schaeffer of Beloit was quite interested in getting involved with the customer.

2. OTHER VENDORS CONTACTED

2.1 Stebbins:

Vessel lining and manufacturing. Mechanical / Structural design only. No process design process guarantees.

2.2 French Oil Mill Machinery Co.:

Screw presses for high (26,000 PSI) and low pressure specialty applications. No reactors. Can do high-pressure pilot testing in a 3 ½" diameter screw press. Experience with differing metallurgy. Original high-pressure development to press oil out of seeds. Will not work for mud like material. Processes include: Pulp and paper, rendering, sugar and Polymer dewatering. *Jim King (937) 773-8420*.

2.3 BondTech:

No design. Custom fabrication of auto claves and impregnation vessels. *(606) 667-2616*.

2.4 Ellet Industries:

Mechanical design and fabrication. No process design or sizing. Heat and corrosion resistant process equipment: heat exchangers, towers and reactors. Lots of experience with different metallurgy and cladding: Titanium, Hastelloy B3, B4, C22, C276, Zirconium and Zirconium Cladding. Have experience with Inconel and no experience with stellite. 50% of their business is titanium. *Al Shindel (604) 941-8211*.

2.5 The Dupps Co.:

The Dupps Company engineers, designs and fabricates equipment for the rendering, grain, paper and agricultural industries. Their main business is food and food waste products. They manufacture cookers, dryers, screw presses, and dewatering presses. They have equipment worldwide. Their main customers are Tyson Foods, Smithfield Foods, IB Coagra, and Champion International Paper.

The cookers are largely used for the meat, poultry and rendering industry to cook down food waste. The temperatures are normally 300 degrees F and pressures 125-130 PSI. They were developed as batch process in the 1920's and became continuous in the 1960's.

The screw press is used for sludge in the paper industry. They have done some bimetallic flighting for the presses. They do turn key design as well as individual equipment. Frank Dupps (937) 855-6555.

3. CONCLUSION

Of the vendors in Table I, Anco-Eaglin is likely to be the most creatively involved in design. They are smaller and may be less expensive than the bigger companies. Beloit may have the most "ethanol" experience. Ahlstrom has the most straightforward digester for chips, but is less desirable for non-wood feedstock with a vertical digester. Considering the cooking of chips only, HGI would recommend Ahlstrom's Kaymr digester. HGI would also recommend pursuing Anco-Eaglin further for pricing. Beloit would be a third alternative.

Harris Group Inc.
Engineering for Optimum Performance.®

PROJECT NO.: 99-10600
TABLE I: ACID HYDROLYSIS REACTOR VENDOR COMPARISON

APRIL 25, 2000
REVISION: 1

VENDOR	ANCO-EAGLIN	GLV (PANDIA)	AHLSTROM (KAMYR)	ANDRITZ	SUNDS	SUNDS	STAKE TECH
Technology Used:	Pressurized Screw Feeder, Steam Jacketed Reactor With Blow Valve.	Screw Fed Horizontal Digester Constant Speed Impeller Discharge Zone	Vertical Digester With Impregnation Vessel	Inclined Drag Chain with Flights (M&D) Horizontal/ Vertical	Vertical Impregnation With Horizontal Digester Cut Flight & Paddle Type Screw Design	Vertical Digester, Vertical Impregnation	Co-Ax Plug Feeder with Regprocating Action, Horizontal Helical Screw Continuous Digester.
Conditions Under Which It Has Operated:	Up to 3000 PSI 1000'F	300 PSI 420' F	174 PSI 360' F	170 PSI-300 PSI at Saturation Temp	180 PSI 380' F	180 PSI 380' F	200 to 400 PSI 445' F
Original Design Intent:	Various Applications: sugar cane pith to fuel; garbage; chicken feathers	Wood to fiber board by steaming chips	Digest Chips to produce pulp for paper (M&D-saw dust to pulp)	Originally designed for chips, then used for sawdust	NSSC was horizontal with lower production designed to cook wood chips for paper board pulp	Pulping of wood chips for paper board & corrugated medium	Developed 25 years ago to make cattle feed out of hard wood. (Expensive for ethanol)
Materials Of Construction Used:	Stainless, Carpenter 20, Hastelloy C2000, Titanium	Acid resistant brick. Have experience with exotic metals as well.	Inconel, 316L, 317L, 904L, 2205 Duplex SS explosion welding of Titanium.	304SS, 316LSS, Hastelloy Design, Own Alloys, Zirconium Cladding in Plate Industry	Stainless steel no large scale experience with other metals	Stainless steel no large scale experience with other metals	Inconel Clad, and Zirconium Clad digesters
Examples Of Inst. Location, Service Capacity:	Garbage-Food Waste: Toronto, Canada: building material (glue). Chicken feathers: Vancouver, BC. 15,000 lb/hr to produce hydrolyzed protein	Pulp mills: World-wide Furfural Plant: Beltway, Florida - Operated for 30 years & is now closed.	Weyerhaeuser, Longview, WA. Longview Fiber-2, Longview, WA. Househound, Vancouver 1990. Selgar, Castlegar BC 1994.	Mostly used to cook sawdust to pulp Also used for coffee roasting and peanut butter, world wide since mid 60's. Not many sold recently.	Ashfault dispersion, CA. 1980 Stone Container, Hoge, LA. 1948 Abitibi in New Brunswick. Domitar, Trenton, ONT. Manasha, North Bend, OR. 1972.	Longview Fiber, Longview, WA Mead, Stevenson. (many others)	Weyerhaeuser: Pulp Production. Springfield, OR: Regenerate straw to plywood. Cattle feed-No longer operating (3 units). Finsugar, Finland: Zylatol / Cattle feed: No longer operating
Through Put Of Current Equipment:	Build to Application, 15,000 lb/hr largest	1728 TPD pulp @ 10 lb/ft3 chips 600 TPD @ 3lb/Ft3 grass.	3600 BDTPD Chips (1800 BTPD Pulp with 50% yield)	100" P/A x 100' long for up to 1-1/2 hour cooks 500 TPD	6' x 30' long. Can be built as big as vertical.	1000 TPD@ 15 lb/ft3 chips	150 T/hr of birch
Pilot Testing:	Pilot equipment sent to site not high pressure, 100 psi	Pandia Pilot Plant, Leces, Indonesia. A full scale pilot plant	Glens Falls, NY Pilot Lab 320'F, 300psi	No M&D, some batch digesters	TVA has horizontal vessel for testing	No pilot vertical digester- TVA/NREL have small 2lb/day vessel	Pilot Plant- Small batch for 50-100g @ 400psi, Pilot unit 200-300 lb/hr @ 330psi
Horizontal/ Vertical:	90% Horizontal / 10% Vertical	Horizontal / Sloped	Vertical / Can sell M&D	Inclined / Horizontal / Vertical	Horizontal / Vertical	Horizontal / Vertical	Horizontal
Capable of Designing Systen	Yes, EPC	Yes	Yes	Yes	Yes	Yes	Yes
Comments:	ANCO Eaglin Specializes in unusual processes design and fabrication. Acid Hydrolysis, Steam & Water Hydrolysis of Biomass.	Beloit is working on some ethanol projects, and is very interested in teaming on this project. Pandia is used for both wood and non-wood products world-wide	Ahlstrom has 3 types of vertical digesters. They looked at Ethanol from chips about 5 years ago with TVA. Ahlstrom can sell M&D digesters (inclined with flight conveyor). Bauer also sells these as well & has sold 3 in 5 years.	Have worked with feeding cornstover, cotton linters, palm by-products, kenaf, bagasse, jute, hemp, canary grass, wheat straw	For Hasteloy pricing, sketches were sent to a fabricator for bids. Holding company in Finland is interested in project. Sunds is not anxious to make any process. Guarantees for whole process. 20% contingency added to pricing.	Involved in non-wood process and ethanol process with TVA, & NREL, but have done no lab work in house. Hasteloy is less expensive in large quantities and about 1/2 the price of Zerconium. It is also easier to work and harder.	Steam explosion concept to increase digestibility of wood and grasses. Have used Na2So5 and HCL, H2SO4. Have looked at Ethanol- not viable economically.
Contact: **Phone:** **Fax:**	**Rick Eaglin** **(336) 855-7800** **(336) 855-7831**	**Jack Schaefer** **(513) 425-0460** **(513) 425-0476**	**Jay Miele / Eric Wiley** **(518) 793-5111** **(518) 793-1917**	**Brad Court** **(770) 613-7050**	**Garth Russel** **(770) 263-7863** **(770) 441-9652**	**Garth Russel** **(770) 263-7863** **(770) 441-9652**	**Andrew Richard** **(905) 455-1990** **(905) 455-2529**

APPENDIX B
RECOMMENDED MATERIALS OF CONSTRUCTION

REPORT NO. 99-10600/12

RECOMMENDED MATERIALS OF CONSTRUCTION

PROJECT NO. 99-10600
PROCEESS DESIGN AND COST
ESTIMATION OF CRITICAL EQUIPMENT
IN THE BIOMASS TO ETHANOL PROCESS

NATIONAL RENEWABLE ENERGY LABORATORY
GOLDEN, COLORADO
SUBCONTRACT NO. ACO- 9-29067-01

DATE: FEBRUARY 3, 2000

REV 1: JANUARY 2, 2001

TABLE OF CONTENTS

1. INTRODUCTION

National Renewable Energy Laboratory (NREL) requested information concerning the metallurgy required for various process conditions being considered in converting wood chips to ethanol via dilute sulfuric acid hydrolysis. NREL was also concerned with determining the price difference in reactor costs for the different metallurgies. Harris Group Inc. (HGI) researched available corrosion information provided by NREL, the Nickel Development Institute (NiDI) and other published information. With the help of Paul Dillon of C.P. Dillon and Associates, HGI chose specific metals for corrosion testing. HGI retained InterCorr Intemational Inc., to do corrosion testing and Paul Dillon to help analyze the data. Corrosion studies were conducted at three different process temperatures and three different concentrations of acid with six different alloys.

2. SUMMARY

Corrosion testing done on various metals with varying temperatures and strengths of dilute sulfuric acid revealed the following:

- Reactors with operating temperatures of 210 °C at acid strengths near 1.5% and above require zirconium metallurgy.
- For operating conditions near 0.6% acid concentration and 190° C, Alloy 825 metallurgy would be required.
- For concentrations at 2.5% acid and operating conditions of approximately 80° C, Alloy 825 would be required.

The price of zirconium is roughly twice that of Alloy 825. The operating conditions listed in Table 3 highlight the substantial difference in the material and fabrication costs.

3. DISCUSSION

NREL is looking at a number of different processes to convert wood to ethanol. The combinations of high temperatures and dilute sulfuric acid raised questions about what sort of metallurgy would be required. HGI reviewed some early NREL corrosion testing, testing in literature and information provided by the Nickel Development Institute. With this information and the help of Paul Dillon of C. P. Dillon and Associates, six metals were chosen for testing at 3 different temperatures and acid concentrations. (See Table 2.) The solution temperatures and concentrations were based on the information provided in Table 1. This information was provided in a September 18, 1999 fax. The process equipment layout was based on the following PFD's:

- PFD-P100-A201 Revision D
- PFD-P202-A201 Revision A
- PFD-P301-A201 through A204 Revision C

Table 1: Process conditions

Condition	Temperature °C	% Sulfuric Acid	Residence Time (minutes)
Process 100			
Presteamer	100	0	Unknown
Reactor	180	0.7	10
Process 200 Stage 1			
Presteamer	100	0	Unknown
Reactor	183	0	9
Process 300 Stage 1			
Impregnator	100	0.8	Unknown
Reactor	185-190	0.5	4
Process 300 Stage 2			
Impregnator	100	2.5	Unknown
Reactor	210	1.7	2

InterCorr International Inc. performed the corrosion testing, and Paul Dillon assisted with the analysis. Tennessee Valley Authority provided solutions for the testing from actual cooks. The 2.5% concentration was prepared from the 0.6% solution by adding sulfuric acid to bring it to the desired percentage. No de-aeration was done to the solution during testing.

The test results are shown in Table 2. (The detailed test reports can be found in the appendix in both the January 18, 2000 letter from C.P. Dillon and Associates and the January 21, 2000 report from InterCorr.)

The alloys in Table 2 are in an order of increasing price. The metallurgy was first chosen based on low corrosion rates in terms of mils per year, mpy, (preferably below 5 mils per year) and no corrosion pitting. Then price and fabrication costs are considered. The corrosion results in Table 2 were quite definitive. For the 2.5 % @ 80 °C test Alloy 825 appears to be the best selection. No pitting was experienced under this condition. The corrosion rate is the lowest of the allowable metals and the price is the lowest as well. For higher temperatures as seen with the 1.5% Acid and 210° C test, zirconium is the best alloy. It also showed no pitting. For the 0.6% Acid @ 190 ° C test solution, Alloy 825, though a bit high on the corrosion rate in terms of mpy, showed no pitting. It is recommended over the zirconium due to its price difference and very close corrosion rates.

Table 2: Corrosion Test Results

Conditions	**2.5 % acid @ 80 °C**		**1.5% Acid @ 210 ° C**		**0.6 % Acid @ 190 ° C**	
Corrosion Rate	mpy	Pitting	mpy	Pitting	mpy	Pitting
Alloy 20 CB3	16	0	800+	3	14	0
Alloy 825	3	0	400+	3	8	0
Alloy G-30	3	0	400+	2	7	Less than 1
Alloy C276	6	0	50	0	15	0
Alloy 2000	4	0	140	0.5	11	0.5
Zirconium 702	Not run	N/A	5	0	6	0

The suggested metallurgy has been added to the Process Conditions in Table 3. The metallurgy factor for the material relative cost per square foot and a 150 PSIG design pressure has been included for each vessel. The relative strengths of the materials are taken into account for the metals considered and therefore the wall thickness may vary between metals. A fabrication factor is also included. Fabrication varies due to the difficulty in working with certain metals. These numbers are based on data from March of 1984 from Cosmos Minerals Corporation in Carmarillo, CA. (See appendix.) Due to variability in the price of metals and the age of the charts, the factors are relative numbers only and should not be used to calculate actual vessel costs. Budget numbers will be quoted by vendors for actual costs.

Table 3: Condensed Process Conditions

Condition	**Temperature °C**	**% Sulfuric Acid**	**Recommended Metallurgy**	**Relative Cost /Sq. Ft.**	**Fabrication Factor**
Process 100					
Presteamer	100	0	316 L SS	0.29	0.6
Reactor	180	0.7	Alloy 825	1.4	1.16
Process 200 Stage 1					
Presteamer	100	0	316 L SS	0.29	0.6
Reactor	183	0	316 L SS	0.29	0.6
Process 300 Stage 1					
Impregnator	100	0.8	316 L SS	0.29	0.6
Reactor	185-190	0.5	Alloy 825	1.4	1.16
Process 300 Stage 2					
Impregnator	100	2.5	Alloy 825	1.4	1.16
Reactor	210	1.7	Zirconium	2.87	2.46

The residence time in the vessels will also influence the relative price. Smaller vessels with less residence time will have a higher cost per volume than larger vessels.

4. CONCLUSIONS

The recommended metals for the process conditions are shown in Table 3. Lower acid concentrations or low temperatures with higher acid concentrations will make significant difference in metallurgy required for the different process conditions. If hydrolysis conversion results are similar, vessel pricing should be considered when determining which acid hydrolysis process to pursue.

cc 99-10600
file 0303
cc LM, JCL, ARS

C.P. DILLON & ASSOCIATES

Corrosion Control Consultants
1134 Hickory Mills Road
Hurricane, WV 25526
Tel. 304-562-5884
FAX 304-562-6011
CPDILLON@AOL.COM

C.P. Dillon, P.E. *President* | **O.J. Drescher, P.E.** *Vice-President* | **G.B. Elder, P.E.** *Vice-President*

MEMORANDUM

TO: Ms. Andrea Slayton, Harris Group, Seattle, WA

COPY TO: Dr. Julio Moldanado, InterCorr International

SUBJECT: Corrosion Testing Results in NREL Solutions

DATE: January 18, 2000

INTRODUCTION: In accordance with your recent request, I have review the results of the laboratory corrosion tests conducted by Dr. Moldanado relative to the proposed process for conversion of biomasses to ethanol in the presence of dilute sulfuric acid at elevated temperatures. My observations and conclusion are as follows.

OBSERVATIONS: Tests of 24-hours duration were conducted at 190°C (375°F) and 210°C (410°F)in actual NREL solutions of 0.6% and 1.5% sulfuric acid concentration. A solution in which the acid concentration was artificially raised to 2.5% H_2SO_4 was also tested at 80°C (175°F). Following are general corrosion rates in mils per year (mpy) and pit depth in mils in 24 hours.

ALLOYS	2.5% H_2SO_4	1.5% H_2SO_4		0.6% H_2SO_4	
	80°C	210°C		190°C	
	mpy	mpy	Pitting	mpy	Pitting
Alloy 20Cb3	16	800+	3	14	0
Alloy 825	3	400+	3	8	0
Alloy G-30	3	400+	2	7	<1
Alloy C276	6	50	0	15	0
Alloy 2000	4	140	0.5	11	0.5
Zirconium 702	Not run	5	0	6	0

It should be noted that pit depth cannot be extrapolated to an annual rate (as one can with general corrosion) because pits may be arrested as new pits are incurred at other sites. Nevertheless, pitting and crevice corrosion indicate potential problems in the long run.

CONCLUSIONS: In the 80°C liquor at 2.5% H_2SO_4, Alloys 825 and G30 appear to be the obvious choices, with rates of <5 mpy. The latter may cost a little more and probably adds little in the way of improved resistance.

With 0.6% H_2SO_4 at 190°C, alloy 825 (UNS N08825) or Alloy G-30 look to be acceptable (with an adequate corrosion allowance) and would be far less expensive than zirconium (R70200). However, only the alloy 825 is devoid of pitting. The higher rates for Ni-Cr-Mo alloys suggest the presence of organic compounds capable of complexing nickel, such as amines. Also, it should be noted that even a rate of 5-6 mpy for zirconium *might* be unacceptable because of possible hydriding. Although the actual metal loss for zirconium is small, absorption of nascent atomic hydrogen at the local cathodes may cause hydriding, embrittlement and generally unacceptable mechanical properties.

Obviously, none of the superaustenitic alloys are resistant with 1.5% H_2SO_4 at 210°C. Alloy C276 is more resistant to pitting and crevice corrosion under these conditions than are the other nickel-rich alloys but is unacceptable in terms of general corrosion. Zirconium remains a possibility even under these rigorous conditions.

I believe the alloys of choice are Alloy 825 and Alloy G30, subject to actual experience and evaluation.

If we can be of further service, please call on us.

Respectfully submitted.

C. P. Dillon

C.P. Dillon

InterCorr® International, Inc.
Services, Systems & Software

REPORT ON CORROSION EXPOSURES OF VARIOUS MATERIALS IN NREL SOLUTIONS

PREPARED FOR:

MS ANDREA SLAYTON
HARRIS GROUP, INC.
SEATTLE, WASHINGTON USA

PREPARED BY:

DR. JULIO G. MALDONADO
***INTERCORR* INTERNATIONAL, INC.**
HOUSTON, TEXAS USA

Project: L993877G
Date: January 21, 2000

INTRODUCTION

Presented herein is the final report on the corrosion exposures of various materials in NREL solutions provided to the Harris Group by *InterCorr* International, Inc. The purpose of this testing was to evaluate the general corrosion and localized corrosion resistance of the materials in actual NREL solution compositions. This work was conducted per your request and purchase order number 10600-2.

SUMMARY

Single corrosion coupons from six (6) different materials (Alloy 20Cb-3, Alloy 825, Alloy G-30, Alloy C-276, Alloy C-2000 and Alloy Zr-702) were exposed to three (3) different NREL solution compositions (1.5%, 0.6% and 2.5% H_2SO_4) at 210 C, 190 C and 80 C, respectively, for 24 hours. Alloy Zr-702 was only exposed at 210 and 190 C. Corrosion rates ranged from 5 mpy (Zr-702) to 802 mpy (20Cb-3) for materials tested at 210 C; 6 mpy (Zr-702) to 15 mpy (C-276) for materials tested at 190 C; and 3 mpy (825 and G-30) to 16 mpy (20Cb-3) for materials tested at 80 C. Localized corrosion in the form of pitting was observed on all the materials tested at 210 C, except C-276 and Zr-702. Similarly, pitting attack was observed on alloys G-30 and C-2000 tested at 190 C. No signs of localized corrosion were observed in any of the materials tested at 80 C.

EXPERIMENTAL

MATERIALS AND SPECIMENS

Single corrosion coupons from six (6) different materials including Alloy 20Cb-3, Alloy 825, Alloy G-30, Alloy C-276, Alloy C-2000 and Alloy Zr-702 were procured by *InterCorr* for testing. The corrosion coupons were circular and measured 1.25 inches in diameter and 0.125 inch thick and contained a 0.375 inch hole in the center of the coupon. Upon receipt, the coupons were cataloged and assigned unique *InterCorr* identification numbers for traceability and quality assurance. The *InterCorr* identification numbers and the corresponding material description of the coupons are provided in Table 1. Material test reports for the coupons are presented in Appendix I.

Two NREL solution compositions (0.6% H_2SO_4 – Solution A and 1.5% H_2SO_4 – Solution B) were provided by the Tennessee Valley Authority for testing. A third composition (Solution C) was prepared by adding sulfuric acid to increase the concentration of Solution A from 0.6 to 2.5% H_2SO_4. The particular solution description and concentration as well as the temperature employed for testing of each individual coupon are listed in Table 1.

PROCEDURE

Prior to testing, the coupons were cleaned with toluene and rinsed with acetone. The coupons were then measured to the nearest 0.001 inch (0.025 mm) and weighed to the nearest 0.1 mg.

A five liter-Alloy C-276 autoclave vessel was employed to conduct three separate exposures at 210, 190 and 80 C. Four (4) glass test tubes with a capacity of 750 ml (each) were placed inside the autoclave to contain the testing solution called for in each particular exposure. The coupons were positioned in the test tubes as follows: Alloy 20Cb-3 and Alloy 825 in tube 1; Alloy C-276 and Alloy C-2000 in tube 2; Alloy G-30 in tube 3; and Alloy Zr-702 in tube 4. When paired, the coupons were positioned such that they were galvanically isolated from each other. The solution volume to exposed surface area ratio used was 120 ml/in^2. After coupon and solution loading, the autoclave was sealed and heated to the target temperature (210, 190 or 80 C). No deaeration procedure was employed in any of the exposures.

Upon completion of the individual exposures, the coupons were retrieved and photographed to document the surface appearance. The coupons were then cleaned of corrosion products per the specifications of ASTM G1, rinsed in toluene / acetone, dried and re-weighed to the nearest 0.1 mg. Corrosion rates of each coupon were calculated according to the following equation:

$$Corrosion\ \ Rate = \frac{3442 \cdot W}{A \cdot D \cdot T}$$

where:

3442 = constant
W = weight loss (mg)
A = area (cm^2)
D = density (g/cm^3)
T = time (hours).

The coupons were also visually examined at 50x magnification for evidence of pitting or other form of localized attack. Any pitting was further characterized according to the specifications of ASTM G46. The coding used in this analysis is provided in Table 2.

RESULTS AND DISCUSSION

Photographs of the coupons after exposure are provided in Appendices II, III and IV for the 210, 190 and 80 C exposures, respectively. After exposure and before cleaning, the coupons tested at 210 and 190 C presented a dark gray to black color surface scale. The black scale coloration appears to be due to the partial polymerization of the testing solutions (Solutions A and B) at the two highest temperatures. In contrast, coupons tested at 80 C had a light brown color scale with no polymerization of the solution (Solution C) observed. Localized corrosion in the form of pitting was observed on all the materials tested at 210 C, except C-276 and Zr-702. Similarly, pitting attack was observed on alloys G-30 and C-2000 tested at 190 C. No signs of localized corrosion were observed in any of the materials tested at 80 C.

General corrosion results are presented in Tables 3-A, 4-A and 5 for the 210, 190 and 80 C exposures, respectively. Materials tested at 210 C presented general corrosion rates ranging from 5 mpy for Alloy Zr-702 (IC#6881-8) to 802 mpy for Alloy 20Cb-3 (IC#6876-6). Materials tested at 190 C presented general corrosion rates ranging from 6 mpy for Alloy Zr-702 (IC#6881-11) to 15 mpy for Alloy C-276

(IC#6879-12). Materials tested at 80 C presented general corrosion rates ranging from 3 mpy for Alloys 825 and G-30 (IC# 6877-3 and 6878-62) to 16 mpy for Alloy 20Cb-3 (IC# 6876-8).

Localized corrosion results are presented in Tables 3-B and 4-B for the 210 and 190C exposures, respectively. Materials tested at 210 C presented pitting depths ranging from 0.5 mils for Alloy C-2000 (IC# 6880-21) to 3.4 mils for Alloy 825 (IC#6877-11). Alloys C-2000 and G-30 tested at 190 C, presented pitting depths of 0.5 mils and 0.8 mils, respectively.

Table 6 presents the initial and final pH of the solutions. Except for the C-276 and C-2000 pair, the pH of the solutions after exposure in the 210 C exposure (Solution B) was lower than the initial pH. The pH of the solution after the 190 C exposure was higher than the initial. No pH measurement after exposure of the Zr-702 was obtained since the solution in the test tube had polymerized completely. The pH of the solution after the 80 C exposure was about 0.2 pH units lower than the initial pH.

CONCLUSIONS

Based on the results of this investigation, the following conclusions were made:

1. The coupons tested at 210 and 190 C presented a dark gray to black color surface scale. In contrast, coupons tested at 80 C had a light brown color scale
2. Corrosion rates ranged from 5 mpy (Zr-702) to 802 mpy (20Cb-3) for materials tested at 210 C; 6 mpy (Zr-702) to 15 mpy (C-276) for materials tested at 190 C; and 3 mpy (825 and G-30) to 16 mpy (20Cb-3) for materials tested at 80 C.
3. Materials tested at 210 C presented pitting depths ranging from 0.5 mils for Alloy C-2000 (IC# 6880-21) to 3.4 mils for Alloy 825 (IC#6877-11). Alloys C-2000 and G-30 tested at 190 C, presented pitting depths of 0.5 mils and 0.8 mils, respectively. No signs of localized corrosion were observed in any of the materials tested at 80 C.

Prepared by: ______________________ Date: January 21, 2000

Dr. Julio G. Maldonado
Manager, Technical Services Division

Reviewed by: ______________________ Date: January 21, 2000

Dr. Michael S. Cayard
Vice President

JGM3\993877G_Rpt

TABLE 1

Material Identification

InterCorr ID Number	Material Description	NREL Testing Environment	Testing Temperature (C)	Sulfuric Acid Content (%)
6876-6	Alloy 20Cb-3	Solution B	210	1.5
6876-7	Alloy 20Cb-3	Solution A	190	0.6
6876-8	Alloy 20Cb-3	Solution C	80	2.5
6877-11	Alloy 825	Solution B	210	1.5
6877-12	Alloy 825	Solution A	190	0.6
6877-13	Alloy 825	Solution C	80	2.5
6878-60	Alloy G-30	Solution B	210	1.5
6878-61	Alloy G-30	Solution A	190	0.6
6878-62	Alloy G-30	Solution C	80	2.5
6879-11	Alloy C-276	Solution B	210	1.5
6879-12	Alloy C-276	Solution A	190	0.6
6879-13	Alloy C-276	Solution C	80	2.5
6880-21	Alloy C-2000	Solution B	210	1.5
6880-22	Alloy C-2000	Solution A	190	0.6
6880-23	Alloy C-2000	Solution C	80	2.5
6881-8	Alloy Zr-702	Solution B	210	1.5
6881-11	Alloy Zr-702	Solution A	190	0.6

TABLE 2

Pit Coding per ASTM G46

G 46

	A DENSITY	B SIZE	C DEPTH
1	$2.5 \times 10^3/m^2$	$0.5\ mm^2$	0.4 mm
2	$1 \times 10^4/m^2$	$2.0\ mm^2$	0.8 mm
3	$5 \times 10^4/m^2$	$8.0\ mm^2$	1.6mm
4	$1 \times 10^5/m^2$	$12.5 mm^2$	3.2 mm
5	$5 \times 10^5/m^2$	$24.5 mm^2$	6.4 mm

TABLE 3-A

Corrosion Rate Results
Solution "B", 210 C

InterCorr No.	Material	Weight Loss (g)	Corrected Weight Loss * (g)	Exposed Surface Area (in^2)	Exposure Time (hrs)	Density (g/cm^3)	Corrosion Rate (mpy)
6876-6	20Cb3	0.8346	0.8266	2.84	24	8.08	802
6877-11	825	0.4440	0.4360	2.86	24	8.14	417
6878-60	G-30	0.4587	0.4507	2.87	24	8.22	426
6879-11	C-276	0.0652	0.0572	2.86	24	8.89	50
6880-21	C-2000	0.1646	0.1566	2.89	24	8.50	142
6881-8	Zr702	0.0119	0.0039	2.86	24	6.10	5

* - Weight loss corrected for mechanical cleaning (0.0080 g)

TABLE 3-B

Localized Corrosion Results
Solution "B", 210 C

InterCorr No.	Material	Pitting Per ASTM G46 Density	Size	Depth	Max. Pit Depth (mils)
6876-6	20Cb3	A-5	B-1	C-1	3.23
6877-11	825	A-3	B-4	C-1	3.38
6878-60	G-30	A-5	B-1	C-1	2.52
6879-11	C-276	N/A	N/A	N/A	0
6880-21	C-2000	A-5	B-1	C-1	0.47
6881-8	Zr702	N/A	N/A	N/A	0

TABLE 4-A

Corrosion Rate Results
Solution "A", 190 C

InterCorr No.	Material	Weight Loss (g)	Corrected Weight Loss * (g)	Exposed Surface Area (in^2)	Exposure Time (hrs)	Density (g/cm^3)	Corrosion Rate (mpy)
6876-7	20Cb3	0.0222	0.0142	2.84	24	8.08	13.8
6877-12	825	0.0164	0.0084	2.87	24	8.14	8.0
6878-61	G-30	0.0156	0.0076	2.88	24	8.22	7.2
6879-12	C-276	0.0253	0.0173	2.87	24	8.89	15.1
6880-22	C-2000	0.0196	0.0116	2.89	24	8.50	10.5
6881-11	Zr702	0.0128	0.0048	2.90	24	6.10	6.0

* - Weight loss corrected for mechanical cleaning (0.008g)

TABLE 4-B

Localized Corrosion Results
Solution "A", 190 C

InterCorr No.	Material	Pitting Per ASTM G46 Density	Size	Depth	Max. Pit Depth (mils)
6876-7	20Cb3	N/A	N/A	N/A	0
6877-12	825	N/A	N/A	N/A	0
6878-61	G-30	A-1	B-1	C-1	0.79
6879-12	C-276	N/A	N/A	N/A	0
6880-22	C-2000	A-1	B-1	C-1	0.47
6881-11	Zr702	N/A	N/A	N/A	0

TABLE 5

Corrosion Rate Results
Solution "C", 80 C

InterCorr No.	Material	Weight Loss (g)	Corrected Weight Loss * (g)	Exposed Surface Area (in^2)	Exposure Time (hrs)	Density (g/cm^3)	Corrosion Rate (mpy)
6876-8	20Cb3	0.0181	0.0168	2.84	24	8.08	16.3
6877-13	825	0.0050	0.0037	2.95	24	8.14	3.4
6878-62	G-30	0.0049	0.0036	2.89	24	8.22	3.4
6879-13	C-276	0.0079	0.0066	2.87	24	8.89	5.8
6880-23	C-2000	0.0062	0.0049	2.89	24	8.50	4.4

* - Weight loss corrected for mechanical cleaning (0.0013g)

TABLE 6

pH Measurement Results

Materials	pH Solution B Before Exposure	pH Solution B After Exposure	pH Solution A Before Exposure	pH Solution A After Exposure	pH Solution C Before Exposure	pH Solution C After Exposure
20 CB-3 and 825	1.31	1.29	1.69	1.88	1.26	1.06
G-30	1.31	1.19	1.69	1.92	1.26	1.00
C-276 and C-2000	1.31	1.47	1.69	1.84	1.26	1.05
Zr-702	1.31	1.08	1.69	Solution Polymerized	Not Examined	Not Examined

APPENDIX I

MATERIAL TEST REPORTS

MATERIAL TEST REPORT

DATE : 12/21/99
PAGE : 1
ORDER: 41059

Metal Samples Company
P.O. Box 8
152 Metal Samples Road
Munford, AL 36268
Ph. (256)358-4202 Fx. (256)358-4515

ıstomer: 01138 INTERCORR INTERNATIONAL INC
Your PO#: 21236

Lot No. M174 Mill: ALLEGHENY LUDLUM Our Order Line No. 1
escription: 20CB3 .125" X 48" X 63"
ıemical Properties:

C:0.020	Cr:19.570	Cu:3.160	Fe:BALANCE
Mn:0.290	Mo:2.120	Nb:0.550	Ni:34.090
P:0.019	S:0.0005	Si:0.250	Ta:0.010

Physical Properties:

Tensile-PSI:96,500	Elong-%:37.0
Yield-PSI:53,000	Condition:ANLD
Hardness:RB 86	

Lot No. J927 Mill: INCO ALLOYS Our Order Line No. 2
escription: I825 .125"X48"X96"
hemical Properties:

Al:0.100	C:0.010	Cr:22.800	Cu:1.700
Fe:26.420	Mn:0.390	Mo:3.300	Ni:44.190
S:0.001	Si:0.120	Ti:0.970	

Physical Properties:
Condition:ANLD

ıot No. H158 Mill: HAYNES INT'L Our Order Line No. 3
escription: HAST.G30 .125"X48"X66"&7
Chemical Properties:

C:0.010	Co:2.200	Cr:29.100	Cu:1.900
Fe:14.600	Mn:1.100	Mo:5.000	Nb:0.880
Ni:BALANCE	P:0.008	S:<0.002	Si:0.260
W:2.800			

hysical Properties:

Tensile-PSI:102,000	Elong-%:60.0
Yield-PSI:46,000	Condition:ANLD

ıot No. N296 Mill: HAYNES INT'L Our Order Line No.
escription: C276 .125"X 21.375" X 123.125"

MATERIAL TEST REPORT

Metal Samples Company
P.O. Box 8
152 Metal Samples Road
Munford, AL 36268
Ph. (256)358-4202 Fx. (256)358-4515

ustomer: 01138 INTERCORR INTERNATIONAL INC
Your PO#: 21236

ot No. N296 (Continued...)

Chemical Properties:

C:0.001	Co:0.340	Cr:15.930	Fe:5.840
Mn:0.510	Mo:15.700	Ni:BALANCE	P:0.008
S:0.001	Si:0.030	V:0.160	W:3.370

hysical Properties:

Tensile-PSI:117,000	Elong-%:57.0
Yield-PSI:55,000	Condition:ANLD
Hardness:RB 88	

ot No. M005 Mill: HAYNES INT'L Our Order Line No. 5
escription: C2000 .125" X 37" X 54"

Chemical Properties:

C:0.007	Co:0.010	Cr:23.110	Cu:1.680
Fe:0.250	Mn:0.200	Mo:16.230	Ni:BALANCE
P:<0.004	S:0.004	Si:0.020	

hysical Properties:

Tensile-PSI:115,000	Elong-%:60.0
Yield-PSI:58,000	Condition:ANLD
Hardness:RB 91	

ot No. M027 Mill: TELEDYNE ALBANY Our Order Line No. 6
escription: ZR702 .125" X 46.5 X 60.5"

Chemical Properties:

C:0.010	Fe:+CR=0.066	H:<0.0003	N:0.005
O:0.140	Zr:+HF=>99.200		

Physical Properties:

Tensile-PSI:61,200	Elong-%:25.6
Yield-PSI:42,966	Condition:ANLD

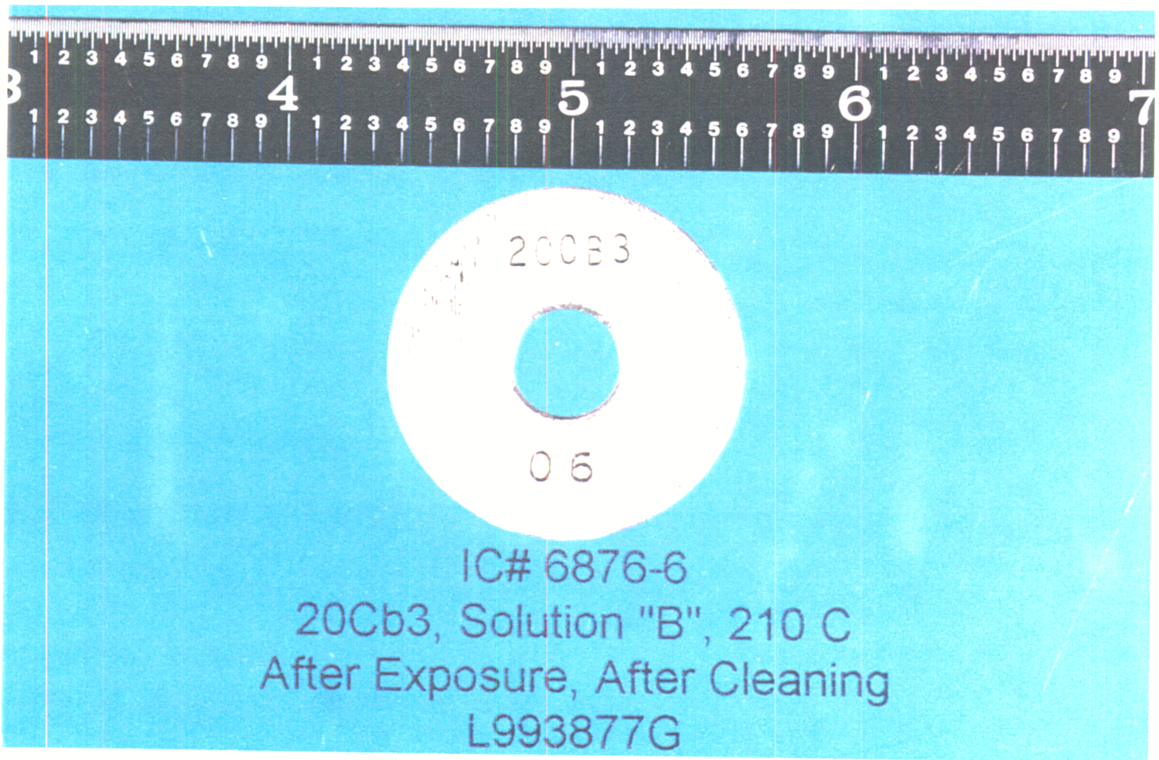
We certify that the Material Test Report is correct to the best of our knowledge and that the material supplied meets your required P.O. specifications.

THANK YOU, Quality Control Dept. Larry Braden (KP)

APPENDIX II

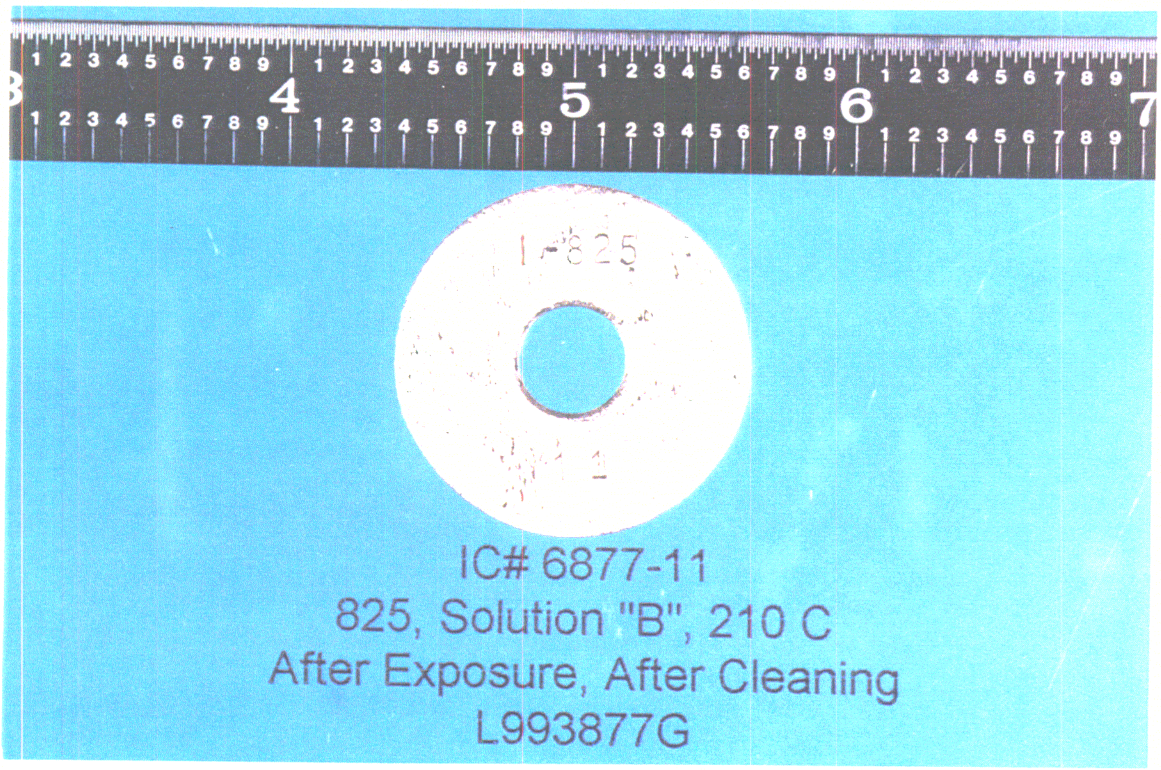
SOLUTION B – PHOTOGRAPHIC DOCUMENTATION

20Cb3 (IC #6876-6) after exposure / before cleaning. (P/N 5016-7)



20Cb3 (IC #6876-6) after exposure / after cleaning. (P/N 5016-22)

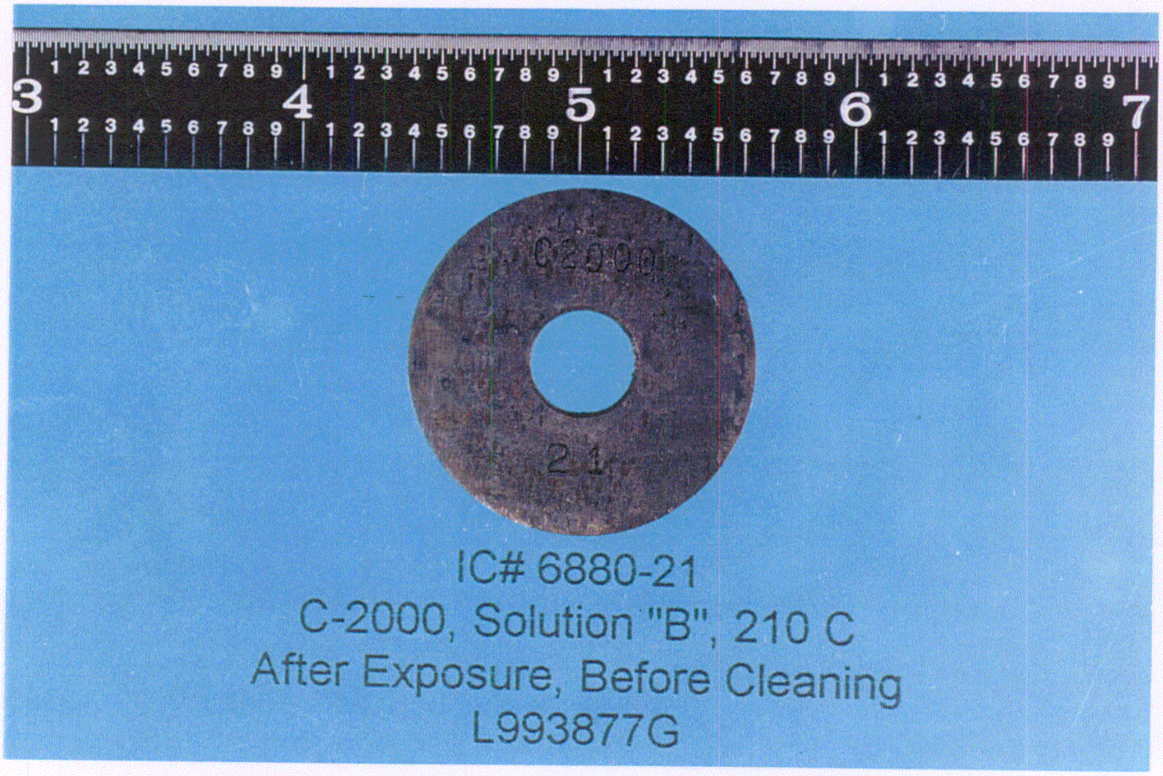
825 (IC #6877-11) after exposure / before cleaning. (P/N 5016-2)



825 (IC #6877-11) after exposure / after cleaning. (P/N 5016-23)

C-276 (IC #6879-11) after exposure / before cleaning. (P/N 5016-4)

C-276 (IC #6879-11) after exposure / after cleaning. (P/N 5018-0)



C-2000 (IC #6880-21) after exposure / before cleaning. (P/N 5016-5)

C-2000 (IC #6880-21) after exposure / after cleaning. (P/N 5018-1)

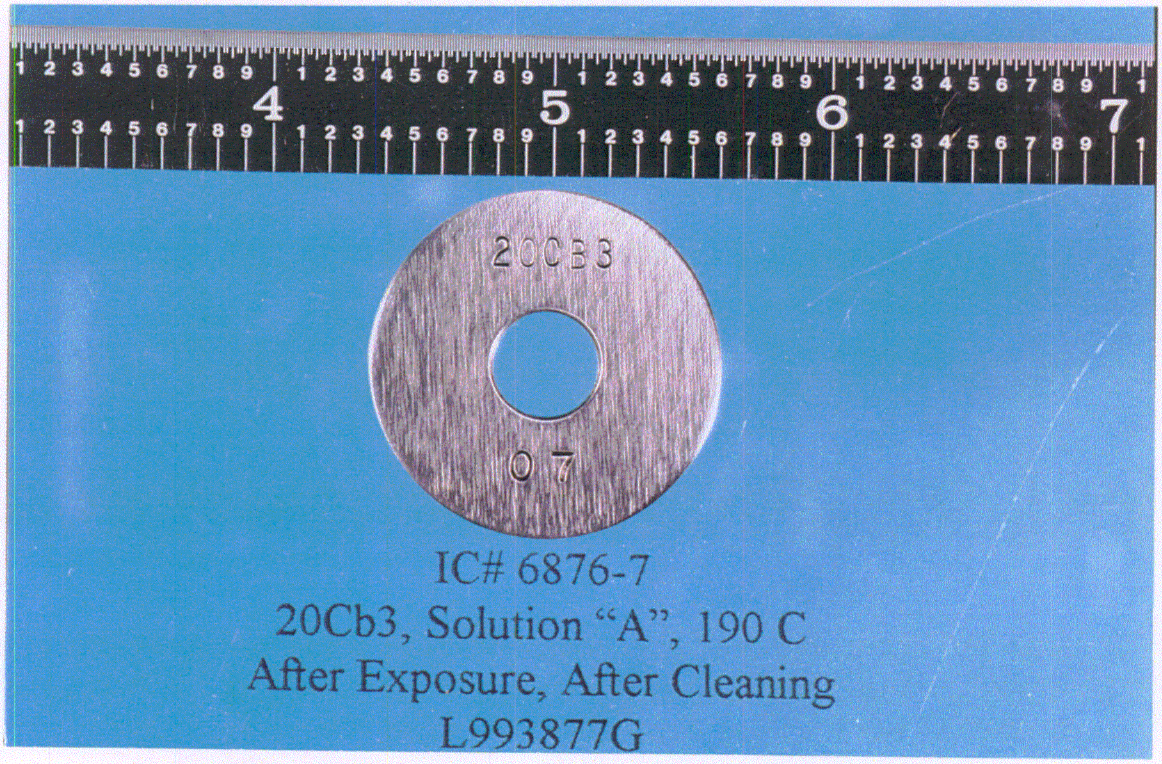
Zr-702 (IC #6881-8) after exposure / before cleaning. (P/N 5016-6)

Zr-702 (IC #6881-8) after exposure / after cleaning. (P/N 5018-2)

APPENDIX III

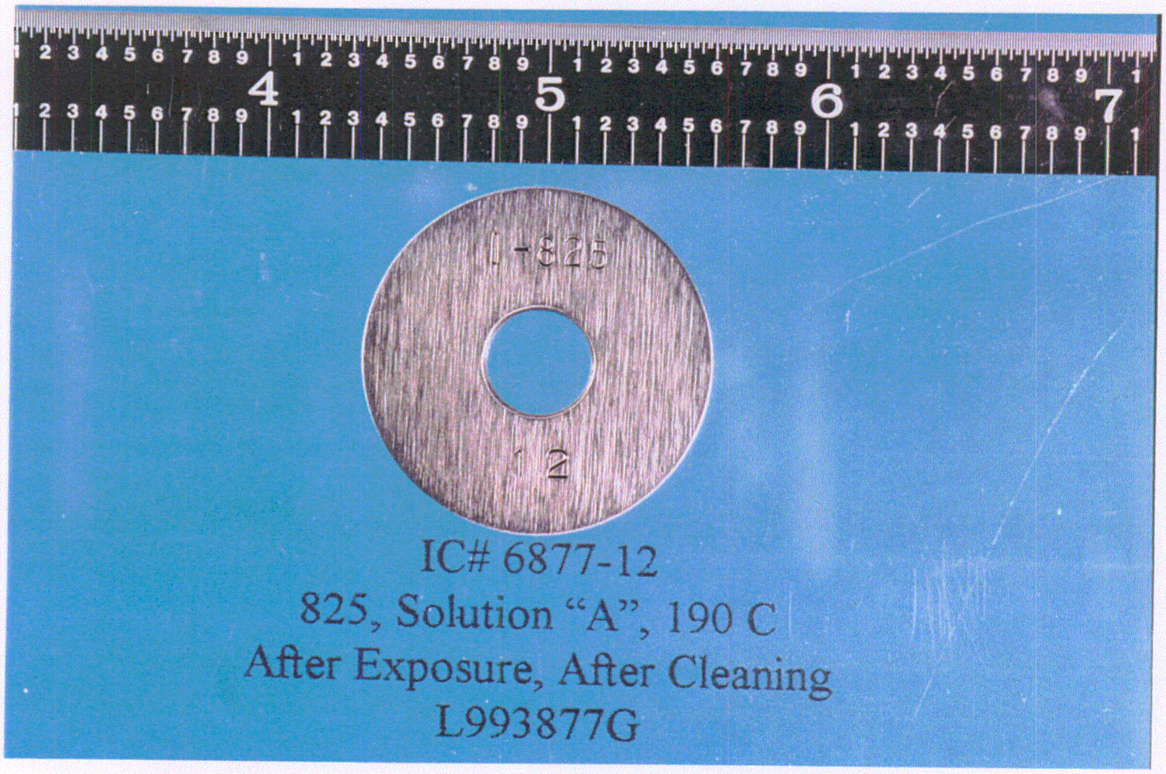
SOLUTION A – PHOTOGRAPHIC DOCUMENTATION

20Cb3 (IC #6876-7) after exposure / before cleaning. (P/N 5023-18)



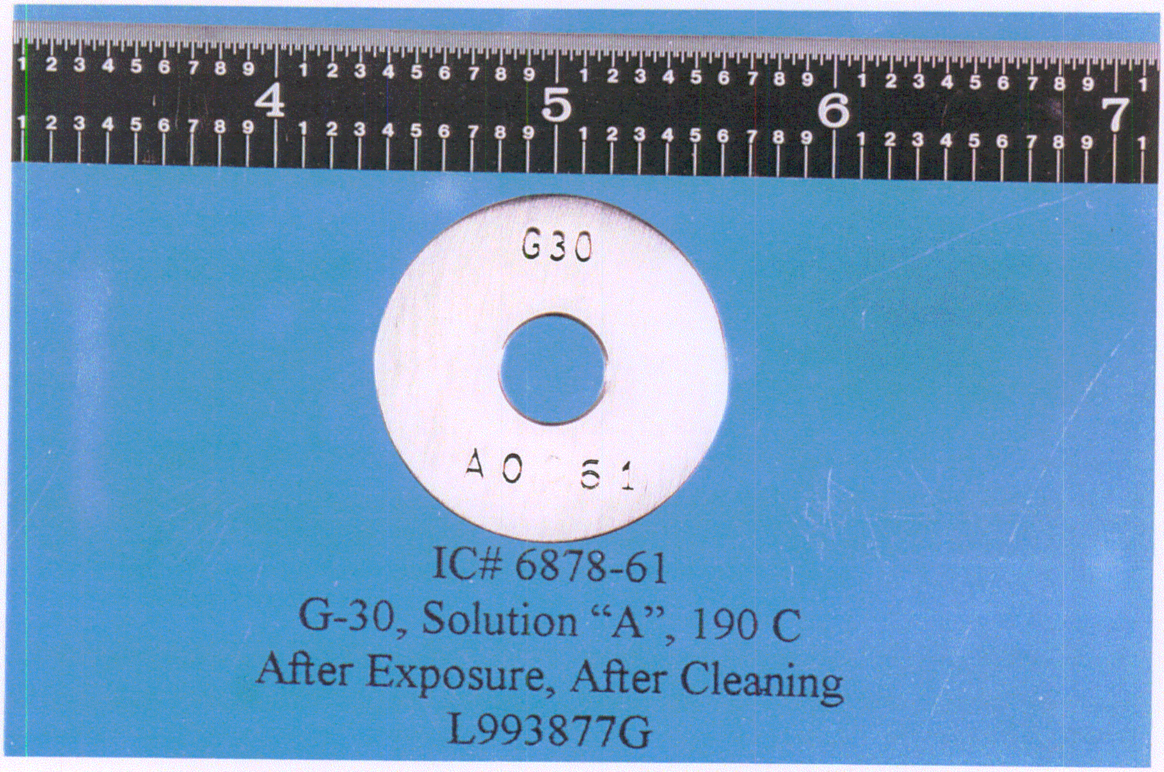
20Cb3 (IC #6876-7) after exposure / after cleaning. (P/N 5026-21)

825 (IC #6877-12) after exposure / before cleaning. (P/N 5023-19)

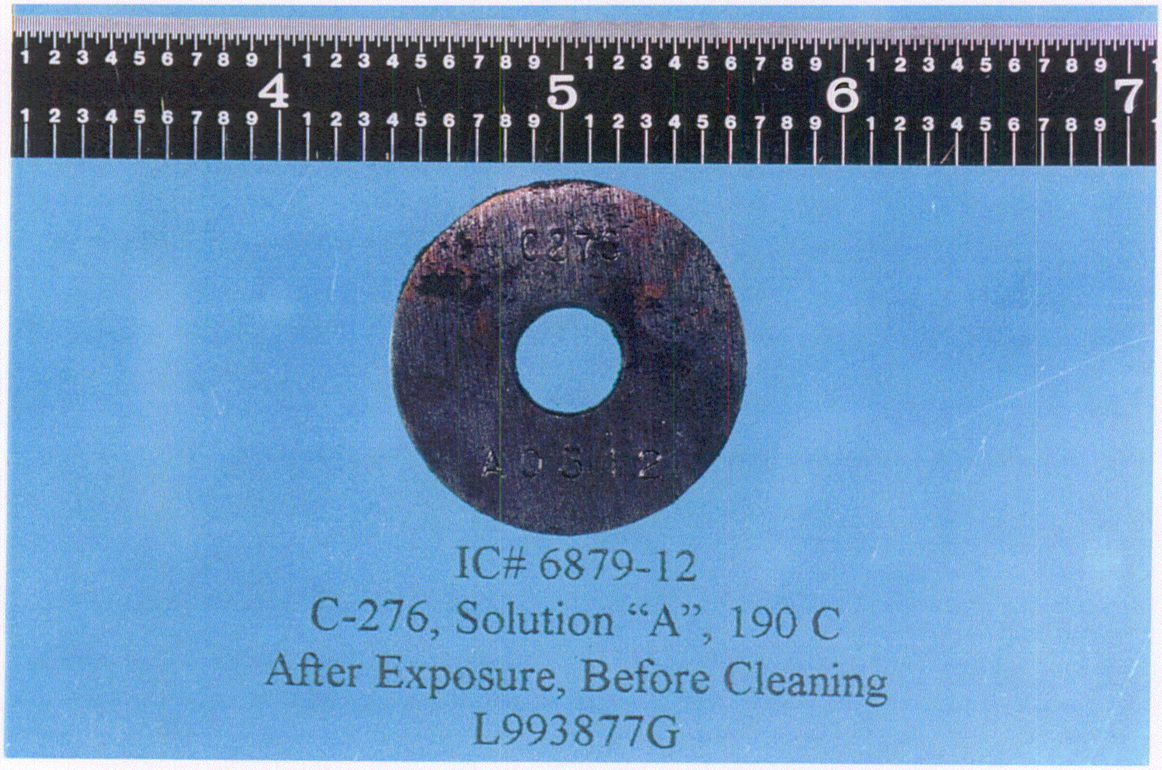


825 (IC #6877-12) after exposure / after cleaning. (P/N 5026-22)

G-30 (IC #6878-61) after exposure / before cleaning. (P/N 5023-20)



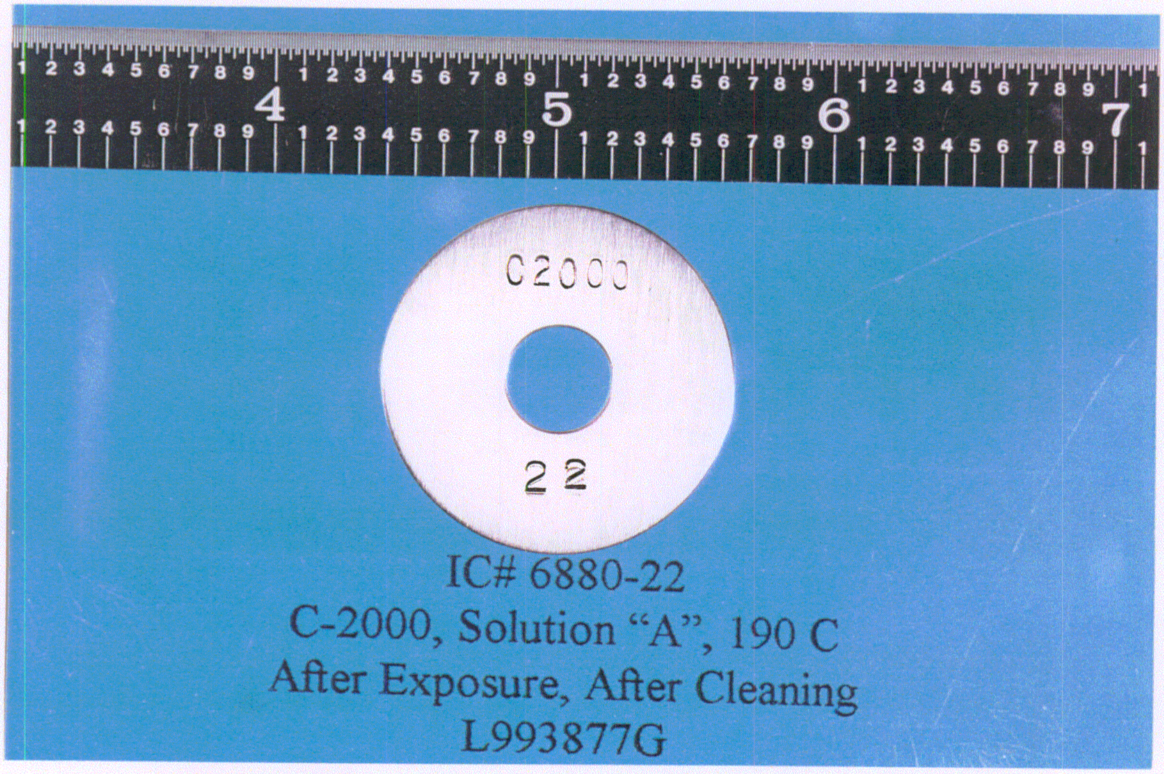
G-30 (IC #6878-61) after exposure / after cleaning. (P/N 5026-23)



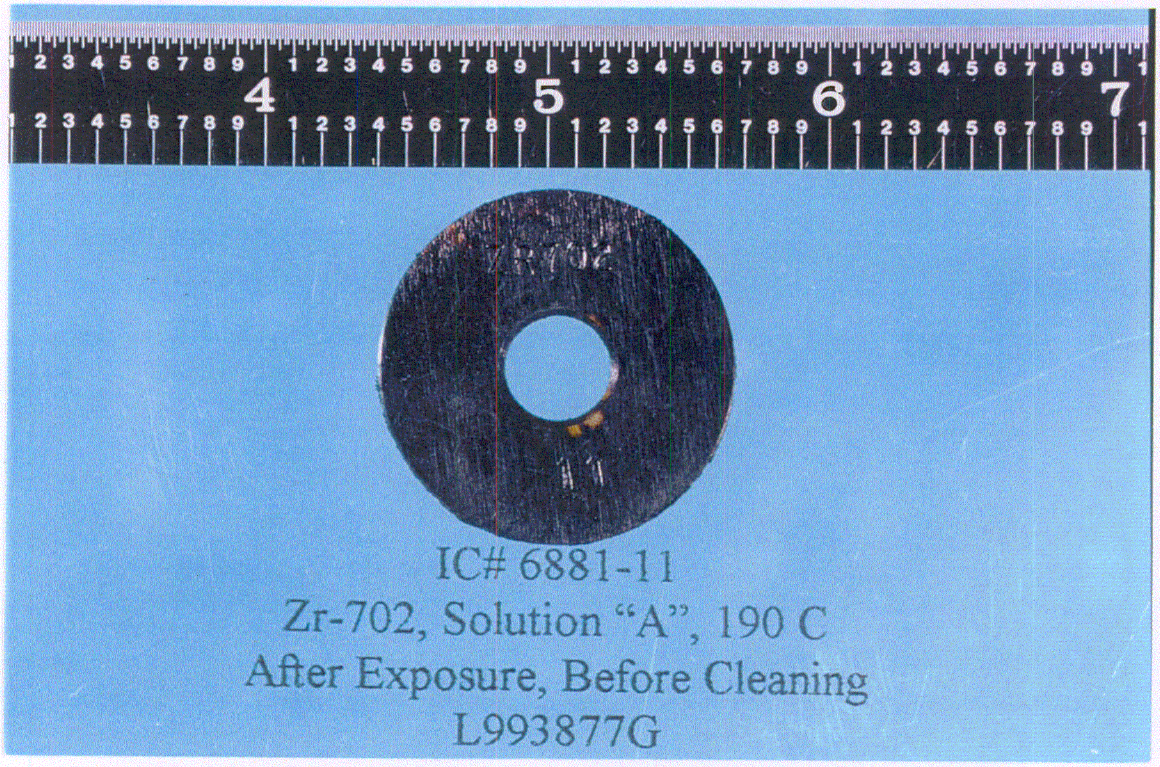
C-276 (IC #6879-12) after exposure / before cleaning. (P/N 5023-21)

C-276 (IC #6879-12) after exposure / after cleaning. (P/N 5026-24)

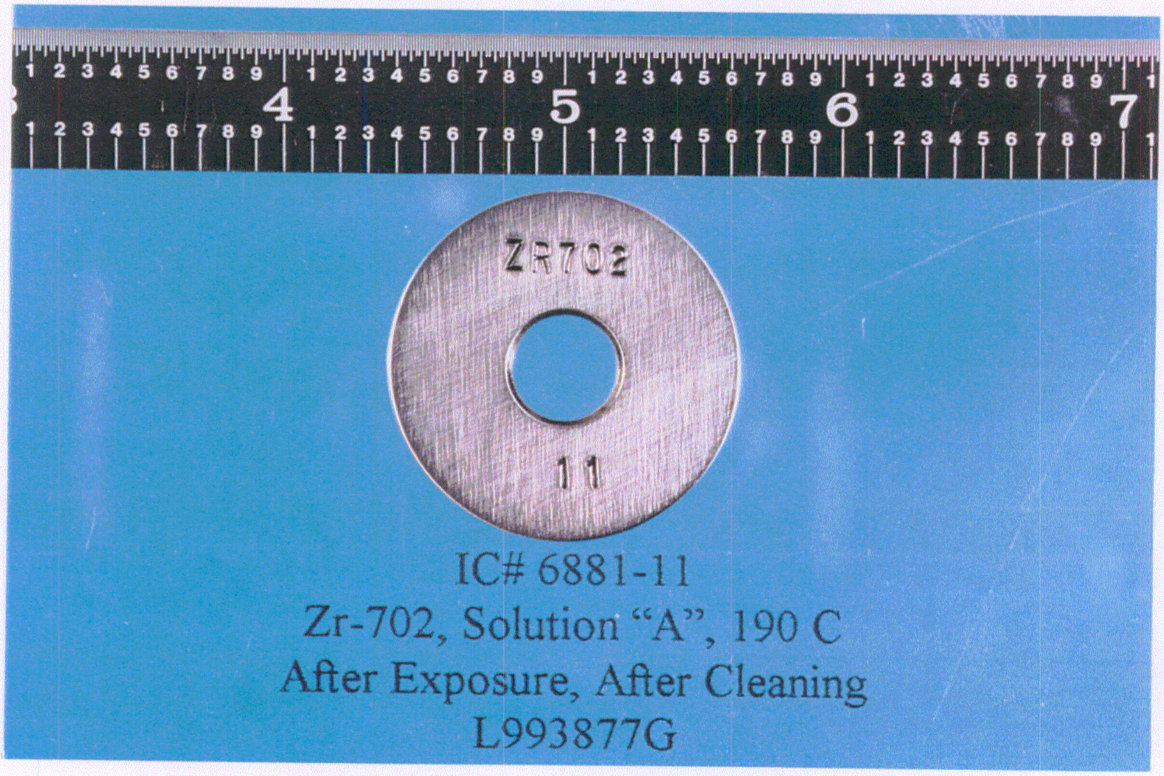
C-2000 (IC #6880-22) after exposure / before cleaning. (P/N 5023-22)



C-2000 (IC #6880-22) after exposure / after cleaning. (P/N 5021-0)



Zr-702 (IC #6881-11) after exposure / before cleaning. (P/N 5023-23)

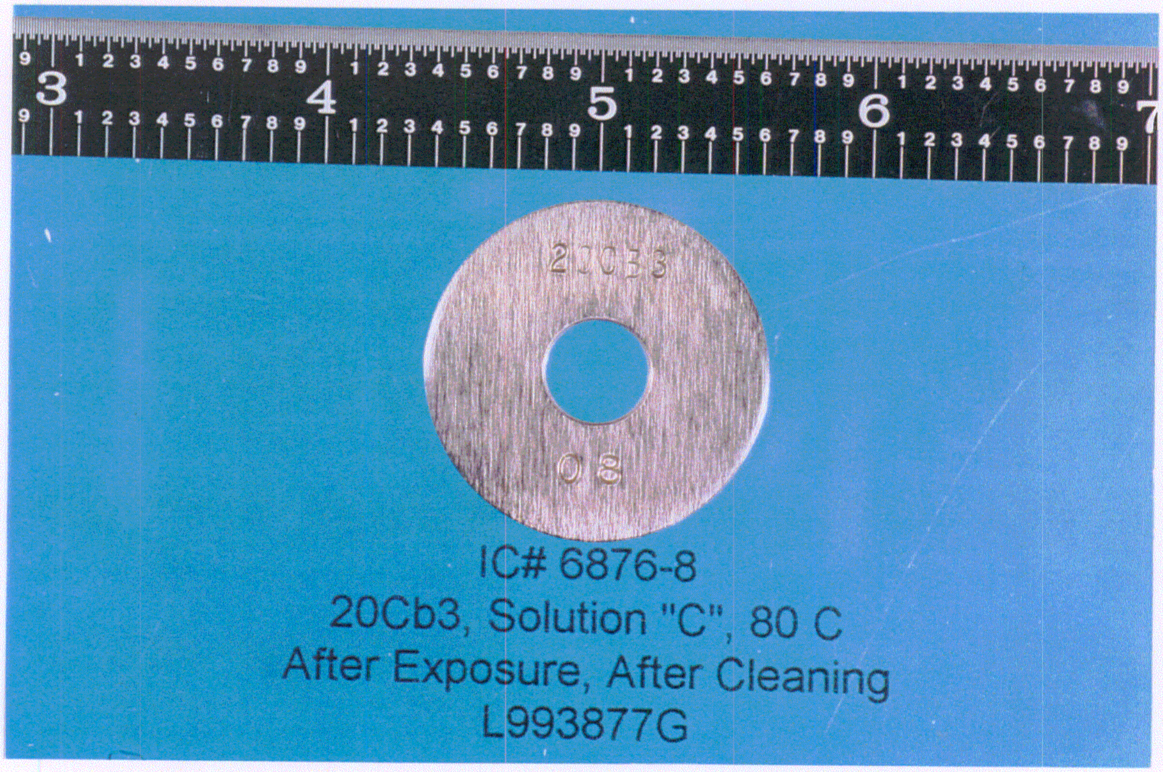


Zr-702 (IC #6881-11) after exposure / after cleaning. (P/N 5021-1)

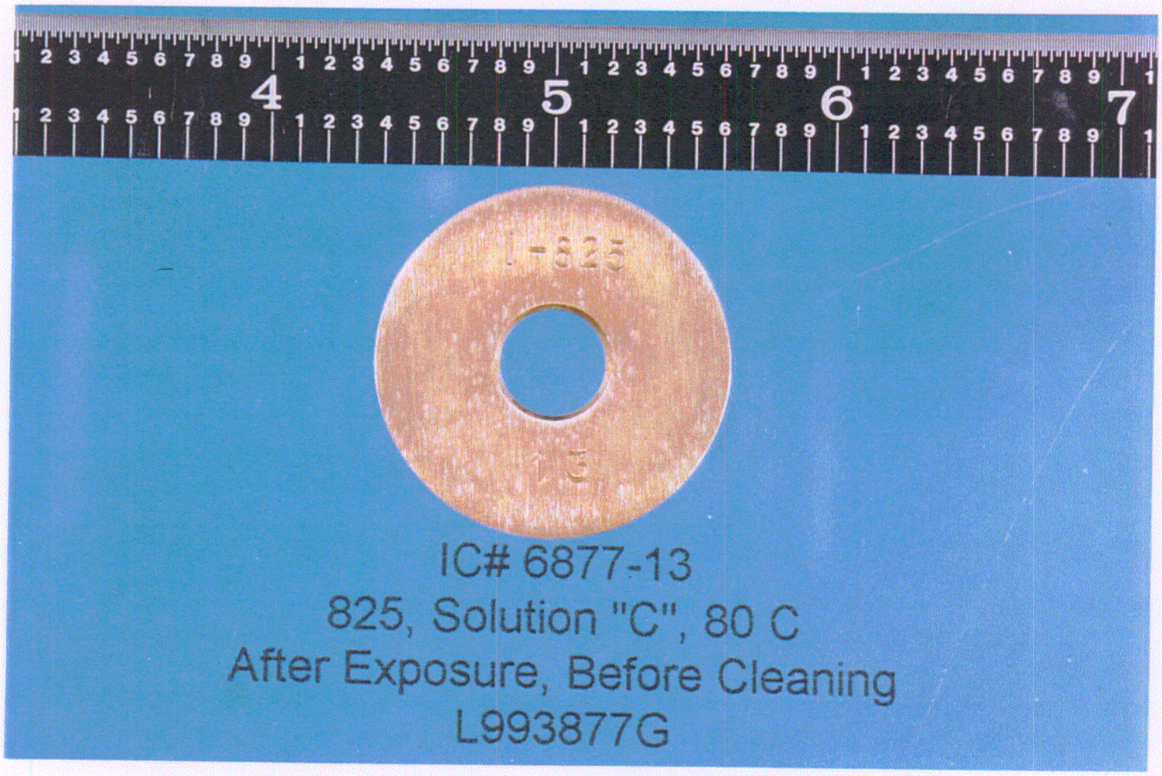
Appendix IV

Solution C – Photographic Documentation

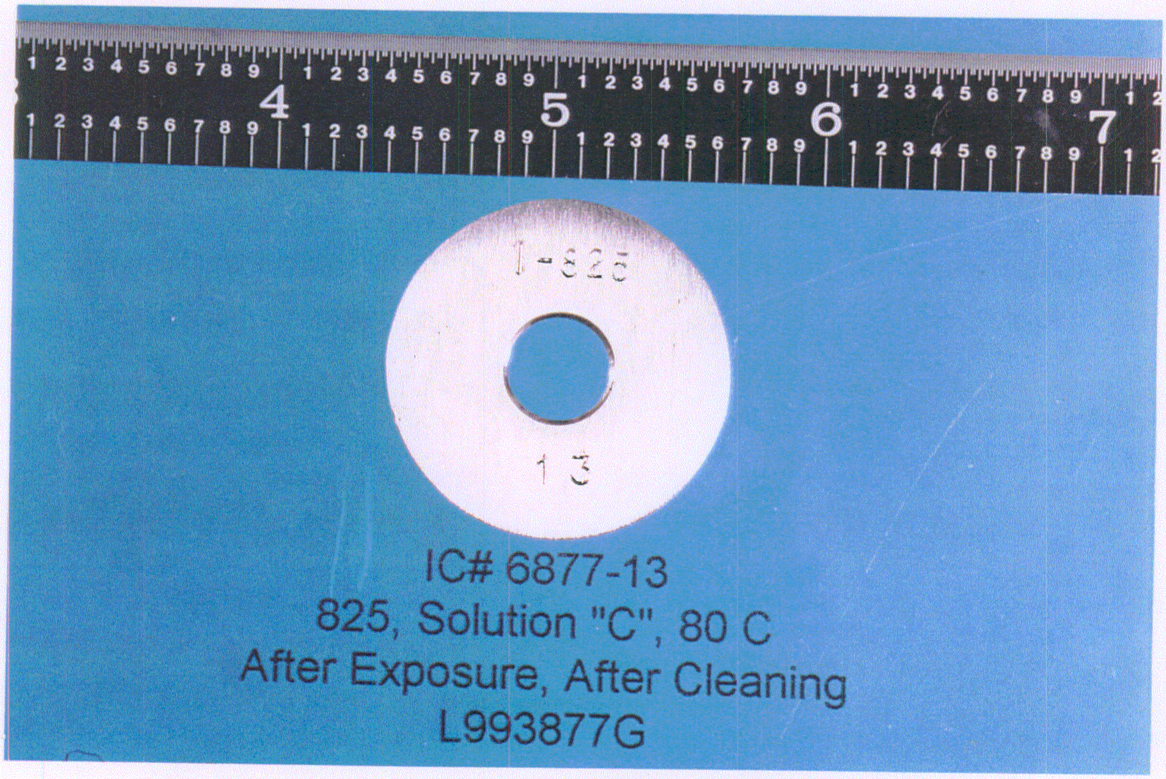
20Cb3 (IC #6876-8) after exposure / before cleaning. (P/N 5030-2)



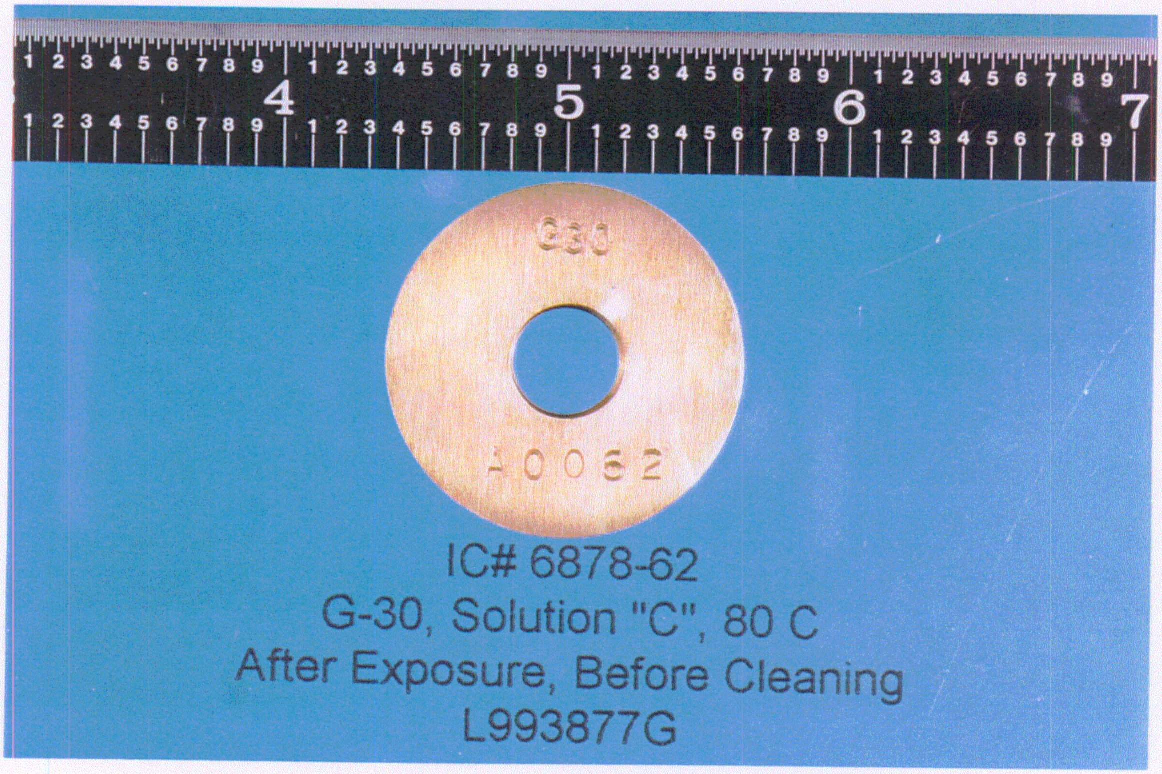
20Cb3 (IC #6876-8) after exposure / after cleaning. (P/N 5029-3)



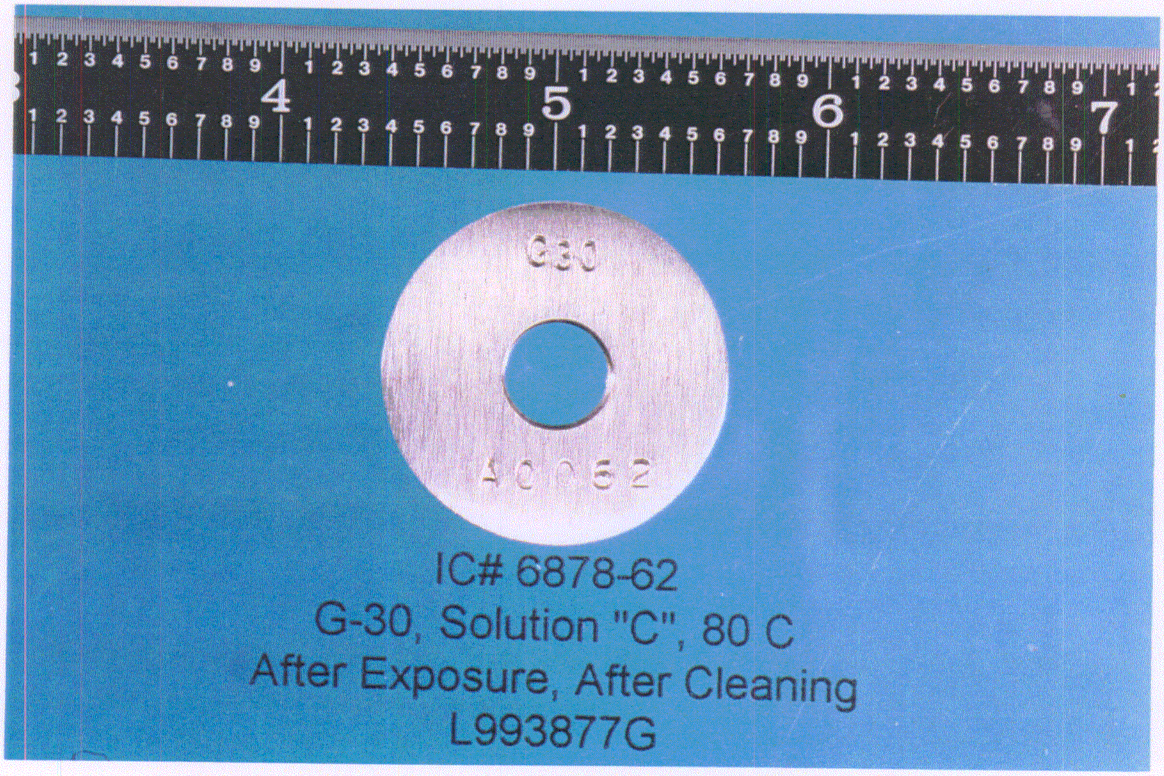
825 (IC #6877-13) after exposure / before cleaning. (P/N 5030-3)



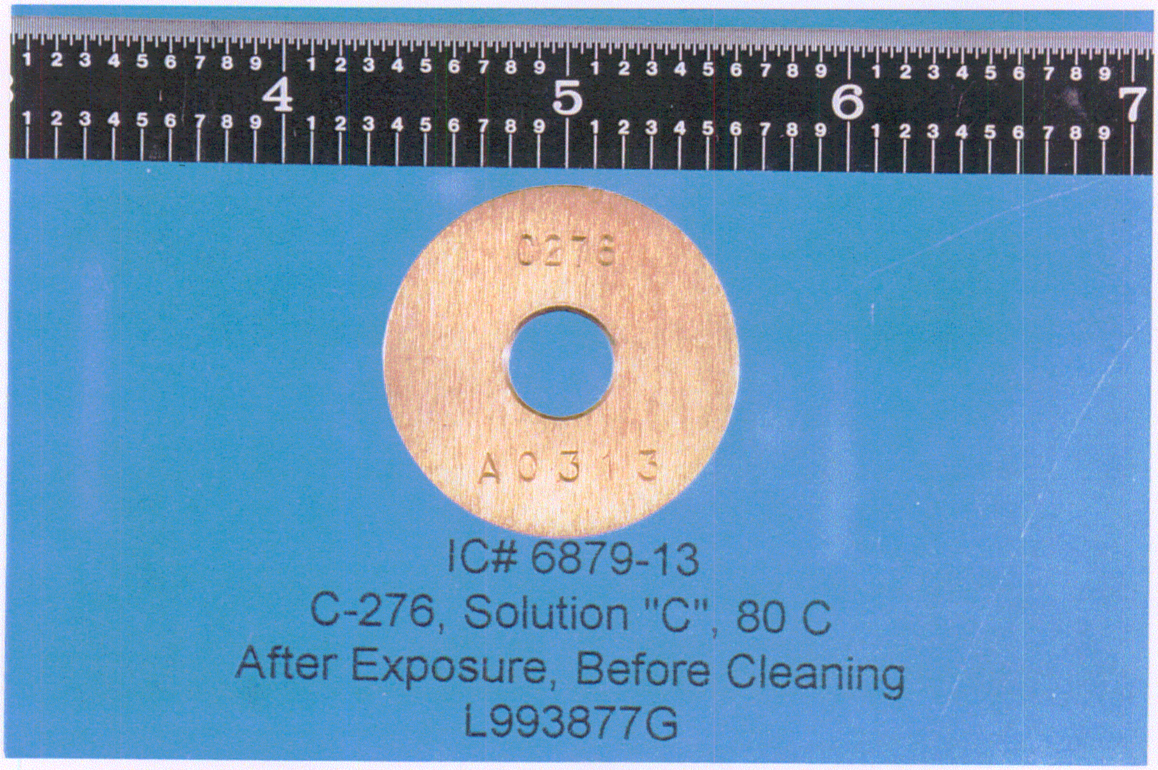
825 (IC #6877-13) after exposure / after cleaning. (P/N 5029-4)



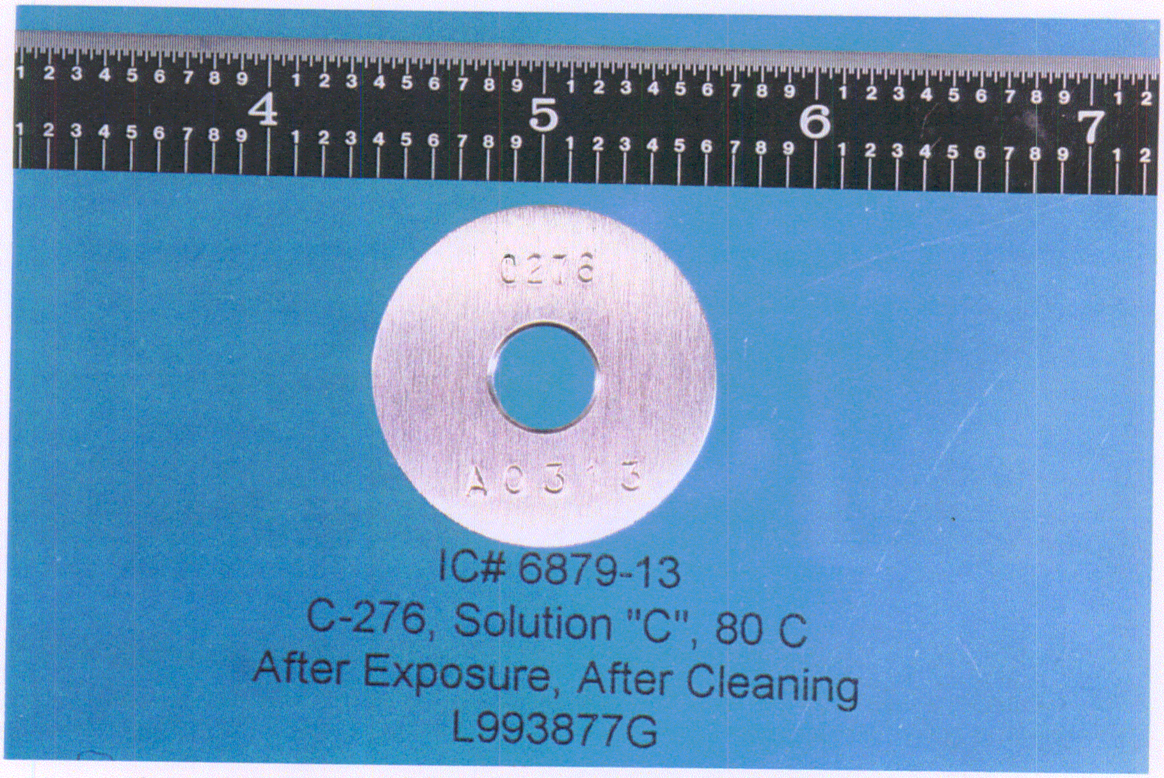
G-30 (IC #6878-62) after exposure / before cleaning. (P/N 5030-4)



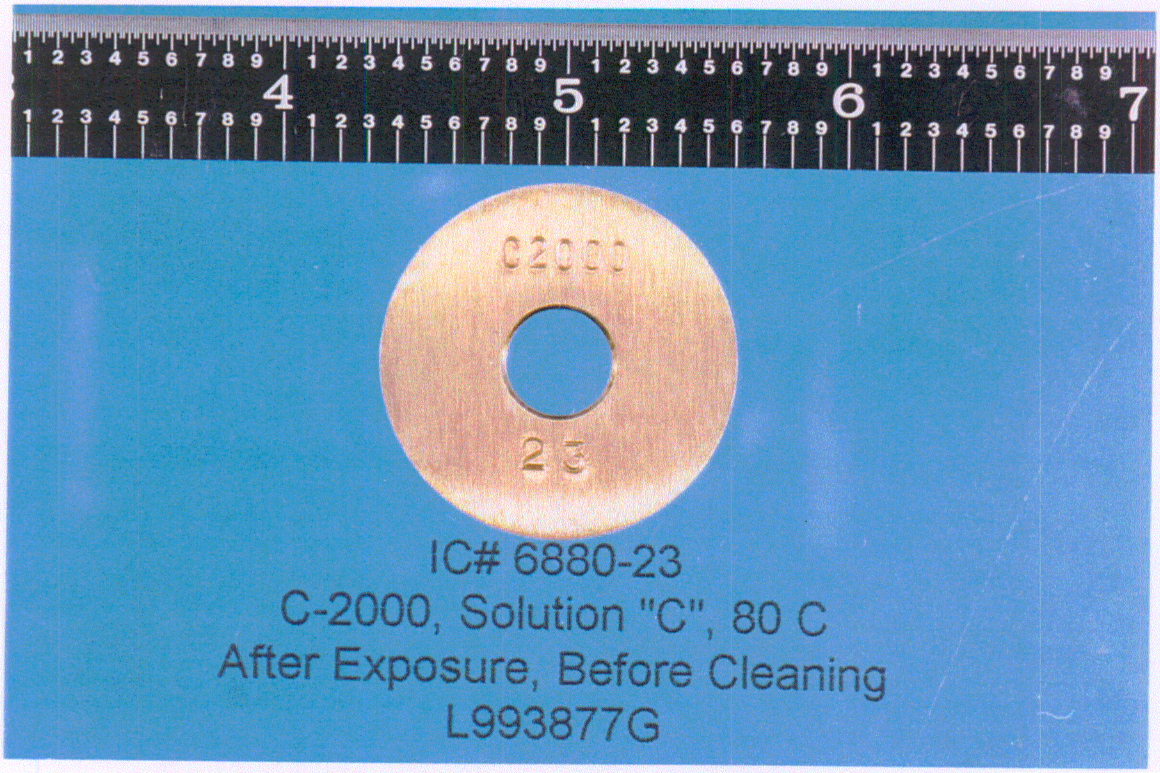
G-30 (IC #6878-62) after exposure / after cleaning. (P/N 5029-5)



C-276 (IC #6879-13) after exposure / before cleaning. (P/N 5030-0)



C-276 (IC #6879-13) after exposure / after cleaning. (P/N 5029-6)



C-2000 (IC #6880-23) after exposure / before cleaning. (P/N 5030-1)

C-2000 (IC #6880-23) after exposure / after cleaning. (P/N 5029-7)

APPENDIX C
PRICING CALCULATIONS

NO INFORMATION

APPENDIX D
ACID REACTOR HYDROLYSIS SPECIFICATION

TECHNICAL SPECIFICATION 99-10600/01

ACID HYDROLYSIS REACTORS

CONFIDENTIAL

PROJECT NO. 99-10600
PROCEEESS DESIGN AND COST
ESTIMATION OF CRITICAL EQUIPMENT
IN THE BIOMASS TO ETHANOL PROCESS

DATE: FEBRUARY 4, 2000
REV 1: JANUARY 22, 2001

1. GENERAL DESCRIPTION AND SCOPE OF WORK

This specification covers the requirements to design, fabricate and supply Acid Hydrolysis Reactors for a confidential client to be located in the United States of America. The Acid Reactors are to be supplied in accordance with this specification. The specification, codes, and standards referenced in specifications and data sheet(s) shall govern in all cases where references thereto are made. In case of conflict between the referenced specifications, codes, or standards and these specifications, the Harris Group Inc. shall be contacted for clarification.

How seemingly insignificant the apparent omission or conflict, the Vendor shall promptly upon discovery thereof so notify Harris Group Inc. in writing and shall secure written instructions from the Harris Group Inc. before proceeding with work affected thereby.

1.1 General

The proposed facility will convert wood chips to fuel-grade ethanol by converting wood to sugars in an acid hydrolysis process and then fermenting the sugars. The vendor is requested to supply pricing for process conditions listed in Section 2.0 Table 1.0 for the acid hydrolysis equipment. For the most part hydrolysis will involve pre-steaming the chips, impregnating the chips with dilute sulfuric acid and a short reaction time with high pressure steam. The product from the reactor will be discharged as shown on the corresponding Process Flow Diagrams attached.

1.2 Vendor Scope of Supply

The pre-steamer and reactor shall be furnished complete and shall consist of, but not necessarily be limited to:

- Pre-steamer Chip Feeder
- Chip Pre-steamer Vessel
- Pre-steamer to Reactor Feed Transfer Equipment
- Hydrolysis Reactor
- Reactor Discharge Valve
- Cast iron or fabricated steel baseplates
- Drive components including sheaves, V-belts, reducers, etc.
- Piping integral to equipment
- Control, instrument and power wiring integral to equipment
- Drive guards
- Instrumentation as required for a complete operating unit and as otherwise specified
- Motor support frame
- Motors, starters and controls
- Structural Steel

- Access platforms, ladders and supports
- "Acid cooking liquor" recirculation pumps (if required)

The following will be furnished by others:

- Foundations and anchor bolts
- Installation and erection
- Wiring to and from equipment
- Piping and ductwork to and from equipment

2.0 OPERATING AND DESIGN CONDITIONS

The vendor is requested to provide quotes on the following process operating conditions. Information has been provided for the suggested metallurgy. The vendor may quote alternative metallurgy for the proposed options with supporting back up information on the expected corrosion rates.

Description	Unit	Conditions
Wood chip types		Yellow poplar, Doug Fir, or Ponderosa Pine
- Average size	Inches	¾"x¾"x ¼"
- Feed Stock Rate	Metric TPD	2000
- Average Wood Density	g/ml	1.217
- Moisture	%	47.9
- Bulk Density	Lb/ cu Ft	8-10
Process 100 ~~Stage One~~		
Process Flow Diagram	Revision E	PFD-P100-A201
Equipment Number		M –202
Chip Pre-steamer Vessel		
- Operating Temperature	^{o}C	100
- Operating Pressure	ATM	1
- Steam Pressure	ATM	4.42
- Steam Flow	Kg/Hr	17,115
- Residence Time	Minutes	20
- Chip Flow into Vessel	Kg/Hr	159,948
- Metallurgy		316 L SS
Hydrolysis Reactor		
- Operating Temperature	^{o}C	180
- Operating Pressure	ATM	9.75
- Acid Concentration (% liquid)	%	0.7
- Acid Flow (2.133% Sulfuric)	Kg/Hr	60,521
- Steam Pressure	ATM	13
- Steam Flow	Kg/Hr	32,638
- Reactor Residence Time	minutes	10

Description	Unit	Conditions
- Total Flow from Reactor	Kg/Hr	271,313
- Metallurgy		Alloy 825
Process 200 Stage One		
Process Flow Diagram	Revision A	PFD-P202-A201
Equipment Number		M-202
Chip Pre- Steamer Vessel		
- Operating Temperature	^{o}C	100
- Operating Pressure	ATM	1
- Steam Pressure	ATM	4.42
- Steam Flow	Kg/Hr	10,929
- Residence Time	minutes	20
- Chip Flow into Vessel	Kg/Hr	159,948
- Metallurgy		316 L SS
Hydrolysis Reactor		
- Acid Concentration	%	0
- Operating Temperature	^{o}C	183
- Operating Pressure	ATM	10.5
- Steam Pressure	ATM	25
- Steam Flow	Kg/Hr	10,929
- Water Flow	Kg/Hr	76,679
- Reactor Residence Time	Minutes	9
- Total Flow from Reactor	Kg/Hr	277,931
- Metallurgy		316 L SS
Process 300 Stage One		
Process Flow Diagram	Revision E	PFD- P300-A201
Equipment Number		M-201
▪ **Chip Pre-steamer Vessel**		
- Operating Temperature	^{o}C	100
- Operating Pressure	ATM	1
- Steam Pressure	ATM	4.42
- Low Pressure Steam Flow	Kg/Hr	16,967
- Chip Flow into Vessel	Kg/Hr	159,948
- Residence Time	Minutes	20
- Metallurgy		316 L SS

Description	Unit	Conditions
▪ **Hydrolysis Reactor**		
- Operating Temperature	°C	190
- Operating Pressure	ATM	12.12
- Acid Concentration (% liquid)	%	0.5
- Acid Flow (1.9 % sulfuric)	Kg/Hr	48,495
- Steam Pressure	ATM	13
- Steam Flow	Kg/Hr	44,617
- Reactor Residence Time	minutes	4
- Total Flow out of the Reactor	Kg/Hr	270,027
- Metallurgy		Alloy 825
Process 300 Stage Two		
Process Flow Diagram	Revision E	PFD-P300-A204
Equipment Numbers		R-202
Chip Pre-Steamer Vessel		
- Operating Temperature	°C	100
- Operating Pressure	ATM	1
- Acid Concentration (% liquid)	%	0.03
- Feed Flow To Pre-steamer	Kg/Hr	123,032
- Feed (% insoluble solids)	%	45.6
- Steam Pressure	ATM	4.42
- Steam Flow	Kg/Hr	5,811
- Residence Time	Minutes	20
- Metallurgy		317L SS
▪ **Hydrolysis Reactor**		
- Operating Temperature	°C	210
- Operating Pressure	ATM	18.39
- Acid Concentration (% liquid)	%	1.7
- Acid Flow (20% Sulfuric)	Kg/Hr	8,476
- Steam Pressure	ATM	23
- Steam Flow	Kg/Hr	25,053
- Total Flow Out of Reactor	Kg/Hr	162,372
- Reactor Residence Time	minutes	3
- Metallurgy		Zirconium Clad

3. SPECIFICATIONS

3.1 Codes and Standards

All equipment shall be designed and constructed in accordance with the latest editions of applicable tank codes or standards. Any conflict between standards shall be referred to the Purchaser who shall determine which standard shall govern.

Reference to the standards of any technical society, organization, or association, or to the laws, ordinances, or codes of governmental authorities shall mean the latest standard, code, or specification adopted, published, and effective at the date of taking bids unless specifically stated otherwise in this specification or the detailed equipment specifications.

Codes and standards may include, but not be limited to:

AISC American Institute of Steel Construction

ANSI American National Standards Institute

ASME American Society of Mechanical Engineers

ASTM American Society of Testing Materials

AWS American Welding Society
D5. Field Welding of Steel Storage Tanks
ANSI/AWS D1.1 - Structural Welding Code

NFPA National Fire Protection Association

OSHA Occupational Safety and Health Act

SSPC Steel Structures Painting Council, Steel Structures Painting Manual, Vol. 2

UBC Uniform Building Code

NEC National Electric Code

ISA Instrument Society of America

3.2 Detailed Specifications

3.2.1 The equipment shall be of heavy-duty construction suitable for continuous operation. Bearings shall be of the anti-friction type and sized for a long service life. Reduction gear units, shall have a Class II or equivalent service rating.

3.2.2 All components of the Reactors and Chip Pre-steamer vessel, its infeed and its discharge system that may be exposed to feed stock, or sulfuric acid shall be fabricated from the suggested metallurgy listed in the table in 2.0 or Purchaser approved equivalent.

3.2.3 Wearable components shall be designed so they are replaceable.

3.2.4 Bearings

Bearings shall be regreasable, anti-friction, self-aligning pillow block type. Pillow blocks shall be applied so that forces are directed radially downward into the base so that the housing is under compression. Should shear forces be induced into housing, manufacturer shall be consulted as to the application and strength of housing. When shear forces are present at base, the fixed bearing shall be next to drive end of shaft. All other bearings shall be the floating type.

Bearings other than pillow-block type shall be restricted to use in enclosed, oil-bath type operation (e.g., reducers).

3.2.5 All equipment supplied as part of this specification must meet applicable industrial safety codes.

3.2.6 Design shall include consideration of dust explosion potential and spontaneous ignition potential.

3.2.7 Chip Feeder and Chip Transfer Equipment shall be designed for high reliability, suitability for handling a wide variety in types of feed stock, low maintenance and operational cost, durability, and low power consumption. Design should be for continuous, smooth feed, sufficient pressure seal against backstroke and accurate feed control.

3.2.8 The Vendor will provide reversing motor starter and controls to permit jog forward and reverse functions. Motor and drive shall be designed to accommodate these functions.

3.2.9 Each valve shall be complete with auxiliary hand wheel operator and any necessary limit switches and spring mounted yoke supports.

3.2.10 All exterior surfaces will be cleaned of welding slag, burrs, and grease.

3.2.11 Ferrous surfaces that should not be painted and are subject to corrosion shall be coated with rust preventative compound, Houghton “Rust Vet 344”, Rust-Oleum “R-9” or Purchaser approved equivalent.

3.2.12 All nozzles will have moisture tight blind flanges attached for shipment of the vessels.

3.2.13 All electrical wiring supplied as a part of the equipment must meet National Electric Code requirements for installation. All wire, switches, boxes and other similar wiring devices will carry an Underwriters’ Laboratories approval label.

3.2.14 The equipment shall be designed for Seismic Zone 3.

3.2.15 The Design Temperature high is 110° F and low is 40 ° F. Design Relative Humidity 20-80%.

3.3 Instrumentation and Control

3.3.1 All instrumentation required for proper monitoring and control of feeder, Chip Pre-steamer Vessel, discharge valves, and Hydrolysis Reactor functions shall be provided by the Vendor.

3.3.2 Process controls, including a full description of the quantity, make and model of equipment offered.

4. MATERIALS AND EQUIPMENT

Unless specifically provided otherwise in each case, all materials and equipment furnished for permanent installation in the work shall conform to applicable standard specifications and shall be new, unused and undamaged.

Individual parts shall be manufactured to standard sizes and gages so that replacement parts furnished at any time can be installed in the field.

5.0 MISCELANEOUS MATERIALS

Miscellaneous materials not otherwise specifically called for shall be furnished by the Vendor. These shall include, but not be limited to, the following as it applies to equipment furnished by the Vendor.

- Guards for all exposed shafts, couplings, sheaves and belts.
- All nuts, bolts, studs and gaskets between components and equipment furnished by the Vendor.
- Safety equipment to prevent dust explosion and spontaneous ignition, if applicable.

ARS/afm

File No.: 99-10600.0501

TECHNICAL SPECIFICATION 99-10600/01

ACID HYDROLYSIS REACTORS

CONFIDENTIAL

PROJECT NO. 99-10600
PROCEEESS DESIGN AND COST
ESTIMATION OF CRITICAL EQUIPMENT
IN THE BIOMASS TO ETHANOL PROCESS

date: February 4, 2000
REV 1: JANUARY 22, 2001

SPECIAL INSTRUCTIONS

1. Completed Proposal Data Sheet.

2. Submit proposals in accordance with this specification. As part of the quotation, fill out and return copies of the Form of Proposal and Required Information of this specification

3. Bidder shall state motor HP and RPM required for equipment.

4. Bidder will include a list of facilities where reactors, similar to the units quoted, are in operation.

TECHNICAL SPECIFICATION 99-10600/01

ACID HYDROLYSIS REACTORS

CONFIDENTIAL

PROJECT NO. 99-10600
PROCEESS DESIGN AND COST
ESTIMATION OF CRITICAL EQUIPMENT
IN THE BIOMASS TO ETHANOL PROCESS

date: February 4, 2000
REV 1: JANUARY 22, 2001

FORM OF PROPOSAL AND REQUIRED INFORMATION

Name of Bidder ______________________________

Address ______________________________

____

Authorized Signature ______________________________

By ______________________________

Date ______________________________

Proposal No. ______________________________

Name of Person to Contact ______________________________

Telephone No. ______________________________

FAX No. ______________________________

The above Bidder, having reviewed all the related purchase inquiry documents, hereby proposes to furnish required equipment as follows:

1. PRICING

1.1 Prices F.O.B. Manufacturer

Total Price

1.1.1 Process 100 ~~Stage One~~ - Chip Pre- Steamer, Hydrolysis Reactor and Auxiliary Equipment $____________

1.1.2 Process 200 Stage One - Chip Pre-Steamer, Hydrolysis Reactor and Auxiliary Equipment $____________

1.1.3 Process 300 Stage One - Chip Pre-Steamer, Hydrolysis Reactor and Auxiliary Equipment $____________

1.1.4 Process 300 Stage Two - Chip Pre-Steamer, Hydrolysis Reactor and Auxiliary Equipment $____________

1.2 Special Tools $____________

1.3 Spare Parts per List $____________

1.4 Microfilming, Drawings & Manuals $____________

1.5 Erection Supervision $____________

1.6 Startup Personnel $____________

1.7 Operator Training $____________

1.8 Proposal validity (min. 90 days), until Date____________

1.9 Prices firm for deliveries as indicated, until Date_____________

1.10 Escalation applicable, if any, and when Date_____________
Escalation Amount %_____________

1.11 Terms of payment __________________________
____

2. DELIVERIES

2.1 Review drawings (from date of order) Weeks_____________

2.2 Certified drawings (from review) Weeks_____________

2.3 Equipment (from return of review drawings) Weeks_____________

3. SHIPPING INFORMATION

3.1 Shipping Point _____________

3.2 Shipping Weight Pounds

3.3.1 Process 100 Chip Pre-Steamer Vessel, Reactor and Auxiliary Equipment _____________

3.3.2 Process 200 Stage One Chip Pre-Steamer Vessel, Reactor and Auxiliary Equipment ____________

3.3.3 Process 300 Stage One Chip Pre-Steamer Vessel, Reactor and Auxiliary Equipment ____________

3.3.4 Process 300 Stage Two Chip Pre-Steamer Vessel, Reactor and Auxiliary Equipment ____________

4. SPECIFICATIONS

4.1	We are quoting exactly as specified	( )
4.2	We are quoting an alternate to the specifications, as detailed in the proposal	( )
4.3	The equipment quoted will satisfy all performance requirements of the specification.	( )

5. ADDITIONAL INFORMATION

Bidder to include the following information with proposal:

5.1	Itemized List and Prices of Special Tools	( )
5.2	Itemized List and Prices of Spare Parts	( )
5.3	Erection Supervision Terms and Conditions, Mandays, etc.	( )
5.4	Startup Personnel Terms and Conditions, Mandays, etc.	( )
5.5	Operator Training Terms and Conditions, Mandays, etc.	( )
5.8	Descriptive Literature and Specifications	( )
5.9	Dimensional Outline and Mounting Drawings	( )
5.10	Schematic Diagrams	( )
5.11	Exceptions to Specifications and Commercial Conditions	( )
5.12	Warranty and Product Liability Statements	( )
5.13	List of Major Sub-Vendors and Manufacturers of Proposed Equipment	( )
5.14	List and References of Similar Equipment Installation	( )
5.15	List and References of Similar Experience with Process Temperatures, Pressures, and/or Acid Concentrations	( )

6. MOTORS

RECOMMENDED MINIMUM

Drive	HP	Speed
Chip Pre-steamer Feeder	________	________
Chip Pre-steamer To Reactor Transfer Equipment	________	________
Reactor Vessel Discharge Valve	________	________
Recirculation Cooking Liquor Pumps (if required)	________	________

7. ADDITIONAL SHEETS

Bidder may attach additional sheets if sufficient space is not available to adequately describe required and additional information.

APPENDIX E
ANDRITZ EQUIPMENT LIST AND DRAWINGS

September 8, 2000

Mr. Lynn Montague
Harris Group
P.O. Box 3855
Seattle, WA 98124-3855

Reference: **Acid Hydrolysis Reactor**
P.O. Request to Generate a Formal Quote per HGI Technical Specification 99-10600/01.
HGI Project No. 99-10600
Andritz Inc. Proposal No. 00-21-39P-1111

Dear Mr. Montague:

We are pleased to submit our enclosed e-mailed quote per your purchase order no. 10600-7 for Andritz engineering. Please accept our apology for being delayed in issuing this to you.

Dimensional outline drawings of the equipment are being sent separately by courier.

Hopefully our quote will assist you with the overall analysis of your potential project. We have presented an equipment list and budget pricing for the four optional system cases as described in your bid inquiry. Please note that this information is preliminary at this time, and is not an offer for sale.

Our equipment train for each line consists basically of a presteaming bin, integral metering conveyor, chute, plug screw feeder, and horizontal digester(s), (reactor(s)). The number of lines of equipment and prices for each system case vary based on the flow rates, operating pressures, chemical usage, and retention times.

Special materials of construction such as Alloy 825, 317L SST, and Zirconium are also included per your specifications. A price deduct is shown for the possibility of using a 316L SST feed screw in the Zirconium Reactors to reduce the capital expense significantly. Depending on the projected life span of the 316L SST feed screw, this may be a more viable option.

ANDRITZ INC.
35 Sherman Street
Muncy, PA , USA 17756
Tel: 570/546-8211
Fax: 570/546-1306

Please call with questions or for additional information as required.

Sincerely yours,
ANDRITZ INC.

Raymond Wilson

Ray Wilson
Sales Engineering
Telephone: 570-546-1143
Fax: 570-546-1116
Email: rlw@andritz-na.com

cc: Mark Hallenbeck - Andritz Inc.

Brad Cort - Andritz Inc.

Ken Bear - Andritz Inc.

Jerry Shoemaker - Andritz Inc.

BASIS OF DESIGN

The equipment train presented in the attached proposal is designed for use of Andritz equipment in an Acid Hydrolysis Reactor System to produce ethanol in accordance with the following criteria. Also reference Harris Group's Technical Bid Specifications 99-10600/01 dated February 4, 2000.

I. Raw Material: Yellow poplar, Doug Fir, or Ponderosa Pine.

- Chip Bulk Density: 8-10 ODlb/ft^3
- Moisture Content 47.9%

II. Production

Design Production - 2000 ODMT/D total system

-
-

III. Final Product: - Ethanol

SCOPE OF PROPOSAL

This proposal includes the supply of the major equipment for the Acid Hydrolysis Reactor System described herein.

The following equipment and services are not included, except where noted in the specifications:

Erection of Equipment, Equipment Installation
Instrument Tubing and Piping and Instrument Wiring
Isolation Valves, Hand Valves and Block Valves
Support Structures and Platforms, Walkways, Ladders, Stairs, Railing and Kick Plates
Civil Engineering, Buildings, Foundations
Wiring
Motor Starters, Motor Protection Equipment, and Motor Excitation Equipment
Painting (Touchup)
Insulation
Piping, Chutes, and Transition Pieces, except as specified

ENGINEERING SERVICES

Andritz will provide details for the system design. It is Andritz's intent to pass on to the purchaser the working technology gained in previous processing systems and instrumentation and control design.

The following are the major engineering services to be provided by Andritz with the contract:

- Process design parameter for Andritz supplied equipment.
- Material and energy balances and/or information required for sizing process control instrumentation.
- Preliminary P & I diagrams and block logic for Andritz supplied equipment.
- Machine outline drawings for each piece of Andritz supplied equipment, complete with piping and wiring requirements.
- Operating and maintenance manuals for all Andritz supplied equipment.

SCOPE OF PROPOSAL
(continued)

DRAWING AND MANUAL SUBMITTALS

Andritz will provide drawings, in three (3) sets (one (1) reproducible and two (2) prints), and manuals in three (3) sets as follows:

A. SYSTEM DRAWINGS

1. General Layout - Preliminary drawings will be issued within three (3) weeks of receipt of order. Finalized "For Approval" drawings will be contingent on installation and custom component design decision.

2. Process Flow Diagram - Issued for approval within three (3) weeks of receipt of order.

3. Process Control Interlock Diagrams - Issued for approval within twelve (12) weeks of receipt of order.

B. EQUIPMENT DRAWINGS

1. Where single pieces of equipment are unaffected by system configuration "For Approval" drawings will be issued within three (3) weeks of receipt of order.

2. For components custom designed to suit, "For Approval" drawings will be issued as details become finalized. Preliminary drawings will be made available in partial form to suit engineering/construction schedule.

C. EQUIPMENT MANUALS

Equipment manuals will be issued at time of shipment. Copies will be supplied to assist as required.

PROJECT MANAGEMENT

Andritz will appoint a Project Manager for the duration of the contract. Project Management services are included in this package and are as follows:

a) Production of a complete critical path project schedule for scope of order.

b) Coordinate with the customer's engineers and Andritz engineering on system design and drawing commitments.

c) Coordinate with Purchasing and Manufacturing on material procurement and fabrication to ensure Andritz commitments are maintained.

d) Provide monthly progress reports to the customer.

This approach ensures that customer of Andritz will get the most up-to-date technology with an on time start-up of the equipment provided for the following sections.

INSTALLATION AND START-UP

The services of qualified Andritz Service Representatives will be made available upon request to assist in installation, training, and start-up at an additional charge for both time and expenses. This proposal provides for services of Andritz service representatives as detailed elsewhere in this proposal. Additional charges for service representatives will be on a time and expenses basis in accordance with the enclosed service policy.

QUALITY ASSURANCE PROGRAM

A Quality Assurance Program has been written to establish guidelines to Andritz manufacturing facilities and vendors that supply raw materials, parts, sub-assemblies or services to Andritz.

This Quality Assurance Program was written to emphasize the importance of prevention, detection and correction of product defects and assure that the product is produced at the desired quality level.

This program is concerned with all technical and manufacturing aspects, and the quality of all material contained in the finished product. It reflects the current level of technology, especially as related to engineering design, manufacturing processes, and advances in material and testing methods.

Andritz manufacturing facilities and vendors are required to furnish Andritz with Quality Manuals on request.
Andritz, Inc. has qualified for ISO 9001 Certification.

EQUIPMENT LIST

Item	Quantity	Description	Remarks
Process 100S1 - Alloy 825			
Five (5) Lines			
1.01	Five (5)	Bin, Presteaming, 50 m3 gross volume (20 min. retention, 85% fill), with 20" diameter Metering Conveyor. Mainly 316L SST. Hydraulic 15 HP Drive on Stoker, and ACVF Controller and 30 HP Motor on Conveyor included.	
1.02	Five (5)	Chute, Atmospheric, 8 Ft High, 316L SST less level controls.	
1.03	Five (5)	Twin Agitator Feeder for Plug Screw Feeder, 316L SST Including 7.5 HP Motor.	
1.04	Five (5)	Plug Screw Feeder, 316 SST Inlet Housing, except with Feed Screw and Tapered Compression Housing of Alloy 825 including the following:	
	Five (5)	Fabricated Base for PSF and Drive Components, HRS	
	Five (5)	Gearbox and Couplings including ACVF Controller and 600 HP Motor.	
1.05	Five (5)	Inlet Tee, 31-1/2", Alloy 825	
1.06	Five (5)	Blow Back Valve, Alloy 825 including Accumulator.	
1.07	Ten (10)	72" x 45'-10" flange to flange Horizontal Digester	
		ALLOY 825 - 200 PSIG Including the following:	
	Twenty (20)	Mechanical Seals, Chesterton, Special	
	Twenty (20)	Lubrication System for Seals	
	Twenty (20)	Level Switch	
	Twenty (20)	Flow Meter	
	Twenty (20)	Pressure Switch	
	Ten (10)	Drive Components Including ACVF Controller and 25 HP Motor	

EQUIPMENT LIST

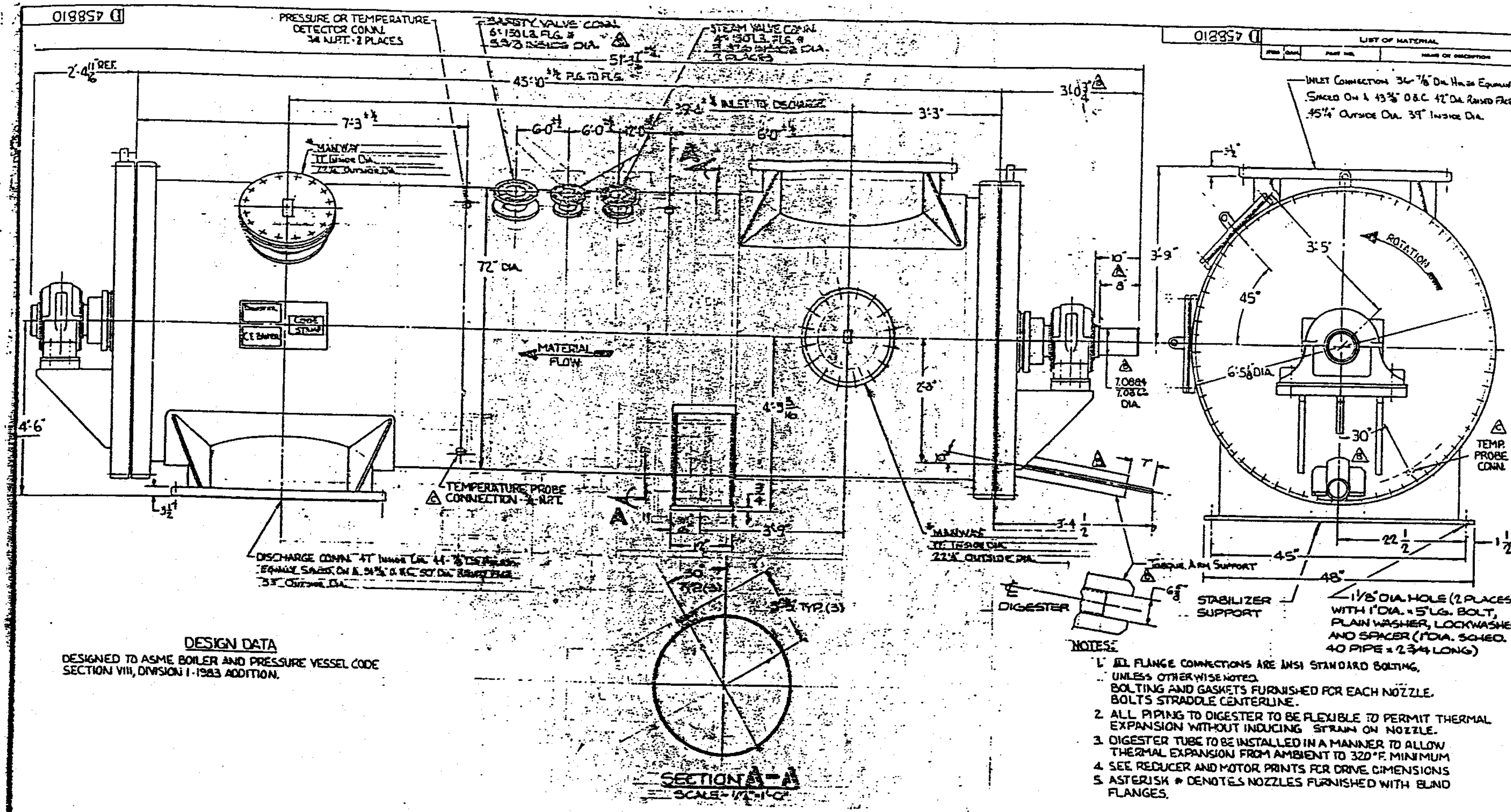
Item	Quantity	Description	Remarks
Process 200S1 - 316L SST			
Five (5) Lines			
2.01	Five (5)	Bin, Presteaming, 50 m3 gross volume, (20 min. retention, 85% fill), with 20" diameter Metering Conveyor. Mainly 316L SST. Hydraulic 15 HP Drive on Stoker, and ACVF Controller and 30 HP Motor on Conveyor included.	
2.02	Five (5)	Chute, Atmospheric, 8 Ft High, 316L SST less level controls.	
2.03	Five (5)	Twin Agitator Feeder for Plug Screw Feeder, 316L SST Including 7.5 HP Motor.	
2.04	Five (5)	Plug Screw Feeder, Mainly 316 SST including the following:	
	Five (5)	Fabricated Base for PSF and Drive Components, HRS	
	Five (5)	Gearbox and Couplings including ACVF Controller and 600 HP Motor.	
2.05	Five (5)	Inlet Tee, 31-1/2", 316 SST	
2.06	Five (5)	Blow Back Valve, 316 SST including Accumulator.	
2.07	Ten (10)	72" x 45'-10" flange to flange Horizontal Digester	
		316 SST - 200 PSIG Including the following:	
	Twenty (20)	Mechanical Seals, Chesterton, Special	
	Twenty (20)	Lubrication System for Seals	
	Twenty (20)	Level Switch	
	Twenty (20)	Flow Meter	
	Twenty (20)	Pressure Switch	
	Ten (10)	Drive Components Including ACVF Controller and 25 HP Motor	

EQUIPMENT LIST

Item	Quantity	Description	Remarks
Process 300S1 - Alloy 825			
Four (4) Lines			
3.01	Four (4)	Bin, Presteaming, 70 m3 gross volume, (20 min. retention, 85% fill), with 24" diameter Metering Conveyor. Mainly 316L SST. Hydraulic 20 HP Drive on Stoker, and ACVF Controller and 40 HP Motor on Conveyor included.	
3.02	Four (4)	Chute, Atmospheric, 10 Ft High, 316L SST less level controls.	
3.03	Four (4)	Twin Agitator Feeder for Plug Screw Feeder, 316L SST Including 7.5 HP Motor.	
3.04	Four (4)	Plug Screw Feeder, 316 SST Inlet Housing, except with Feed Screw and Tapered Compression Housing of Alloy 825 including the following:	
	Four (4)	Fabricated Base for PSF and Drive Components, HRS	
	Four (4)	Gearbox and Couplings including ACVF Controller and 700 HP Motor.	
3.05	Four (4)	Inlet Tee, 31-1/2", Alloy 825	
3.06	Four (4)	Blow Back Valve, Alloy 825 including Accumulator.	
3.07	Four (4)	72" x 45'-10" flange to flange Horizontal Digester	
		ALLOY 825 - 225 PSIG Including the following:	
	Eight (8)	Mechanical Seals, Chesterton, Special	
	Eight (8)	Lubrication System for Seals	
	Eight (8)	Level Switch	
	Eight (8)	Flow Meter	
	Eight (8)	Pressure Switch	
	Four (4)	Drive Components Including ACVF Controller and 25 HP Motor	

EQUIPMENT LIST

Item	Quantity	Description	Remarks
Process 300S2 - 317L and Zirconium Clad			
Four (4) Lines			
4.01	Four (4)	Bin, Presteaming, 70 m3 gross volume, (20 min. retention, 85% fill), with 24" diameter Metering Conveyor. Mainly 317L SST. Hydraulic 20 HP Drive on Stoker, and ACVF Controller and 40 HP Motor on Conveyor included.	
4.02	Four (4)	Chute, Atmospheric, 10 Ft High, 317L SST less level controls.	
4.03	Four (4)	Twin Agitator Feeder for Plug Screw Feeder, 317L SST Including 7.5 HP Motor.	
4.04	Four (4)	Plug Screw Feeder, 317 SST Inlet Housing, Feed Screw and Tapered Compression Housing including the following:	
	Four (4)	Fabricated Base for PSF and Drive Components, HRS	
	Four (4)	Gearbox and Couplings including ACVF Controller and 700 HP Motor.	
4.05	Four (4)	Inlet Tee, 31-1/2", 317L SST	
4.06	Four (4)	Blow Back Valve, 317L SST including Accumulator.	
4.07	Four (4)	72" x 45'-10" flange to flange Horizontal Digester	
		Zirconium Clad - 325 PSIG Including the following:	
	Eight (8)	Mechanical Seals, Chesterton, Special	
	Eight (8)	Lubrication System for Seals	
	Eight (8)	Level Switch	
	Eight (8)	Flow Meter	
	Eight (8)	Pressure Switch	
	Four (4)	Drive Components Including ACVF Controller and 25 HP Motor	



DESIGN DATA

DESIGNED TO ASME BOILER AND PRESSURE VESSEL CODE SECTION VIII, DIVISION 1-1983 ADDITION.

NOTES:

1. ALL FLANGE CONNECTIONS ARE ANSI STANDARD BOLTING, UNLESS OTHERWISE NOTED. BOLTING AND GASKETS FURNISHED FOR EACH NOZZLE. BOLTS STRADDLE CENTERLINE.
2. ALL PIPING TO DIGESTER TO BE FLEXIBLE TO PERMIT THERMAL EXPANSION WITHOUT INDUCING STRAIN ON NOZZLE.
3. DIGESTER TUBE TO BE INSTALLED IN A MANNER TO ALLOW THERMAL EXPANSION FROM AMBIENT TO 320°F MINIMUM.
4. SEE REDUCER AND MOTOR PRINTS FOR DRIVE DIMENSIONS.
5. ASTERISK * DENOTES NOZZLES FURNISHED WITH BLIND FLANGES.

DIGESTER PERFORMANCE DATA

MINIMUM DISTANCE MAT'L TRAVEL FROM INLET TO DISCHARGE - 37'-4 1/2"

DISTANCE MAT'L TRAVELS IN ONE REVOLUTION OF DIGESTER SCREW - 24 INCHES

MAXIMUM WORKING VOLUME OF DIGESTER 895 CUBIC FEET - 100% FILL

Top Vessel

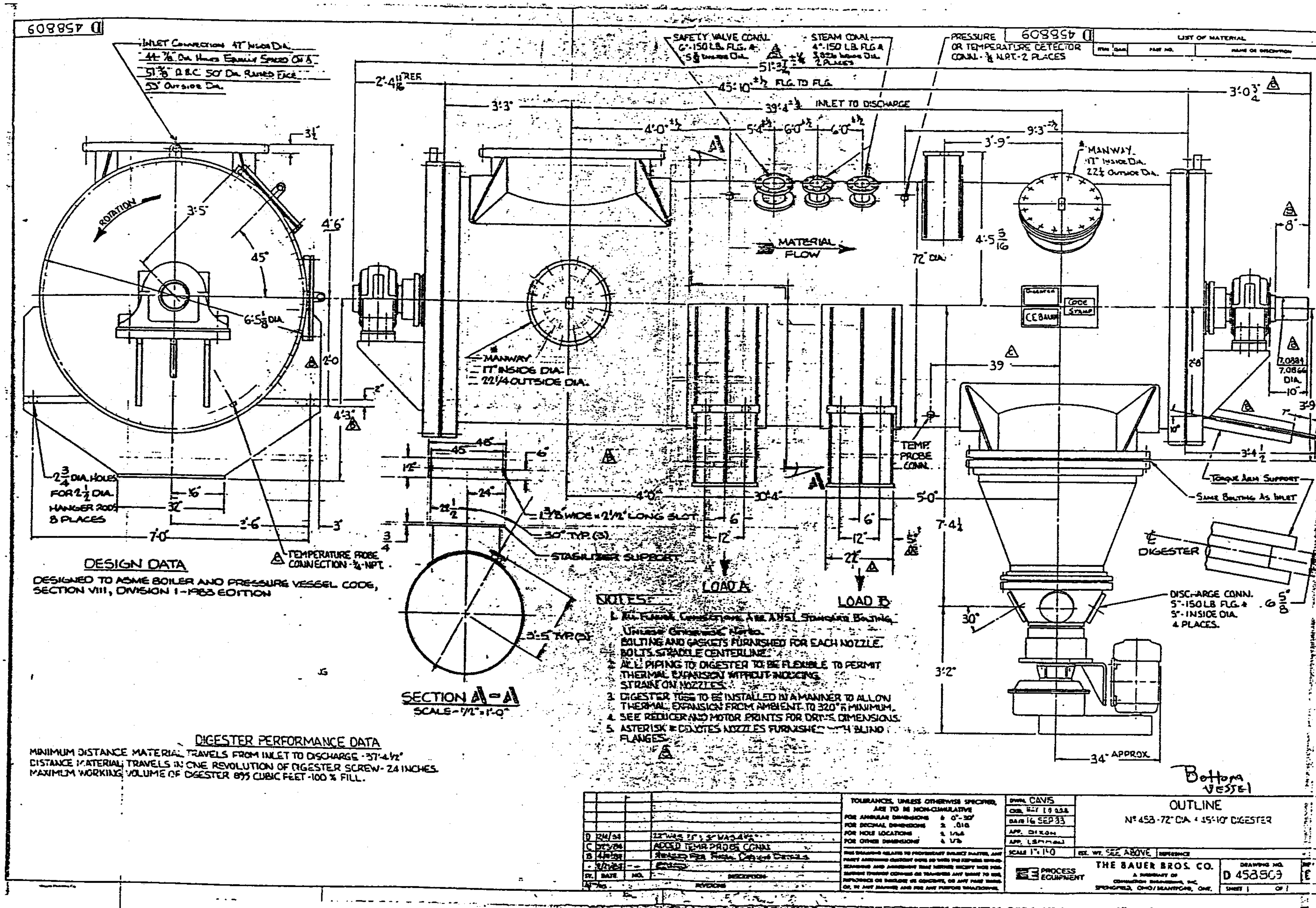
REV	DATE	NO.	DESCRIPTION
C	5/23/84		ADDED TEMP. PROBE CONN.
B			[illegible]
-			REVISED

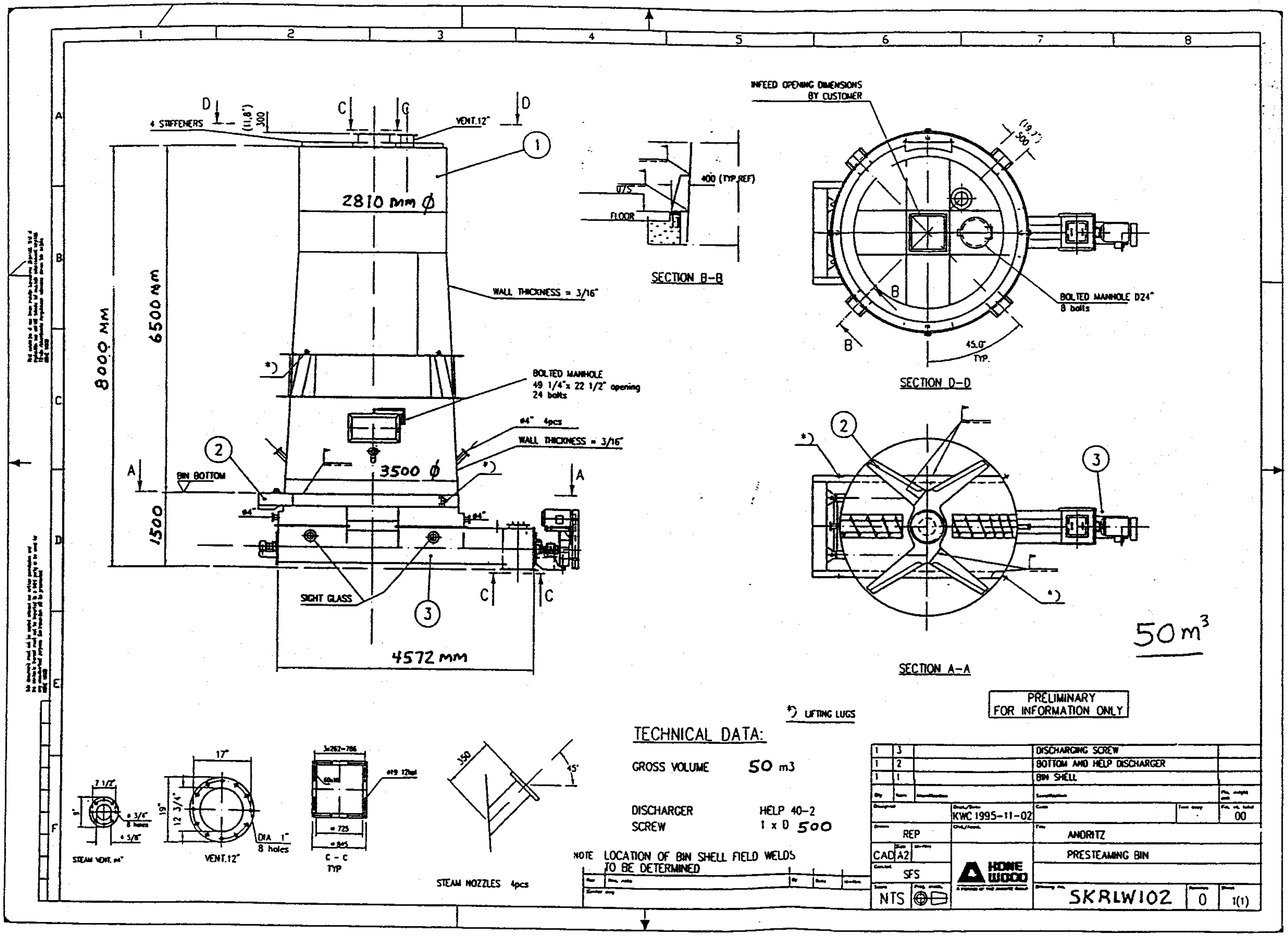
TOLERANCES, UNLESS OTHERWISE SPECIFIED, ARE TO BE NON-CUMULATIVE
FOR HOLE LOCATIONS ± 1/64
FOR OTHER DIMENSIONS ± 1/8

DWN. DAVIS
DATE 19 SEP 83
APP. LEMMON
SCALE 1"=1'0"
EST. WT. SEE ABOVE

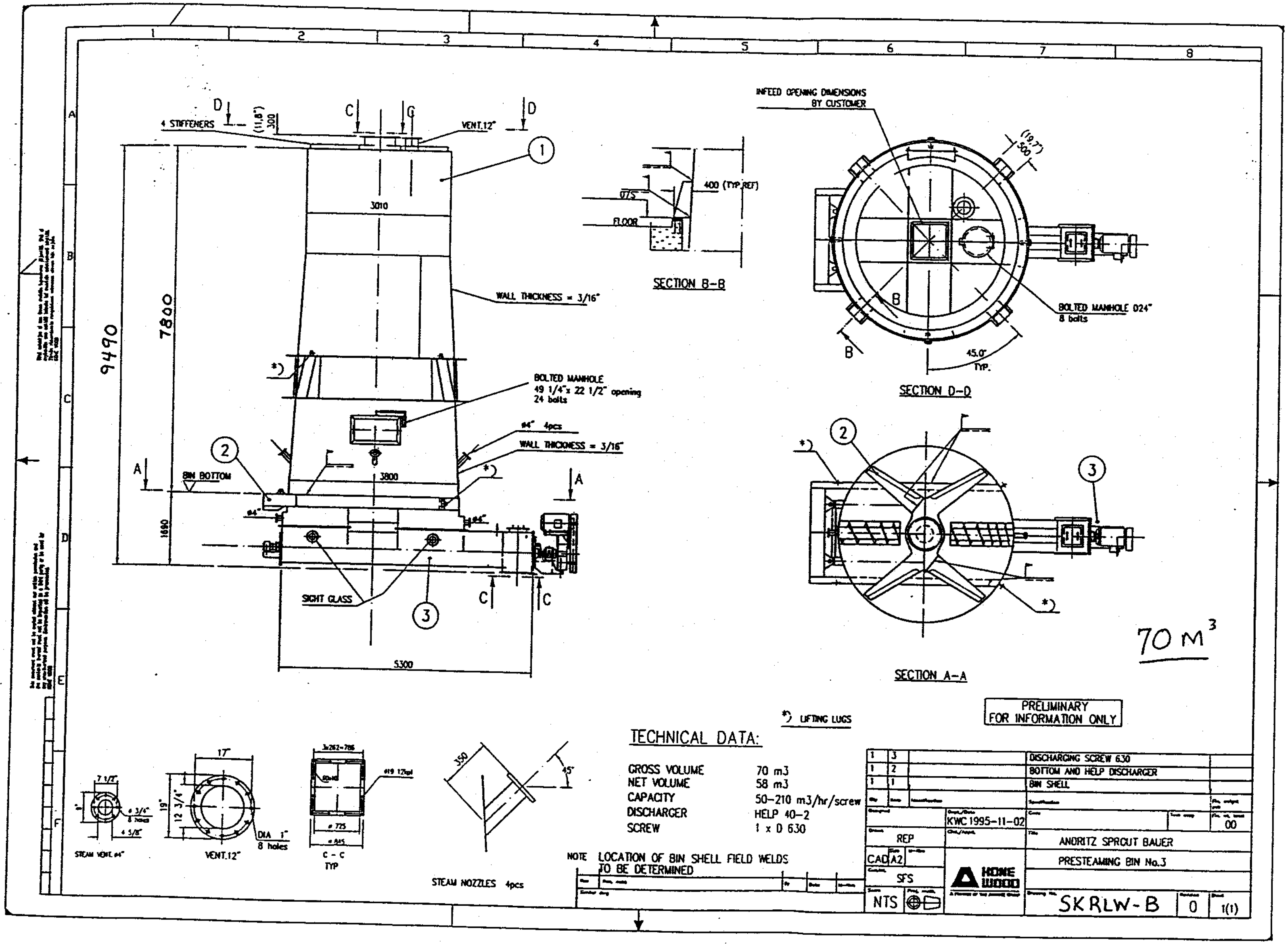
OUTLINE
Nº 458 - 72" DIA. x 45'-10" DIGESTER

PROCESS EQUIPMENT
THE BAUER BROS. CO.
DRAWING NO. D 453310
REV C
SHEET 1 OF 1


D 458809
INLET CONNECTION 47" INSIDE DIA.
44-7/8" DIA. HOLES EQUALLY SPACED ON 51-3/8" B.C. 50" DIA. RAISED FACE
53" OUTSIDE DIA.
SAFETY VALVE CONN. 6"-150 LB. FLG.
STEAM CONN. 4"-150 LB. FLG. 2 PLACES
PRESSURE OR TEMPERATURE DETECTOR CONN. - 3/4 N.P.T.-2 PLACES
LIST OF MATERIAL
45'-10" FLG. TO FLG.
INLET TO DISCHARGE
ROTATION
MATERIAL FLOW
MANWAY 17" INSIDE DIA. 22 1/4 OUTSIDE DIA.
72" DIA.
CE BAUER
CODE STAMP
TEMP. PROBE CONN.
1 3/8 WIDE x 2 1/2" LONG SLOT
30° TYP. (3)
STABILIZER SUPPORT
LOAD A
LOAD B
TORQUE ARM SUPPORT
SAME BOLTING AS INLET
DIGESTER
DISCHARGE CONN. 5"-150 LB. FLG. 5"-INSIDE DIA. 4 PLACES.
2 3/4 DIA. HOLES FOR 2 1/2 DIA. HANGER 200# 8 PLACES
TEMPERATURE PROBE CONNECTION - 3/4-NPT.
DESIGN DATA
DESIGNED TO ASME BOILER AND PRESSURE VESSEL CODE, SECTION VIII, DIVISION 1-1983 EDITION
SECTION A-A
SCALE - 1 1/2" = 1'-0"
NOTES:
1. ALL FLANGE CONNECTIONS ARE ANSI STANDARD BOLTING UNLESS OTHERWISE NOTED. BOLTING AND GASKETS FURNISHED FOR EACH NOZZLE. BOLTS STRADDLE CENTERLINE.
2. ALL PIPING TO DIGESTER TO BE FLEXIBLE TO PERMIT THERMAL EXPANSION WITHOUT INDUCING STRAIN ON NOZZLES.
3. DIGESTER TO BE INSTALLED IN A MANNER TO ALLOW THERMAL EXPANSION FROM AMBIENT TO 320°F MINIMUM.
4. SEE REDUCER AND MOTOR PRINTS FOR DRIVE DIMENSIONS.
5. ASTERISK * DENOTES NOZZLES FURNISHED WITH BLIND FLANGES.
DIGESTER PERFORMANCE DATA
MINIMUM DISTANCE MATERIAL TRAVELS FROM INLET TO DISCHARGE - 37'-4 1/2"
DISTANCE MATERIAL TRAVELS IN ONE REVOLUTION OF DIGESTER SCREW - 24 INCHES
MAXIMUM WORKING VOLUME OF DIGESTER 895 CUBIC FEET - 100 % FILL.
Bottom Vessel
OUTLINE
No 453-72" DIA. x 45'-10" DIGESTER
TOLERANCES, UNLESS OTHERWISE SPECIFIED, ARE TO BE NON-CUMULATIVE
ADDED TEMP. PROBE CONN.
REVISIONS
DESCRIPTION
DWN. DAVIS
DATE 16 SEP 83
SCALE 1"=1'-0"
PROCESS EQUIPMENT
THE BAUER BROS. CO.
D 458809



4 STIFFENERS
(11.8")
300
VENT.12"
2810 mm Ø
WALL THICKNESS = 3/16"
8000 MM
6500 MM
BOLTED MANHOLE
49 1/4"x 22 1/2" opening
24 bolts
ø4" 4pcs
WALL THICKNESS = 3/16"
3500 Ø
BIN BOTTOM
1500
SIGHT GLASS
4572 mm
400 (TYP.REF)
FLOOR
SECTION B-B
INFEED OPENING DIMENSIONS
BY CUSTOMER
(19.7")
500
BOLTED MANHOLE D24"
8 bolts
45.0°
TYP.
SECTION D-D
SECTION A-A
50 m3
*) LIFTING LUGS
PRELIMINARY
FOR INFORMATION ONLY
TECHNICAL DATA:
GROSS VOLUME 50 m3
DISCHARGER HELP 40-2
SCREW 1 x 0 500
NOTE LOCATION OF BIN SHELL FIELD WELDS
TO BE DETERMINED
STEAM VENT. ø4"
VENT.12"
17"
19"
12 3/4"
DIA 1"
8 holes
C - C
TYP
STEAM NOZZLES 4pcs
45°
350
1 3 DISCHARGING SCREW
1 2 BOTTOM AND HELP DISCHARGER
1 1 BIN SHELL
KWC 1995-11-02
00
REP
ANDRITZ
PRESTEAMING BIN
CAD A2
SFS
KONE WOOD
NTS
SKRLW102
0
1(1)


4 STIFFENERS
VENT.12"
(11.8") 300
3010
WALL THICKNESS = 3/16"
9490
7800
BOLTED MANHOLE
49 1/4"x 22 1/2" opening
24 bolts
ø4" 4pcs
WALL THICKNESS = 3/16"
BIN BOTTOM
3800
1690
SIGHT GLASS
5300
SECTION B-B
400 (TYP REF)
FLOOR
INFEED OPENING DIMENSIONS BY CUSTOMER
(19.7") 500
BOLTED MANHOLE Ø24"
8 bolts
45.0° TYP.
SECTION D-D
SECTION A-A
70 M³
*) LIFTING LUGS
PRELIMINARY FOR INFORMATION ONLY
TECHNICAL DATA:
GROSS VOLUME 70 m3
NET VOLUME 58 m3
CAPACITY 50-210 m3/hr/screw
DISCHARGER HELP 40-2
SCREW 1 x D 630
NOTE LOCATION OF BIN SHELL FIELD WELDS TO BE DETERMINED
STEAM VENT ø4"
VENT.12"
DIA 1" 8 holes
C - C TYP
STEAM NOZZLES 4pcs
DISCHARGING SCREW 630
BOTTOM AND HELP DISCHARGER
BIN SHELL
KWC 1995-11-02
REP
CAD A2
SFS
NTS
ANDRITZ SPROUT BAUER
PRESTEAMING BIN No.3
SKRLW-B
0
1(1)
00

PROCEDURE TO REMOVE PLUG SCREW FEEDER SCREW:

1. REMOVE COUPLING GUARD AND REDUCER OUTPUT COUPLING SPACER.
2. REMOVE BEARING HOUSING AND DRIVE SHAFT AS ONE UNIT.
3. PULL SCREW AXIALLY OUT TOWARDS DRIVE END.

QUANTITIES ARE FOR ONE UNIT

ASSY OR PT NO & QTY 03	02	01	00	PC NO	DESCRIPTION	PATT NO	MAT'L SPEC	DWG. PT OR PC NO
			X	01	INSTALLATION AND ASS'Y. 20"P.S.F. WITH BASE AND SPOOL HOLDER.			
			1	02	ASS'Y. 20" P.S.F. WITH FEED TABLE			D4390-707-00
			1	03	BASE. 20" PLUG FEEDER			D4429-630-00
			8	04	SCREW.CAP HX HD. 1-1/4-7UNC X 4" LG. GR. 5		STL	WA46168
			4	05	SCREW.CAP HX HD. 1-1/4-7UNC X 4-1/2"LG. GR. 5		STL	WA46173
			8	06	WASHER. FLAT. LARGE. 1-1/4		STL	WA01963
			12	07	WASHER. SPLIT. LOCK. 1-1/4		STL	WA01846
			12	08	NUT. HEX. 1-1/4-7UNC		STL	WA93390
			8	09	PIN. TAPER			A2707-000-00
			8	10	NUT. HEX 3/8-16UNC		SST	WA24944
			3	11	SHIM PACK			B3451-563-00
			1	12	SHIM PACK. (REDUCER)			B3451-563-01
			6	13	SHIM PACK. (BASE)			B3451-565-00
			6	14	NUT. HEX. 2-4.5NC		STL	WA55337
			1	15	COUPLING. HIGH SPEED			A3037-192/02
			1	16	COUPLING. LOW SPEED			A3037-192/03
			1	17	GUARD. COUPLING (OUTPUT SHAFT)			D4367-505-09
			1	18	REDUCER.			A3037-192/01
			6	19	WASHER. SPLIT. LOCK. 2		STL	WA25999
			1	20	GUARD. COUPLING (INPUT SHAFT)			D4367-504-09
			6	21	SCREW.CAP HX HD. 2-4.5NC X 5-3/4" LG. GR. 5		STL	WA98475
			9	22	SCREW.CAP HX HD.. 1/2-13UNC X 1" LG.		STL	WA44552
			9	23	WASHER. SPLIT. LOCK. 1/2		STL	WA01365
			6	24	WASHER. FLAT. 2		STL	WA20663
			4	25	SCREW.CAP HX HD. 1 1/4-7UNC X 5 1/2 LG. GR. 5		STL	WA75773
			1	26	ADAPTER. MOTOR		STL	D4429-306-00

ESTIMATED COMPONENTS WEIGHTS. LB.

SCREW	2900 LB.	(1.315 Kg.)
BEARING ASSEMBLY	6150 LB.	(2.790 Kg.)
TAPERED HOUSING	1935 LB.	(878 Kg.)
INLET HOUSING ASSEMBLY	1900 LB.	(862 Kg.)
REDUCER	5100 LB.	(2.313 Kg.)
MOTOR	3000 LB.	(1.361 Kg.)
BASE	6100 LB.	(2.767 Kg.)

REF. DWG. D4389-509

REV	DESCRIPTION	DATE	BY
D	DCN [illegible]: SEE SHT 2	[illegible]	RDB
C	PER DCN 8380440	[illegible]	ERB
C	ADD IDENTIFIERS		
B	PER DCN 8379913	[illegible]	ERB
B	PC 25 WAS D4429-505-00		
B	PC 17 WAS D4663-505-07		
A	PER DCN 8379494	[illegible]	ERB
A	ADD DIM. SHT. 2		
A	REV. ED. NO.		
3	FINAL RELEASE	[illegible]	ERB
2	PRELIMINARY RELEASE	[illegible]	RCS
1	PRELIMINARY	121797	RDB

ROUGH EST. WEIGHT LBS.
FINISH EST. WEIGHT LBS.

TOLERANCES - UNLESS OTHERWISE NOTED
MACHINING LINEAR .X ± .1" .XX ± .02" .XXX ± .005" ANGLE ± 30'
FABRICATION [illegible]
CAST/FORGE ± [illegible]
MACHINED FILLET RADII .047" ± .016"
MAX MACHINED SURFACE ROUGHNESS 125 / MICROINCHES (AA)

ANDRITZ — ANDRITZ Inc. Muncy, PA., USA

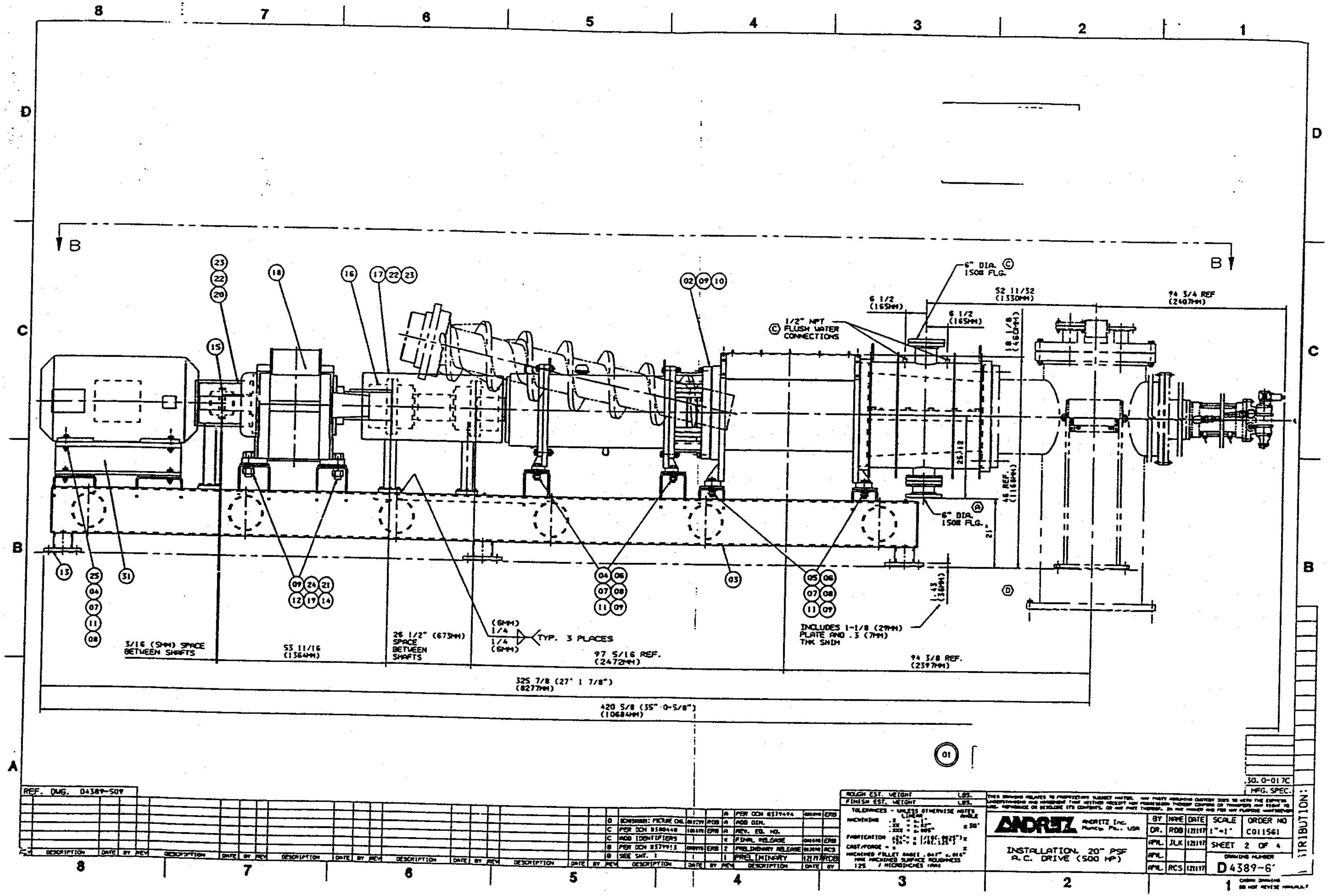
INSTALLATION. 20" PSF
A.C. DRIVE (500 HP)

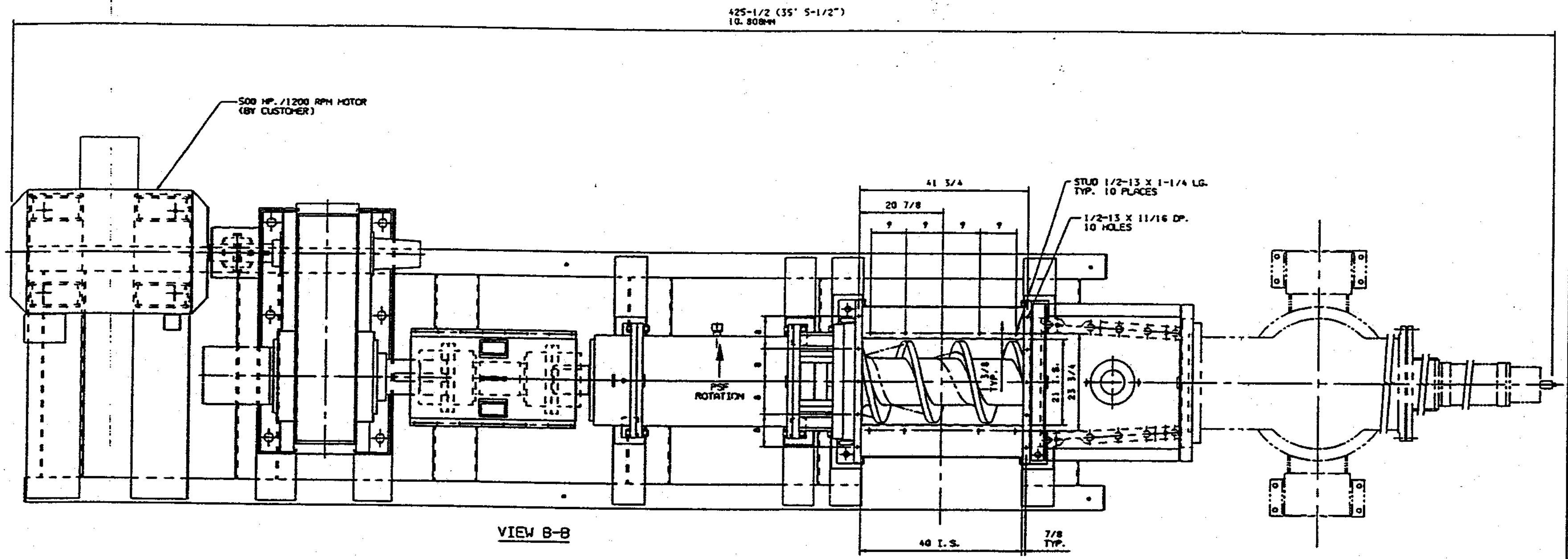
BY	NAME	DATE
DR.	RDB	121197
APVL.	JLX	121197
APVL.		
APVL.	RCS	121797

SCALE 1"=1"
ORDER NO C011561
SHEET 1 OF 4
DRAWING NUMBER D4389-6

30. 0-017C
MFG. SPEC.
DISTRIBUTION:

CADAM DRAWING DO NOT REVISE MANUALLY


B
6" DIA. 150# FLG.
1/2" NPT FLUSH WATER CONNECTIONS
6 1/2 (165MM)
52 11/32 (1330MM)
94 3/4 REF (2407MM)
18 1/8 (460MM)
46 REF. (1168MM)
25 1/2
21"
1.43 (36MM)
INCLUDES 1-1/8 (29MM) PLATE AND .3 (7MM) THK SHIM
3/16 (5MM) SPACE BETWEEN SHAFTS
53 11/16 (1364MM)
26 1/2" (673MM) SPACE BETWEEN SHAFTS
(6MM) 1/4
1/4 (6MM)
TYP. 3 PLACES
97 5/16 REF. (2472MM)
94 3/8 REF. (2397MM)
325 7/8 (27' 1 7/8") (8277MM)
420 5/8 (35' 0-5/8") (10684MM)
REF. DWG. D4389-509
ROUGH EST. WEIGHT LBS.
FINISH EST. WEIGHT LBS.
TOLERANCES - UNLESS OTHERWISE NOTED
ANDRITZ
ANDRITZ Inc. Muncy, Pa., USA
INSTALLATION, 20" PSF
A.C. DRIVE (500 HP)
BY NAME DATE
DR. RDB
APVL. JLK
APVL. RCS
SCALE 1"=1'
ORDER NO C011561
SHEET 2 OF 4
DRAWING NUMBER
D 4389-6'
30.0-017C
MFG. SPEC.
DISTRIBUTION:
PER DCN 8579494
ADD DIM.
REV. EQ. NO.
FINAL RELEASE
PRELIMINARY RELEASE
PRELIMINARY
PER DCN 8580448
ADD IDENTIFIERS
PER DCN 8579915
SEE SHT. 1
DESCRIPTION DATE BY REV



VIEW B-B

REF. DWG. D4389-509

REV	DESCRIPTION	DATE	BY
D	SCHEMATIC:SEE SHT		RDB
C	PER DCN 3580448		ERB
C	ADD IDENTIFIERS		
B	PER DCN 3579913		ERB
B	SEE SHT. 1		

REV	DESCRIPTION	DATE	BY
A	PER DCN 3579496		ERB
A	ADD DIM. SHT. 2		
A	REV. EQ. NO.		
3	FINAL RELEASE		ERB
2	PRELIMINARY RELEASE		ACS
1	PRELIMINARY	121797	RCB

ROUGH EST. WEIGHT LBS.
FINISH EST. WEIGHT LBS.

TOLERANCES - UNLESS OTHERWISE NOTED

ANDRITZ Inc.
Muncy, Pa., USA

INSTALLATION, 20" PSF
A.C. DRIVE (500 HP)

BY	NAME	DATE	SCALE	ORDER NO
DR.	RDB	121197	1"=1'	C011561
APPL.	JLK	121197	SHEET 3 OF 4	
APPL.			DRAWING NUMBER	
APPL.	RCS	121797	D 4389-6	

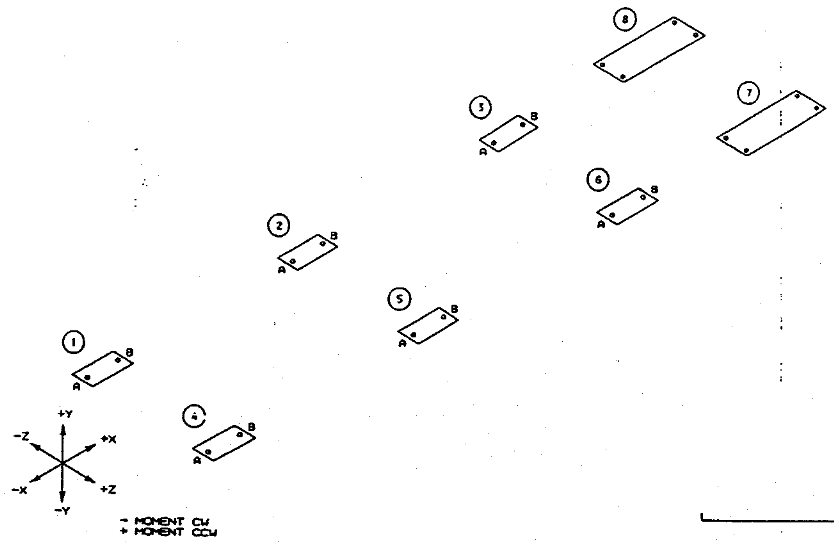
30.0-017C
MFG. SPEC.
DISTRIBUTION:

FOOT PRINT REACTIONS

LOCATION	
1	4484# (19.9kN.)
2	8130# (36.2kN.)
3	4017# (17.9kN.)
4	1677# (7.5kN.)
5	5862# (26.1kN.)
6	3185# (14.2kN.)
7	6000# (26.7kN.)
8	6000# (26.7kN.)

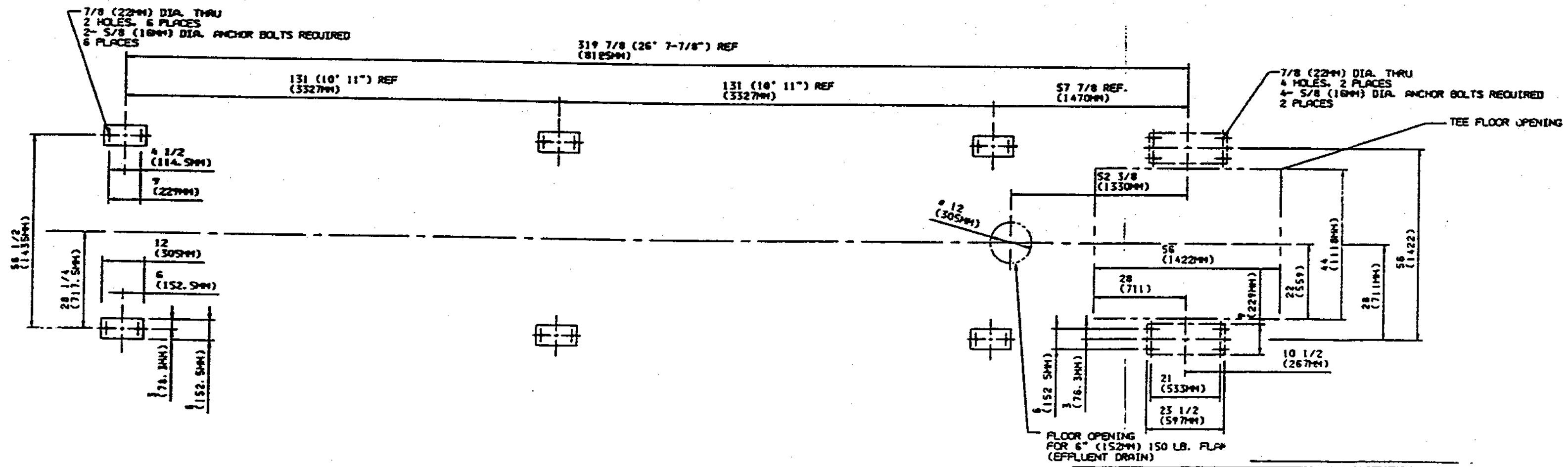
LOADING NOTES:

1. FORCE NOTES ARE IN LBS. (kN)
2. MOMENT LOADS ARE IN FT. LBS. (N-M)
3. ALL LOADS DO NOT OCCUR SIMULTANEOUSLY
4. ANCHOR BOLT LOADS FOR LOCATIONS 7 & 8 ARE PER BOLT.



ANCHOR BOLT LOADINGS

LOCATION		TENSILE	SHEAR
1	A	2230 (9.9kN.)	2749 (12.2kN.)
	B	2230 (9.9kN.)	2749 (12.2kN.)
2	A	2230 (9.9kN.)	2749 (12.2kN.)
	B	2230 (9.9kN.)	2749 (12.2kN.)
3	A	2230 (9.9kN.)	2749 (12.2kN.)
	B	2230 (9.9kN.)	2749 (12.2kN.)
4	A	2230 (9.9kN.)	2749 (12.2kN.)
	B	2230 (9.9kN.)	2749 (12.2kN.)
5	A	2230 (9.9kN.)	2749 (12.2kN.)
	B	2230 (9.9kN.)	2749 (12.2kN.)
6	A	2230 (9.9kN.)	2749 (12.2kN.)
	B	2230 (9.9kN.)	2749 (12.2kN.)
7		1526 (6.8kN.)	1000 (4.4kN.)
8		1526 (6.8kN.)	1000 (4.4kN.)



30.0-017C

MFG. SPEC.

REF. DWG. D4389-S09

REV	DESCRIPTION	DATE	BY	REV	DESCRIPTION	DATE	BY
				A	PER DCN 3379494	[illegible]	ERB
D	DCN#380821: SEE SHT 2	[illegible]	RDB	A	ADD DIM. SHT. 2		
C	PER DCN #380448	[illegible]	ERB	A	REV. EQ. NO.		
C	ADD IDENTIFIERS			3	FINAL RELEASE	[illegible]	ERB
B	PER DCN 3379915	[illegible]	ERB	2	PRELIMINARY RELEASE	[illegible]	RCS
B	SEE SHT. 1			1	PRELIMINARY	121797	RDB

ROUGH EST. WEIGHT LBS.

FINISH EST. WEIGHT LBS.

TOLERANCES - UNLESS OTHERWISE NOTED

MACHINING — LINEAR: .X ± .1", .XX ± .02", .XXX ± .005" — ANGLE ± 30'

FABRICATION <24" ± 1/16(.0625"), >24" ± 1/8(.125")

CAST/FORGE ±

MACHINED FILLET RADII .047" ±.016" MAX

MACHINED SURFACE ROUGHNESS 125 / MICROINCHES (RMS)

ANDRITZ — ANDRITZ Inc. Muncy, Pa., USA

INSTALLATION, 20" PSF A.C. DRIVE (500 HP)

BY	NAME	DATE
DR.	RDB	121197
APVL.	JLK	121197
APVL.		
APVL.	RCS	121797

SCALE 1"=1'

ORDER NO C011561

SHEET 4 OF 4

DRAWING NUMBER D4389-6

CADAM DRAWING DO NOT REVISE MANUALLY

TRIBUTION:

ASSEMBLY NOTES:

1. AT ASSEMBLY USE DANGER PLATES PCS. 06 & 07 AS TEMPLATES TO LOCATE (8) .104 DIA. HOLES (DRILL #37) FOR DRIVE SCREWS PC. 08.
2. AT ASSEMBLY USE NAME PLATE PC. 07 AS A TEMPLATE TO LOCATE (2) .25 DIA. HOLES FOR ROUND HEAD SLOTTED MACHINE SCREWS PC. 10.
3. BAG AND ATTACH ALL LOOSE PIECES TO TEE FOR SHIPPING.

INSTALLATION NOTES:

1. ADJUST BLOW BACK VALVE FLANGE TO PROPERTY SEAT CONE IN SPOOL.

QUANTITIES ARE FOR ONE UNIT

ASSY OR PT NO & QTY 03	02	01	00	PC NO	DESCRIPTION	PATT NO	MATL SPEC	DWG. PT OR PC NO
			X	01	ASSEMBLY. INLET TEE WITH SUPPORT FEET			
					31-1/2" I.D.. 20" P.S.F. ASME SA240-(316LSST)		316LSST	
		X		02	RECOMMENDED SPARE PARTS			
			1	03	TEE. 31-1/2" I.D. WITH SUPPORT FEET BRACKETS			
					(PURCHASE FINISHED) ASME SA240-(316LSST)		316LSST	D4834-833/01
		1	1	04	SPOOL. B.B.V. ASME SA351 GRADE CF3M			C4453-514/02
			1	05	ASSY. BLOW BACK VALVE WITH 10 X 30 AIR CYL.			
					ASME SA240-(316LSST)		316LSST	D4391-630-00
			2	06	PLATE. DANGER			B2735-056/01
			8	07	SCREW DRIVE #6 X 5/16" LG.		STL	WA08306
			1	08	PLATE. NAME		ZINC	C4000-276/05
			2	09	SCREW. MACH.. RD. HD. SLOT. #10-24 NC X 5/8"LG.		18-8SST	WA66872
			2	10	NUT. HEX. FIN. #10-24 NC		18-8SST	WA38347
			2	11	FOOT. SUPPORT	HRS	28.0-063	D3935-014-01
			2	12	BRACKET. SUPPORT	HRS	28.0-063	C4171-101-00
			2	13	SHAFT. SUPPORT	HRS	28.0-065	C3898-003/01
			4	14	BEARING. SELF LUBRICATED D.U. GARLOCK			
					NO. 64DU64			WA82443
			4	15	NUT. HEX. 1-1/4-7UNC		STL	WA01322
			4	16	WASHER. FLAT SPECIAL		STL	A2833-704/01
			4	17	PIN. COTTER. 3/16 X 3"LG.		STL	WA21290
			8	18	SCREW. CAP SOC HD. 7/8-9UNC X 2-1/2 LG GR. 5		STL	WA23746
			8	19	WASHER. LOCK SPLIT. 7/8		STL	WA01351
			8	20	NUT. HEX. 7/8-9UNC		STL	WA01316
			12	21	STUD. 1-1/8-8UNC LENGTH BY MANUFACTURER SA193-B7		STL	
			12	22	WASHER. LOCK SPLIT. 1-1/8		STL	WA20877
			24	23	NUT. HEX. 1-1/8-8NC SA194-2H		STL	WA24950
			36	24	STUD. 7/8-9 UNC X 6 1/2 LG.		SA193-B7	WA46132
			72	25	NUT. HEX. 7/8-9 UNC		SA194-2H	WA45164
			1	26	GASKET. 35-7/8 I.D. X 37-3/8 O.D DURLON #500			B3451-516/01

(PURCHASE COMPLETE)

DESIGN DATA

DESIGN AND BUILD TO LATEST EDITION OF ASME BOILER AND PRESSURE VESSEL CODE. SECTION VIII. DIVISION 1. CODE STAMPED. MUST ALSO MEET ALL LOCAL CODES AND REQUIREMENTS AT INSTALLATION SITE.

HE

REF. DWG. D4834-632

REV	DESCRIPTION	DATE	BY	REV	DESCRIPTION	DATE	BY
				B	REV. TAG NO.S		ERG
				A	PER DCN #379522		ERG
C	PER DCN #386096		RCB	A	REV. BD. LOC. NO'S.		
C	PC. 05 WAS D4391-628		RCB	3	FINAL RELEASE		ERG
C	ADD PC. 26		RCB	2	PRELIMINARY RELEASE		RCS
B	PER DCN #380406		ERG	1	PRELIMINARY RELEASE		MHM

ROUGH EST. WEIGHT LBS.
FINISH EST. WEIGHT LBS.

TOLERANCES - UNLESS OTHERWISE NOTED
LINEAR ANGLE
MACHINING ±30°
FABRICATION
CAST/FORGE
MACHINED FILLET RADII
125 / MICROINCHES (AA)

ANDRITZ — ANDRITZ Inc. Muncy, Pa., USA

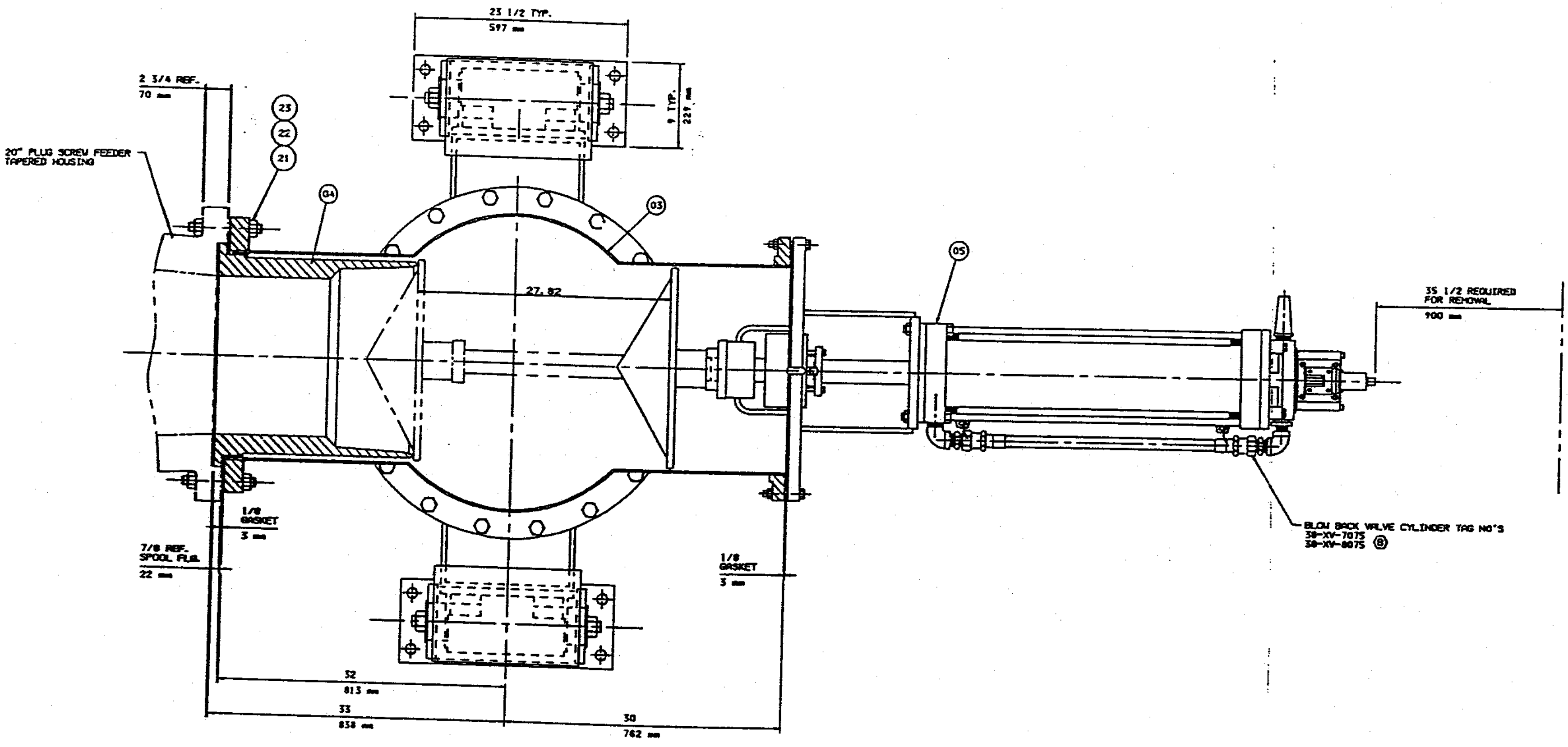
ASSEMBLY. INLET TEE
31-1/2 I.D.. W/ SUPPORT FEET
20" PLUG SCREW FEEDER

BY	NAME	DATE	SCALE	ORDER NO
DR.	MHM		NTS	C011561
APVL.			SHEET 1 OF 3	
APVL.	CKB		DRAWING NUMBER	
APVL.	RCS		D 4834-63	

MFG. SPEC.

TRIBUTION:

CADD DRAWING DO NOT REVISE MANUALLY



SECTION A-A

ASSEMBLY, INLET TEE 31-1/2" I.D. WITH FOOT SUPPORT FOR 20" PLUG SCREW FEEDER.

REF. DWG. D4834-632

REV	DESCRIPTION	DATE	BY	REV	DESCRIPTION	DATE	BY
				B	REV. TAG NO. 3	[illegible]	ERB
				A	PER DCN 8379522	[illegible]	ERB
				A	REV. BD. LOC. NO'S.		
C	PER DCN 8381096	[illegible]	RDB	3	FINAL RELEASE	[illegible]	ERB
C	SEE SHT 1 & 3	[illegible]	RDB	2	PRELIMINARY RELEASE	[illegible]	RCS
B	PER DCN 8380408	[illegible]	ERB	1	PRELIMINARY RELEASE	[illegible]	MHM

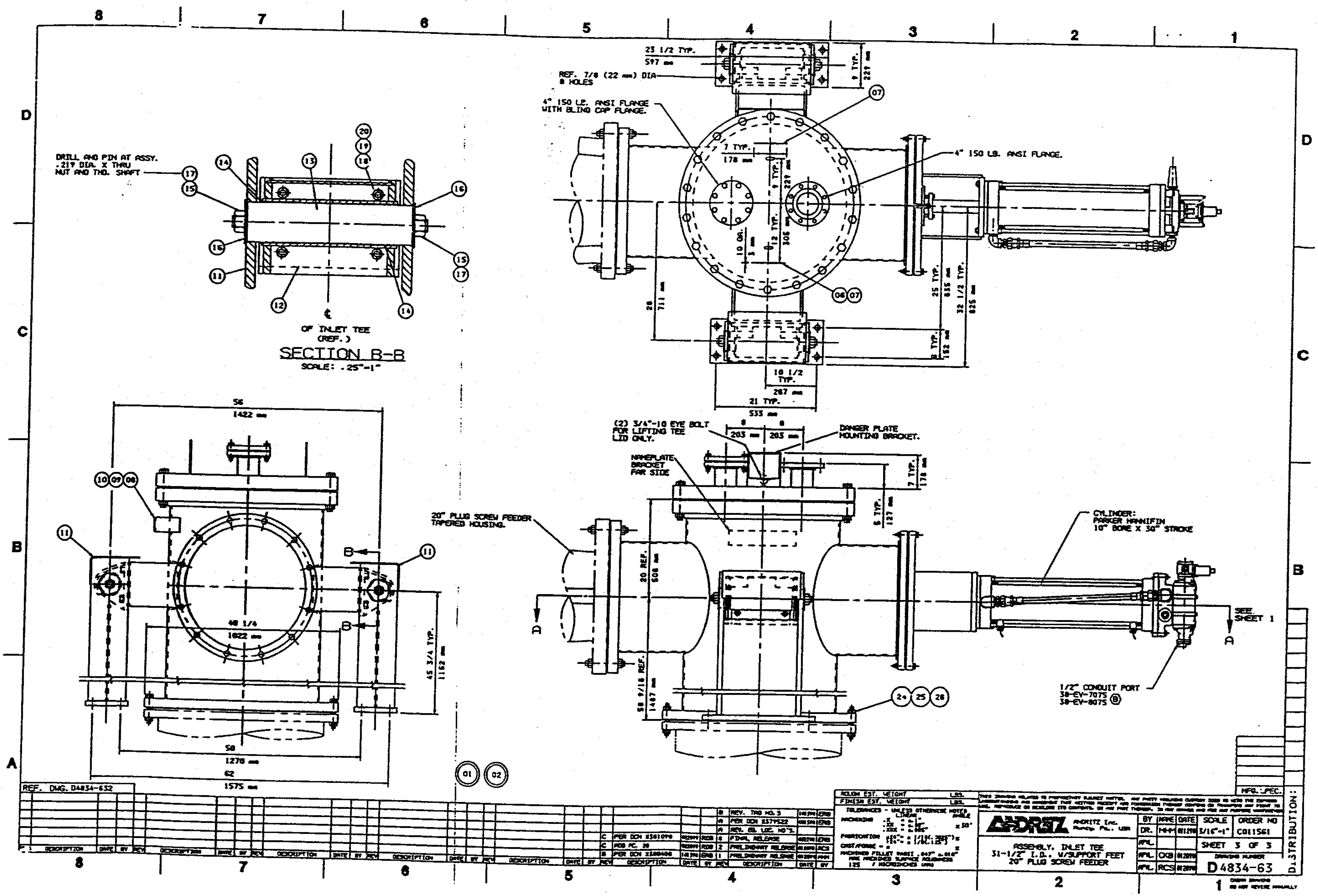
ROUGH EST. WEIGHT LBS.
FINISH EST. WEIGHT LBS.
TOLERANCES - UNLESS OTHERWISE NOTED

ANDRITZ Inc. Muncy, Pa., USA

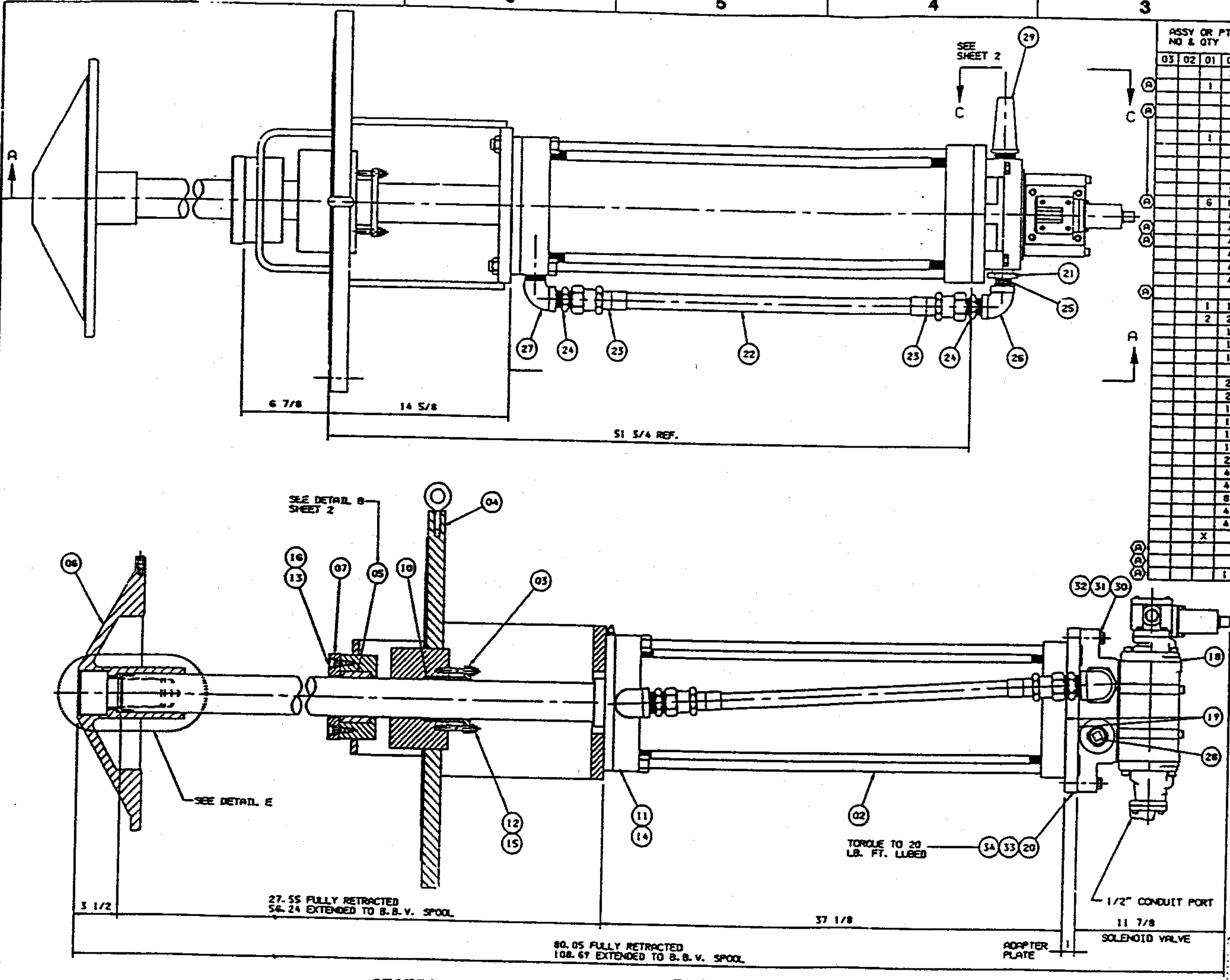
ASSEMBLY, INLET TEE
31-1/2 I.D. W/ SUPPORT FEET
20" PLUG SCREW FEEDER

BY	NAME	DATE
DR.	MHM	[illegible]
APPL.		
APPL.	CKB	[illegible]
APPL.	RCS	[illegible]

SCALE NTS
ORDER NO C011561
SHEET 2 OF 3
MFG. SPEC.
DRAWING NUMBER D 4834-63



23 1/2 TYP.
597 mm
REF. 7/8 (22 mm) DIA. 8 HOLES
4" 150 LB. ANSI FLANGE WITH BLIND CAP FLANGE.
4" 150 LB. ANSI FLANGE.
7 TYP.
178 mm
9 TYP.
229 mm
12 TYP.
306 mm
10 GA.
3 mm
28
711 mm
25 TYP.
635 mm
32 1/2 TYP.
825 mm
6 TYP.
152 mm
10 1/2 TYP.
267 mm
21 TYP.
533 mm
DRILL AND PIN AT ASSY. .219 DIA. X THRU NUT AND THD. SHAFT
OF INLET TEE (REF.)
SECTION B-B
SCALE: .25"=1"
56
1422 mm
48 1/4
1022 mm
45 3/4 TYP.
1162 mm
50
1270 mm
62
1575 mm
(2) 3/4"-10 EYE BOLT FOR LIFTING TEE LID ONLY.
DANGER PLATE MOUNTING BRACKET.
NAMEPLATE BRACKET FAR SIDE
8
203 mm
7 TYP.
178 mm
5 TYP.
127 mm
20" PLUG SCREW FEEDER TAPERED HOUSING.
20 REF.
508 mm
58 9/16 REF.
1487 mm
CYLINDER: PARKER HANNIFIN 10" BORE X 30" STROKE
SEE SHEET 1
1/2" CONDUIT PORT 38-EV-7075 38-EV-8075
REF. DWG. D4834-632
PER DCN 8361096
PER DCN 8379522
FINAL RELEASE
PRELIMINARY RELEASE
DESCRIPTION DATE BY REV
ROUGH EST. WEIGHT LBS.
FINISH EST. WEIGHT LBS.
TOLERANCES - UNLESS OTHERWISE NOTED
ANDRITZ
ANDRITZ Inc. Muncy, Pa. USA
ASSEMBLY, INLET TEE
31-1/2" I.D. W/SUPPORT FEET
20" PLUG SCREW FEEDER
SCALE 3/16"=1"
ORDER NO C011561
SHEET 3 OF 3
DRAWING NUMBER
D 4834-63
MFG. SPEC.
DISTRIBUTION:



SECTION A-A

QUANTITIES ARE FOR ONE UNIT

ASSY OR PT NO & QTY 03	02	01	00	PC NO	DESCRIPTION	PATT NO	MATL SPEC	DWG. PT OR PC NO
			X	01	ASSY., B.B.V. 10 X 30 ASME SA240-(316LSST)		28.0-041	
		1	1	02	CYLINDER, AIR 10" DIA. BORE X 30" STROKE			
					3" DIA. ROD			C3046-037/01
			1	03	FOLLOWER, PACKING ASME SA351 GR. CF3M		28.0-019	B3037-011-01
			1	04	HOUSING, BLOW BACK VALVE ASME SA240-(316LSST)		28.0-041	D4391-631/01
		1	1	05	BUSHING, GRAGH ALLOY			B4117-618/01
			1	06	DISC, CONE 120° ASME SA351 GRADE CF3M		28.0-019	B3001-515/01
			1	07	COVER, BUSHING ASME SA240-(316LSST)		28.0-041	B4117-619/01
				08				
			1	09	INSERT		28.0-063	B3001-516/01
		6	6	10	PACKING, 1/4" SQ.			WA97231
			4	11	SCREW, CAP HEX HD. 5/8-11UNC X 5" LG. GR. 5		STL	WA45620
			4	12	STUD, 3/8-16 UNC X 3 LG.		SST	WA50187
			4	13	SCREW, CAP SOC. HD. 3/8-16UNC X 1"LG.		316SST	WA55265
			4	14	NUT, HEX 5/8-11UNC		STL	WA24948
			4	15	NUT, HEX. 3/8-16 UNC	18-8	SST	WA34977
			4	16	WASHER, 3/8 LOCK ASME SA240-(316SST)		316SST	WA46505
				17				
		1	1	18	VALVE, MODIFIED SOLENOID			B4117-614-01
		2	2	19	SEAL, O-RING .139 SECT. X 1-7/8 I.D. 2-225 BUNA-N			WA26568
			1	20	PLATE, CYLINDER/SOLENOID ADAPTER	HRS	28.0-063	B4117-613/01
			1	21	BUSHING, REDUCER, 1-1/4 NPT X 1 NPT		304SST	WA44278
			1	22	HOSE, .88 I.D. X 1.23 O.D. X 5'-6" LG. AEROQUIP			
					FC350-16 (CUT LENGTH TO SUIT), ELASTOMER TUBE			
			2	23	FITTINGS, HOSE S.A.E. 37°(J.I.C.) SWIVEL AERO 251-4411-16		SST	WA82427
			2	24	FITTING, ADAPTER, AEROQUIP 2021-16-16-C		SST	WA43448
			1	25	NIPPLE, PIPE, 1" NPT, SCH. 40 X 2"LG.		304SST	WA45071
			1	26	ELBOW, 90° 1"-11-1/2 NPT		304SST	WA17288
			1	27	ELBOW, 90° STREET, 1"-11-1/2 NPT		304SST	WA44575
			1	28	PLUG, PIPE, 1-1/4" NPT, RAISED HD.		304SST	WA45298
			2	29	MUFFLER, PNEUMATIC EXHAUST, 1-1/4" NPT, ARROW ASP-10		BRONZE	WA87901
			4	30	SCREW, CAP HEX HD. 1/2-13 UNC X 2-1/2"LG. GR. 5		STL	WA45611
			4	31	WASHER, LOCK, 1/2		STL	WA01365
			8	32	WASHER, FLAT, 1/2		STL	WA01349
			4	33	SCREW, CAP HEX HD. 3/8-16 UNC X 1-1/4"LG. GR. 5		STL	WA43495
			4	34	WASHER, LOCK, 3/8		STL	WA01363
		X		35	RECOMMENED SPARE PARTS			
				36				
				37				
			1	38	SCREW, HEX SOC HD. 2 1/4-12 UN X 4 1/2 LG., L.H. THD.		SST	B4117-330/01

DESIGN DATA:

DESIGN AND BUILD TO LATEST EDITION OF ASME BOILER AND PRESSURE VESSEL CODE, SECTION VIII, DIVISION 1, CODE STAMPED. MUST ALSO MEET ALL LOCAL CODES AND REQUIREMENTS AT INSTALLATION SITE.

REF. DWG. D4391-628

01 35

REV	DESCRIPTION	DATE	BY
A	PC 10 WAS [illegible]	[illegible]	[illegible]
A	PC 12 WAS [illegible]	[illegible]	[illegible]
A	PC 13 WAS [illegible]	[illegible]	[illegible]
A	ADD PC 38:	[illegible]	[illegible]
A	REMOVE NOTE 4:	[illegible]	[illegible]
A	ADD NOTE 5:	[illegible]	[illegible]
A	SEE DCR [illegible]	[illegible]	[illegible]
3	FINAL RELEASE	[illegible]	ERB
2	PRELIMINARY RELEASE	[illegible]	PCS
1	PRELIMINARY RELEASE	[illegible]	[illegible]

ROUGH EST. WEIGHT LBS.
FINISH EST. WEIGHT 254 LBS.

TOLERANCES - UNLESS OTHERWISE NOTED
MACHINING: LINEAR .X, .XX, .XXX; ANGLE ±30'
FABRICATION
CAST/FORGE
MACHINED FILLET RADII .047" ±.016"
MAX MACHINED SURFACE ROUGHNESS 125 / MICROINCHES (AA)

ANDRITZ Inc.
Muncy, PA., USA

ASSY., 10 X 30 BLOW BACK VALVE, 31-1/2" I.D. TEE (REF. 20" P.S.F.)

BY	NAME	DATE
DR.	MHH	081298
APVL.		
APVL.	CXB	081298
APVL.	RCS	081298

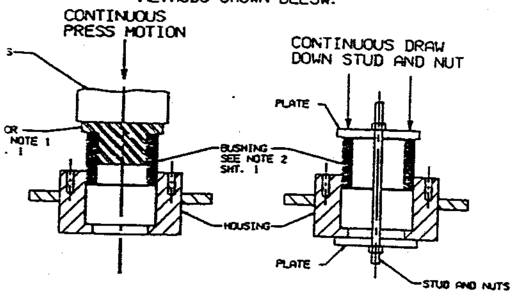
SCALE 1/4"=1"
ORDER NO C011561
SHEET 1 OF 2
DRAWING NUMBER: D4391-6

30.0-017C
MFG. SPEC.
DISTRIBUTION:

CADAM DRAWING
DO NOT REVISE MANUALLY

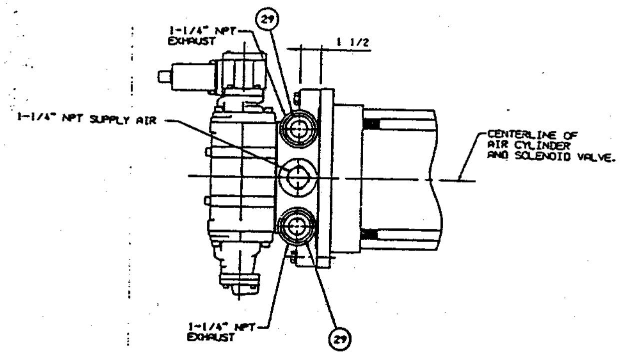
INSTALLATION INSTRUCTIONS FOR BUSHING PC. 05.

INSTALL BUSHING BY ONE OF TWO METHODS SHOWN BELOW.

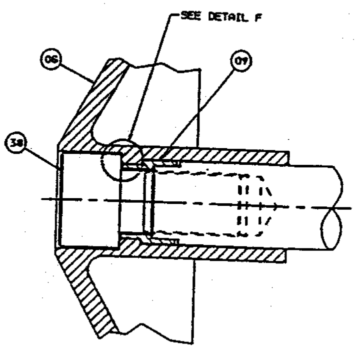


DETAIL B

SCALE: 3/8"=1"



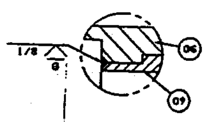
VIEW C-C



DETAIL E

SCALE: 1/2"=1"

Ⓐ



DETAIL F

SCALE: 1"=1"

Ⓐ

REV	DESCRIPTION	DATE	BY
A	ADD DET'S. E & F:	071498	MHH
A	REMOVE DET. D:	071498	MHH
A	SEE DCR 8579771	071498	MHH
2	FINAL RELEASE	082798	ERB
2	PRELIMINARY RELEASE	012098	RCS
1	PRELIMINARY RELEASE	012098	MHH

ROUGH EST. WEIGHT LBS.

FINISH EST. WEIGHT 1254 LBS.

TOLERANCES - UNLESS OTHERWISE NOTED

ANDRITZ Inc. Muncy, Pa., USA

ASSY., 10 X 30 BLOW BACK VALVE, 31-1/2" I.D. TEE (REF. 20" P.S.F.)

BY	NAME	DATE	SCALE	ORDER NO
DR.	MHH	011298	1/4"=1"	C011561
APPL.			SHEET 2 OF 2	
APPL.	CKB	012098	DRAWING NUMBER	
APPL.	RCS	012098	D 4391-6	

30. 0-017C

MFG. SPEC.

DISTRIBUTION:

APPENDIX F
ANCO-EAGLIN EQUIPMENT LIST AND DRAWINGS

IN PDF ONLY