**NEW INDUSTRIAL HEAT PUMP APPLICATIONS TO A SYNTHETIC
RUBBER PLANT**

PHASE IIA

FINAL REPORT

1993

WORK PERFORMED UNDER CONTRACT No. FC07-91ID13052

**FOR
U. S DEPARTMENT OF ENERGY
OFFICE OF INDUSTRIAL TECHNOLOGIES
WASHINGTON, D.C.**

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**BY
TENSA Services, Inc.
Houston, Texas**

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Section 1

SUMMARY

This report summarizes the results of the Phase IIA of the DOE sponsored study, Contract Number DE-FC07-91ID13052, titled "Advanced Industrial Heat Pump Application and Evaluation." In this phase, detailed process design and a detailed cost estimate for the installation of a heat pump were developed.

Three energy conservation retrofit options were identified during Phase I of this study. The first option was a passive heat integration scheme that requires additional process to process interchanger area between the product stream and the reactor feed stream. The economics for this option are:

HEAT EXCHANGE

Hot Utility saved:	5.0 MMBtu/hr
Percent Reduction:	2.9% of the entire plant
Investment:	\$494,200
Total savings:	\$143,241/yr.
Payback period:	3.5 yrs.

Since in Phase I of the project, extensive work was performed on this aspect and the host site was furnished sufficient details of the heat integration option, the task of pursuing this aspect further was left to the host site.

HEAT PUMP

The second option is a semi-open cycle heat pump. There are two potential applications identified in this plant. The first heat pump would condense the toluene flash overhead vapor against boiler feed water to generate low pressure (atmospheric) steam. This steam would be compressed in a steam compressor to be used in the strippers. This heat pump would save 13,908 lbs/hr of steam.

HEAT PUMP 1:

Hot Utility saved	13,908 (lbs/hr)
Percent Reduction:	8.18% of total refinery
Investment:	\$306,970
Net savings:	\$165,262/yr
Payback period:	1.8 years

The second heat pump would compress the stripper overhead vapors, composed of steam and toluene, and condense it in a kettle type heat exchanger against boiler feed water to generate steam at a pressure between 22.7 and 27 psia.

HEAT PUMP 2:

Hot Utility saved:	74,039 (lbs/hr)
Percent Reduction:	43.5%
Investment:	\$1,092,315
Net savings:	\$567,370/yr
Payback period:	1.9 years

Because of the reduction in fossil fuel combustion, the proposed heat pump would also provide environmental emission improvement by reducing the emission of NO_x, SO_x and CO₂. No economic credit has been taken for this additional benefit.

Section 2

INTRODUCTION

The economic feasibility of heat integration and heat pump opportunity were evaluated in Phase I of this study. The results of Phase I are published in the Department of Energy (DOE) Report DOE/ID/12791-1.

The scope of this phase of the study was to finalize the process design of the heat pump scheme, develop a process and instrumentation diagram (P&ID), and a detailed cost estimate for the project. This information is essential for the site management to evaluate the economic viability and operability of the proposed heat pump design, prior to the next phase of installation and testing.

A number of modifications to the plant occurred after the completion of Phase I study. One of the major modifications was in the design of the heat pump itself. In Phase I it was proposed that for heat pump application #1, the toluene flash column overhead vapor would first be compressed in a compressor, and then condensed at a higher pressure against boiler feed water to generate steam at the required pressure and temperature. In Phase II of the project, a detailed computer simulation of the toluene flash column overhead vapor was performed and it was discovered that the presence of about 3% butadiene in the overhead vapor altered the condensing curve significantly. Instead of condensing over a 10-15 (°F) range, the vapor was now condensing over a 60 (°F) range. In order to reduce the total investment on the project due to higher temperature lift, the design of the heat pump was changed to first condense the vapor to generate low pressure steam. The steam would then be compressed in a steam compressor, which costs significantly less than a hydrocarbon compressor.

The main lesson learned during this phase of the project is that it is necessary to obtain good plant data before the compressor and heat exchangers can be sized correctly, and an accurate economic evaluation can be performed. Another valuable lesson that is learned from this project was that wherever possible, a steam compressor should be used instead of a hydrocarbon compressor. This would in most cases, bring down the cost of the project.

Section 3

PROCESS DESCRIPTION

The site selected for the evaluation is American Synthetic Rubber Corporation's (ASRC) polybutadiene plant at Louisville, Kentucky. There are many processes at the Louisville plant, however, the scope of this study was confined to the portion described in this section, as per the agreement between TENSA and ASRC.

The process involves a solution polymerization of butadiene monomer in the presence of toluene, which acts as a solvent. Fresh butadiene, after being preheated to 120°F through a series of heaters (E-1 and E-2) is dried in a butadiene column (C-1) (Figure 3-1). The column has a steam heated reboiler (E-3). The dried butadiene monomer is pumped through a water cooler (E-5) to cool butadiene to 74°F. It is then mixed with dry toluene and the mixture is further cooled to 27°F by passing it through an exchanger (E-16) which uses ammonia refrigerant. This is then fed to the polymerization reactor. Since the polymerization reaction is exothermic, the reactor is cooled between the stages by using ammonia refrigerant to maintain the temperature. The effluent from the reactor containing polybutadiene, toluene, and unpolymerized butadiene monomer is fed into a series of preheaters in the concentration section, where the product is heated in stages to remove the toluene. The viscous mass is preheated from 158°F to 305°F in the primary flash preheaters (E-18) before passing to a flash drum (D-25). The overhead vapors from the flash drum containing unpolymerized butadiene monomer and toluene, combine with the overhead vapors from the subsequent stages of the concentration process. The liquid containing polybutadiene, butadiene monomer, and toluene after getting heated in secondary flash preheater (E19), flashes in drum (D-26). It then passes through the tertiary flash preheaters (E20), before flowing into the tertiary flash drum (D-27). The overhead vapors from the three stages are collected and cooled in a flash overhead condenser (E-21). The liquid, which is about 10% polymer solution in toluene, is blended in tank (T-5). The solution then splits into two trains in the stripping section. High pressure steam (HPS) is injected into the stripping section. The overhead vapors from the stripping section, composed mostly of steam and toluene, are condensed in the stripper condensers (E23 A and B), and then collected in a decanter, where toluene is separated from the water.

FIGURE 3-1A: A S R C: POLYBUTADIENE PROCESS FLOW DIAGRAM
Polymerization and Concentration Sections

FIGURE 3-1 B: A S R C : POLYBUTADIENE PROCESS FLOW DIAGRAM
Stripping Section

FIGURE 3-1 C: A S R C : POLYBUTADIENE PROCESS FLOW DIAGRAM
Drying Section

Wet toluene is sent to the toluene drying section, where it is preheated using toluene column feed bottoms interchanger (E-8), and toluene column feed preheater (E-9), before it passes into the drying column (C-2). This column is reboiled with high pressure steam (E-10). The bottoms from this column, which are dry toluene, are sent through the interchanger (E-8) and then through a dry toluene cooler (E-15) before passing to the storage tank. The overhead vapor from the column is cooled in toluene condensers (E-11 and E-12). The liquid condensate is recycled back to the drying column, while the overhead vapor containing mostly reject butadiene is further cooled in the reject butadiene partial condensers (E-13 and E-14) and then collected in an overhead tank.

The liquid product from the strippers, which is mostly polybutadiene (known as "crumb") is filtered and dried as the final product.

In the proposed modification, the first heat pump will utilize the toluene flash overhead vapors before it flows to (E-21), and condense these vapors by exchanging heat with boiler feed water to generate low pressure steam. In the second heat pump, the overhead vapors from the strippers will be compressed and condensed against boiler feed water to generate steam.

Section 4

HEAT PUMP DESIGN

Design of Heat Pump 1:

One of the major modifications in the entire project over Phase I, was the design of the first heat pump. In the Phase I design, toluene flash overhead vapors were first compressed to a higher pressure, and then condensed against boiler feed water to generate steam at the required pressure. This was because in Phase I of the study, the overhead vapors were assumed to be pure toluene, for which the condensing curve was sharp (10-15°F). However, when the simulations were run for a stream containing 3.4% butadiene and 96.6% toluene, it was found that the vapors condensed over a fairly wide range of temperature 60°F, as shown in Figure 4-1. This increased the size of the heat exchanger to recover the same amount of heat. In addition, the cost of the compressor for hydrocarbons is about 1.5 to 2 times the cost of a steam compressor. In Phase II of the project, the configuration of the heat pump was changed. The toluene flash overhead vapors were first condensed against boiler feed water to generate low pressure steam. This steam was then compressed in a roots blower to the final pressure of 30 psia. By switching to the configuration in Figure 4-2, the following benefits were realized:

- Since the cost of a steam compressor is significantly lower than the cost of a compressor that handles hydrocarbons, the investment on the heat pump is significantly reduced.
- Any fouling that would have taken place in the compressor and the knock-out drum, would now occur in the heat exchanger, thus protecting the life of the compressor.
- Rotary blowers are very inexpensive for low pressure and low head service.

The key features of the compressor are shown in Table 5-3.

Design of Heat Pump 2:

In this case, the stripper overhead vapor was first compressed and then condensed against boiler feed water to generate steam. This steam would then be used in the stripper. The possibility of first condensing the (steam-toluene) vapor against boiler feed water in an exchanger to generate low pressure steam and then compressing the steam to desired pressure was examined. However, this option was discarded because of the low condensing temperature (212°F) of the steam-toluene vapor. Another problem that was examined was the "crumb" problem. The stripper overhead vapors contain little particles of polybutadiene that condense on the walls of the air cooler and form a thick lining. These particles are called "crumb" and they have to be cleaned periodically. If this vapor were to be sent to the compressor without filtering out the "crumb", then these particles would damage it. Therefore, in order to protect the compressor, modifications were proposed to the existing setup. The existing setup has two lines, each with a basket strainer. At the present flow rates, the basket strainers are inadequate, since the crumb particles are able to get past the strainers into the air coolers (E23A and B). In the present mode of operation, the pressure drop across the strainers is monitored and if it exceeds 3-5 psi, the flow is diverted through the other basket strainer, while the other strainer is cleaned using a water-jet.

Several vendors were contacted and the problem was discussed with them. One of the solutions involved retrofitting the basket strainers with Chevron Demister® pads. In addition, one of the vendors suggested that reducing the velocity through the basket strainers would help prevent entrainment of crumb particles. The smaller particles would then be removed in the basket strainers. In addition, a knock out drum was proposed on the section line to the compressor. This would remove the residual "crumb" particles from the vapor. The proposed modification is shown in Figure 4-3.

Section 5

HEAT PUMP DESIGN BASIS

A design basis was established after consultation with ASRC. The design basis for the two heat pumps is as follows:

TABLE 5-1

<u>Heat Pump 1:</u>	
Process Stream:	Toluene flash overhead vapors
Total flow rate:	97,020 (lbs/hr)
Composition: (by weight)	96.6% toluene, 3.4% butadiene
Vapor temperature:	244°F
Vapor pressure:	17 psia
<u>Heat Pump 2:</u>	
Process stream name:	Stripper overhead vapor
Total flow rate:	143,000 (lbs/hr)
Composition: (by weight)	61.6% toluene, 38.4% steam
Vapor temperature:	212°F
Pressure:	17.5 psia

Vapors from both heat pumps will be used to generate steam. This steam will then be utilized in the strippers.

TABLE 5-2

<u>Economic Data</u>	
Total steam requirement:	174,000 lbs/hr
Total steam let down in cogeneration:	135,000 lbs/hr
Steam cost @ generation conditions:	\$3.47/1000 lb.
Steam generated at	300 psig and 555°F
Electricity cost (\$/KW-H):	0.0396
Cost of low-pressure steam after accounting for cogeneration (Appendix B):	\$2.034/1000 lbs
Cost of low pressure steam if demand exceeds 135,000 (lbs/hr):	\$3.47/1000 lbs

TABLE 5-3**Compressor Specifications for Heat Pump 1**

Compressor Type	Roots Blower Model RGS-J
Fluid Handled	Steam
Inlet Pressure, PSIA	15.3
Inlet Temperature, °F	214
Inlet Volume, ACFM	5612
Discharge Pressure, PSIA	30
Pressure Rise Across Blower, PSI	14.7
Maximum Allowable Pressure Rise, PSI	15.4
Estimated Discharge Temperature, °F	252
Blower Speed, RPM	800
BHP at Blower Shaft	486
Maximum Allowable Blower Speed, RPM	800
Approx. WR^2 at Blower Shaft, LB-ft ²	872
Motor	500 HP, 460V, 3-Phase

Other details on the compressor are attached in Appendix A.

TABLE 5-4**Specifications for Heat Pump 1****Heat Exchanger**

The heat exchanger for heat pump 1 is a kettle type exchanger, which is ideally suited for this application. The main features of the exchanger are as follows:

Size 38/52-264	Type: AKU	Total Surface Area: 5971 (sq. ft.)
	Shell Side	Tube Side
Total Fluid Entering (lbs/hr)	13908	97020
Vapor	0	97020
Liquid	13908	0
Fluid Vapor or Condensate	13908	84113
Temperature In, °F	214	244
Temperature Out, °F	214	222
Operating Pressure, PSIA	17.3	17.0
No. of Passes/Shell		2
Pressure Drop, Allowed/Calc., PSI	0.0/0.0	2.0/2.0
Heat Exchanged BTU/hr MTD (°F) 19.56	13,479,000	
Transfer Rate - Service	115.42	

TABLE 5-5**Compressor Specifications for Heat Pump 2**

Compressor Type	Centrifugal Dresser-Roots Model 30-OIB
Fluid Handled	Steam and toluene vapor
Inlet Pressure, PSIA	16.5
Inlet Temperature, °F	214
Inlet Volume, ACFM	28,941
Discharge Pressure, PSIA	40.7
Pressure Rise Across Compressor, PSI	24.7
Estimated Discharge Temperature, °F	347
Speed, RPM	9,205
BHP at Compressor Shaft	2,782
Motor	3000 HP, WP-II

Other details on the compressor are attached in Appendix A.

TABLE 5-6**Specifications for Heat Pump 2****Heat Exchanger**

The heat exchanger for heat pump 2 is a kettle type exchanger, which is ideally suited for this application. The main features of the exchanger are as follows:

Size 69/97 - 288	Type: AKU	Total Surface Area 46,000
	Shell Side	Tube Side
Total Fluid Entering (lbs/hr)	74,039	143,400
Vapor	0	88,400
Liquid	74,039	0
Fluid Vapor of Condensate	-74,039	88,400
Temperature In °F	235	260
Temperature Out °F	235	245
Operating Pressure (PSIA)	25.0	40.7
No. of Passes/Shell		4
Pressure Drop Allowed/Calc., PSI	0 Allowed 0.0 Calc.	2.0 Allowed 2.0 Calc.
Heat Exchanged (BTU/hr)	70,700,000	MTD 16.37°F
Transfer Rate - Service	93.89	

Section 6

ECONOMIC ANALYSIS

The following economic analysis includes a breakdown of the major heat pump component costs, including piping, starters, knock-out drums, strainers, and installation estimates. Table 6-1 shows the cost of installing heat pump 1. Table 6-2 shows the savings and the simple payback for heat pump 1 for current conditions, while Table 6-3 shows the economics in case of future expansion (when stream demand is more than 170,000 lbs./hr.). Similarly, Table 6-4 shows the cost of installing heat pump 2, and the savings for this heat pump are described in Table 6-5 (present conditions) and Table 6-6 (future expansion). The site has been considering expansion and has had an independent consultant conduct a study on the scope for this expansion. As is apparent from the economics for both the heat pumps, the simple payback is under two (2) years.

TABLE 6-1
EQUIPMENT AND INSTALLATION COSTS
FOR HEAT PUMP 1

COMPRESSOR (ROOTS BLOWER) COST	\$107,500
EXPLOSION PROOF MOTOR COST	\$41,200
STARTER COST	\$5,000
TOTAL	\$153,700
TOTAL INSTALLED COMPRESSOR COST (x 1.5)	*\$230,550
HEAT EXCHANGER COST	\$44,280
INSTALLED HEAT EXCHANGER COST (X 1.5)	*\$66,420
K.O. DRUM (Installed Cost)	\$10,000
TOTAL INVESTMENT	\$306,970

*Estimates
Estimates do not include any switch gear cost.

TABLE 6-2**HEAT PUMP 1****SAVINGS FOR PRESENT CONDITIONS**

TOTAL STEAM SAVINGS (LB/HR)	13,908
HOURS/YR	8256
STEAM COST (\$/1000 lb.)	2.034
STEAM SAVINGS (\$/YR)	233,552
ELECTRICITY COST (\$/KWH)	0.0376
POWER (KWH)	295
COMPRESSION COST (\$/YR)	68,298
NET HEAT PUMP SAVINGS (\$/YR)	165,262
SIMPLE PAYBACK	$(306970/165,262) = 1.9$

TABLE 6-3
HEAT PUMP 1
SAVINGS FOR FUTURE EXPANSION

TOTAL STEAM SAVINGS (LB/HR)	13,908
HOURS/YR	8256
STEAM COST (\$/YR)	3.47
STEAM SAVINGS (\$/YR)	398,440
ELECTRICITY COST (\$/KWH)	0.0376
POWER (KWH)	295
COMPRESSION COST (\$/YR)	68,298
NET HEAT PUMP SAVINGS (\$/YR)	330,142
SIMPLE PAYBACK (YRS)	0.9

TABLE 6-4
EQUIPMENT AND INSTALLATION COSTS
FOR HEAT PUMP 2

COMPRESSOR COST	\$284,300
EXPLOSION PROOF MOTOR	\$121,200
STARTER COST	\$27,600
TOTAL	\$433,100
TOTAL INSTALLED COMPRESSOR COST (x1.5)	\$649,650*
HEAT EXCHANGER COST	\$265,770
INSTALLED HEAT EXCHANGER COST	\$398,665
K.O. DRUM (Installed)	\$35,000
STRAINER (Installed)	\$9,000
TOTAL	\$1,092,315

*Estimated
Does not include any switch gear cost

TABLE 6-5**HEAT PUMP 2****SAVINGS FOR PRESENT CONDITIONS**

TOTAL STEAM SAVINGS (LBS/HR)	74,039
STEAM SAVINGS (LBS/YR)	74,039
HOURS/YR	8256
STEAM COST (\$/1000LB)	2,034
TOTAL STEAM SAVINGS (\$/YR)	1,234,315
ELECTRICITY COST (\$/KWH)	0.0376
POWER (KWH)	2920
COMPRESSION COST (\$/YR)	675,945
NET HEAT PUMP SAVINGS (\$/YR)	567,370
SIMPLE PAYBACK (YRS)	1.9

TABLE 6-6**HEAT PUMP 2****SAVINGS FOR FUTURE EXPANSION**

TOTAL STEAM SAVINGS (LBS/HR)	74,039
STEAM SAVINGS (LBS/YR)	74,039
HOURS/YR	8256
STEAM COST (\$/1000LB)	2.034
TOTAL STEAM SAVINGS (\$/YR)	2,121,092
ELECTRICITY COST (\$/KWH)	0.0376
POWER (KWH)	2920
COMPRESSION COST (\$/YR)	675,945
NET HEAT PUMP SAVINGS (\$/YR)	1,445,148
SIMPLE PAYBACK (YRS)	0.75

Section 7

ADDITIONAL BENEFITS OF THE HEAT PUMP

The proposed heat pump also provides improvement in environmental emissions by reducing the emission of NO_x, SO_x, and CO₂ resulting from fossil fuel combustion. No economic credit has been taken for this additional benefit.

Section 8

FUTURE

After a presentation of the results to the site personnel, they have decided not to proceed to the next Phase IIB of this study at this time. The plant is running at full capacity and they plan to take a very short turnaround time next year, which in their opinion will not be sufficient to install the heat pump. An attempt is being made to find alternate sites for installation of the heat pump. Since most synthetic rubber processes are very similar in nature, it is expected that similar potential would be realized at an alternate site. Also, if the new site does not have cogeneration, the cost of steam would be higher and the economics for heat pump would look even better. Phase IIB consists of procurement and installation of the equipment. After the heat pump is commissioned, data will be collected to verify the actual savings with the savings predicted by this heat pump study. A report will be written showing the results.

Appendix A

VENDOR QUOTES

Appendix A -1

VENDOR QUOTE

Heat Exchangers

Begemann Heat Exchangers, Inc.

BEGEMANN HEAT EXCHANGERS, INC.

A Begemann USA Company

19902 Hullsmith-Kohrville Road
P.O. Box 2029 • Tomball, Texas 77377-2029
Phone (713) 376-4455 • Fax (713) 376-4311

FAX

Date: 10/21/91
Company: Tensa Services, Inc.
Attn: Deepak Shukla
Fax #: 789-0907
From: Rick Warkham / Begemann Heat Exchangers I.7 HE1081

Page 1 of 2 Including cover sheet.

Message: Revision to Tensa Inquiry 14. DE-FC07-91103052
follows

BEGEMANN HEAT EXCHANGERS, INC.

A Begemann USA Company

October 21, 1991

TENSA Services, Inc.
6200 Savoy Drive, Suite 540
Houston, Texas 77036-3323
Attn: DEEPAK SHUKLA

RE: TENSA Inquiry No. DE-FC07-91ID3052 Revision
Begemann Heat Exchangers 1.7HE1081 Rev. 3

We appreciate this opportunity to offer our proposal for the revised exchangers. *The attached specification sheet reflects the requirement for two (2) shells in parallel.

ITEM	SIZE/TYPE	WEIGHT	PRICE
1	38/52-264 AKU	26,800#	\$ 44,280.00
* 2	(2) 69/97-288 AKU	180,000#	\$260,900.00

- NOTES:
1. Shipment can be made 11-15 weeks A.D.A.
Allow 3 weeks for drawings after receipt of Purchase Order.
 2. Prices are firm for 30 days and are exclusive of taxes.
 3. Begemann will consider a package discount.
 4. Prices are F.O.B. our Houston Facility.
 5. Terms to be negotiated prior to order.

Should any questions arise please call me at (713) 376-4455.

Regards
Begemann Heat Exchangers

Rick Worsham
V. P., Chief Operating Officer

RW/sm

BEGEMANN HEAT EXCHANGERS, INC.

A Begemann USA Company

August 28, 1991

TENSA Services, Inc.
6200 Savoy Drive, Suite 540
Houston, Texas 77036-3323
Attn: Deepak Shukla

Re: TENSA Inquiry No. DE-FC07-91ID3052 Revision
Begemann Heat Exchangers 1.7HE1081 Rev. 2

We appreciate this opportunity to offer our proposal for the revised exchanger requirement.

ITEM	SIZE/TYPE	WEIGHT	PRICE
1	38/52-264 AKU	26,800#	\$ 44,280.00
2	69/97-288 AKU	89,700#	\$133,200.00

- NOTES: 1. Shipment can be made 11-15 weeks A.D.A.
Allow 3 weeks for drawings after receipt of Purchase Order.
2. Prices are firm for 30 days and are exclusive of taxes.
3. Prices are F.O.B. our Houston Facility.
4. Terms to be negotiated prior to order.

Should questions arise please call me at (713)376-4455

Regards
Begemann Heat Exchangers

Rick Worsham

Rick Worsham
V. P., Chief Operating Officer

RW/sm

BECKMANN HEAT EXCHANGERS

1 Customer TENSA SERVICES, INC.

Cust Inq. No.

Proposal No. 1.7HE1081

2 Date 20 AUG. 1991

Item No. 1

3 Service of Unit TOLUENE FLASH OVHD. LB F W

HORIZONTAL

4 Size 38'-32'-264 Type A K U

Arrangement 1 Parallel 1 Series

5 Shell Recount 3971 EFF Shells per Unit 1 Shell Recount 3971 EFF

6

PERFORMANCE OF ONE UNIT

	BOILER SIDE	TUBE SIDE
9 Fluid Circulated		
10 Fluid Flow Rate	13908	92020
11 Fluid Temperature	13908	92020
12 Fluid Pressure	13908	92020
13 Fluid Velocity	13908	92020
14 Steam	13908	92020
15 Non-Condensables	13908	92020
16 Fluid Vap. or Cond.	13908	92020
17 Steam Condensed	13908	92020
18 Gravity-Liquid	13908	92020
19 Viscosity	13908	92020
20 Molecular Weight	13908	92020
21 Sp. Heat	13908	92020
22 Temperature In	13908	92020
23 Temperature Out	13908	92020
24 Operating Pressure	13908	92020
25 Number of Passes / Shell	13908	92020
26 Velocity	13908	92020
27 Pressure Drop	13908	92020
28 Fouling Resistance	13908	92020
29 Heat Exchanged-BTU/HR	13908	92020
30 Transfer Rate - Service	13908	92020

CONSTRUCTION

32 Design Pressure	PSI	30	ASME CODE	20
34 Test Pressure	PSI	250	ASME CODE	20
35 Design Temperature	DEG. F	250	ASME CODE	20
36 No. Tubes	662	U	X	2500 OD X .060 WALL X 22.00 FT. LG.
37 Tube Material	SA-214	Pitch	2325	TRIANGULAR
38 Shell	SA-214-70	I.D.		
39 Shell Cover	SA-214-70	Fltg. Hd. Cvt.		
40 Channel	SA-214-70	Chan. Cvt.		SA-214-70
41 Tube Sheet	SA-214-70	Flg. Hd. Cvt.		
42 Baffles	C. STEEL	Type		Segm.
43 Baffle Long	XX	Type		
44 Gasket				
45 Connections-Shell-ID	2	Out 1 10-V	0-L Series	150 RF
46 Connections-Channel-ID	16	Out 10	Series	150 RF
47 Corrosion Allow. Shell Side	.0625	Type Side	.0625	
48 Code Requirements	ASME SEC. VIII	TEMA C	IMP. PLATE YES	
49 Weight-Ex. Shell & Rounding				Full Wt.
50 REMARKS:				
51				
52				
53				
54				
55				

BECEMANN HEAT EXCHANGERS

1 Customer Tensa Services, Inc. Cust Inq. No.
 2 Proposal No. 1.7HE1081
 3 Date 20 AUG. 1991 Item No. 2
 4 Service of Unit TOLUENE STRIPPER QVHD / B F W HORIZONTAL
 5 Size 69/ 92-288 Type A K U Arrangement 2 Parallel 1 Series
 6 Sq. Ft. per Unit 46000 EEE Shella per Unit 2 Sq. Ft. per Shell 23000 EEE

PERFORMANCE OF ONE UNIT

	SHELL SIDE		TUBE SIDE	
9 Fluid Circulated	BOILER FEEDWATER		TOLUENE + STEAM	
10 Total Fluid Entering #/HR	74039		143400	
11 Vapor #/HR	0		88400	
12 Liquid #/HR	74039		0	
13 Steam #/HR	0		55000	
14 Non-condensables #/HR				
15 Fluid Vap. or Cond. #/HR	-74039		88400	
16 Steam Condensed #/HR	0		55000	
17 Gravity-Liquid	.950	@ 235 Deg. F	.870	@ 253 Deg. F
18 Viscosity	.260 Cpe	235 Deg. F	.290 Cpe	253 Deg. F
19 Molecular Weight	0.000 / 18.000		25.936 / 0.000	
20 Sp. Heat BTU/#/Deg. F	1.010 / .450		.300 / .420	
21 Temperature In Deg. F	235.0		260.0	
22 Temperature Out Deg. F	235.0		245.0	
23 Operating Pressure -PSIA	25.0		40.7	
24 Number of Passes / Shell	KETTLE		4	
25 Velocity FT./Sec.			0.000	
26 Pressure Drop PSI	0.00 Allowed	0.00 Calc.	2.00 Allowed	2.00 Calc.
27 Fouling Resistance	.0010		.0030	
28 Heat Exchanged-BTU/HR	70700000	MTD (corrected)	16.37	Deg. F
29 Transfer Rate - Service	93.89			

CONSTRUCTION

33 Design Pressure	PSI	50		50
34 Test Pressure	PSI	ASME CODE		ASME CODE
35 Design Temperature	Deg. F	250		270
36 No. Tubes	2273	U X 7500 QD X .060 WALL	X 24.00	Fi. Lg.
37 Tube Material	SA-214	Pitch	.2325	TRIANGULAR
38 Shell	SA516-70	I.D.		
39 Shell Cover	SA516-70	Flg. Hd. Cvc.		
40 Channel	SA516-70	Chan. Cvc. SA516-70		
41 Tube Sheet	SA516-70	Floating		
42 Baffles	C. STEEL	Type Segm.		
43 Baffle-Long XX		Type		
44 Gaskets				
45 Connections-Shell-In	3	Out 1 16-V	0-L Series 150	RF
46 Channel-In	16	Out 4	Series 150	RF
47 Corrosion allow.-Shell Side	.0625	Tube Side	.0625	
48 Code Requirements	ASME SEC. VIII	TEMA C	IMP. Plate	YES
49 Weights-Ea. Shell & Bundle		Bundle		Full Wtr.

50 REMARKS

51
 52
 53
 54
 55

Appendix A-2

VENDOR QUOTE

Motor Starters

Turtle & Hughes, Inc.

Wholesale Electrical Distributors

FROM: TURTLE & HUGHES, INC.
6611 SUPPLY ROW
HOUSTON, TEXAS 77011

P.O. BOX 9588
HOUSTON, TEXAS 77261

TELEPHONE #: (713) 923-9004

TELEFAX #: (713) 923-9009

NUMBER OF PAGES TO FOLLOW: 1

DAVID R. WOLFE
NAME OF PERSON SENDING FAX

COMMENTS:

1

SEP-17-91 TUE 20:38

P.02

SEP 16 1991 09:48 TNSA

P.2

September 13, 1991

Mr. David Wolff
Turtle and Hughes Co.
6611 Supply Row
Houston, TX. 77011

Dear Mr. Wolff:

As a follow-up on our conversation, I am sending you the specifications for the motor starters. The specifications of the two motors are as follows:

MOTOR HP	TYPE	CLASSIFICATION	VOLTAGE Hz./PHASE	RPM	
350	Explosion Proof	CL.1,GRD,DIV1	480/60/3	1800	\$5175.00E
3000	WP11/TEFC	CL.1,GRD,DIV2	2300/60/3	1800	\$27,600.00E

The area classification is Class 1, Division 1, requiring an explosion proof motor. However, the motors and the starters could be installed in the motor room, excepting the host site is not sure if they have enough room in the motor room.

In any case I would propose that you provide a quote for explosion proof and non-explosion proof starters for both the motors.

Should you have any questions, please call me.

Thank You,

Deepak Shukla
Deepak Shukla
Sr. Process Engineer

NOTE: PRICES REFLECT
NEMA-1 ENCLOSURE
NOT EXPLOSION-PROOF!

DS:cs
0913ds

Appendix A-3

VENDOR QUOTE

Compressors and Motors

Roots - Dresser

Note: Several quotes were obtained from Roots - Dresser. Initially, Roots model Nos. 18-OIB and 30-OIB were considered for heat pumps 1 and 2, respectively. Subsequently, after change in design of heat pump 1, Model 1428 RGS-J (Steam Compressor) was considered for heat pump 1.

ROOTS DIVISION
DRESSER INDUSTRIES, INC.
1001 S. Dairy Ashford, Suite 113
Houston, Texas 77077
U.S.A.

Phone: (713) 589-1858
Fax: (713) 589-0468

PROPOSAL FOR: Tensa Services, Inc.
6200 Savoy Drive, Suite 540
Houston, Texas 77036-3323
Mr. Deepak Shukla

Toluene MVR Application
ASRC - Louisville, Kentucky

ROOTS FILE NO. 91-060-107

NAME: Brad Anno

DATE: June 11, 1991

SIGNATURE:

Brad Anno

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Policies:

General Terms of Sale	GTS-5001
Schedule of Rates	TS-5000-1
General Terms of Sale - Technical Services	TS-5000-2
Cancellation Charges Policy	CP-5004
OSHA Supplement	OSHA-5003
Price Adjustment Clause	PA1-5000

Attachment:

Bulletin	B-5750
--------------------	--------

LIST OF EQUIPMENT

ROOTS

DRESSER

Roots offers two (2) Single Stage Centrifugal Compressors (one 18-OIB and one 30-OIB), each complete with the following items :

- Cast iron volute, casing cover.
- Stainless steel welded open radial impeller.
- John Crane Type 28 dry shaft seal.
- Baseplate mounting for driver and compressor.
- Disc type non-lubricated couplings with OSHA approved guard.
- Factory Mechanical Test.
- Tilting pad journal bearings.
- Pivoted shoe type thrust bearing.
- Cast iron horizontally split bearing housing with air buffer connection.
- Forged steel shaft with integral thrust collar and stiff shaft design.
- Roots standard lube system including:
 - Shaft driven main oil pump.
 - Motor driven auxiliary oil pump.
 - Carbon steel oil reservoir with 3-minute retention time (minimum).
 - Water-cooled oil cooler.
 - Oil filter 20 micron - with removable cartridge.
 - Immersion type electric oil heater as required.
 - Oil pressure switches.
 - Oil temperature switches.
 - Weatherproof thermometers and pressure gauges.
- Speed increasing gear, Lufkin or equal.
- Electric motor driver, Siemens or equal.

COMPRESSOR SPECIFICATIONS - TYPICAL

The OIB single stage centrifugal compressor is suitable for air or gas applications with inlet flows to 200,000 CFM and polytropic heads to 34,000 ft lbs/lb.

CASING - The casing is of cast iron construction with all joints machined smooth and air tight. The parallel wall diffuser is designed to fit the rated capacity of the compressor and start the conversion of gas velocity into pressure. The volute is a collecting ring and guides the gas to the discharge nozzle which completes the conversion of gas velocity into pressure. The casing begins and ends with flanges drilled for 125 pounds standard connection. The overhung casing is ruggedly connected to the baseplate and the discharge nozzle can be furnished in any angular position. The inlet nozzle is located axially along the shaft centerline.

IMPELLER - Open and closed impellers are available with backward or radial bladed construction depending on the gas handled and the application. In an open impeller the blades are formed and welded to a forged steel hub. If a closed impeller is required, a forged steel cover disc is added. Cast impellers are also available for certain applications. The impeller is statically and dynamically balanced and then oversped to 15% above operating speed. After this test, the impeller is mounted on the shaft with a heavy fit and is provided with a key. After assembly the entire rotor is dynamically balanced.

SHAFT - The rotor shaft is machined from a steel forging. The diameter of the shaft is designed so the first critical speed of the assembled rotor is well above the maximum operating speed.

BEARING PEDESTAL - A rugged bearing pedestal with cast iron housing is supplied with the housing split on a horizontal plane and fitted with a machined oil tight joint. The radial bearings are pressure lubricated tilting pad bearings.

THRUST BEARING - To guarantee a fixed axial position of the rotor, a pivoted shoe thrust element or equal is mounted in the pedestal housing and operates in contact with the thrust disc which is an integral part of the shaft. The section of the housing accommodating the thrust element is enclosed so the bearing operates submerged in oil.

SEALS - The standard seal for air application is a simple labyrinth. Double labyrinth, carbon ring, or oil film seals are available for other gas applications.

BASEPLATE - A heavy welded steel baseplate is normally furnished under the compressor and drive. The baseplate has the rigidity needed to maintain field alignment between the various components. An internal oil reservoir can be provided within the baseplate with the remaining lubrication system components mounted on the baseplate. When the compressor and driver are to be mounted independently on the foundation, the unit can be supplied with steel soleplates.

ADJUSTABLE INLET GUIDE VANES - To provide efficient part load operation and extend the range of stable operation, variable inlet guide vanes with linkage - type controls may be furnished.

PERFORMANCE

	<u>Toluene Flash</u>	<u>Toluene Stripper</u>
Gas Handled	Toluene/Butadiene	Toluene/Steam
Barometer, PSIA	14.7	14.7
Flow Rate, #/HR	96,120	143,400
Inlet Pressure, PSIA (at compressor flange)	16.0	16.5
Inlet Temperature, °F.	244	214
Inlet Relative Humidity, %	0	0
Inlet Volume, ACFM (at compressor flange)	8,164	28,941
K Value (Cp/Cv)	1.0726	1.1767
Molecular Weight	90.55	35.74
Compressibility Factor at Inlet	0.971003	0.987762
Discharge Pressure, PSIG	9.0	26.0
Discharge Pressure, PSIA	23.7	40.7
Pressure Rise Across Compressor, PSI	7.7	24.2
Polytropic Head, Ft.-Lb./Lb.	4,800	28,698
Speed, RPM	4,704	9,205
BHP at Compressor Shaft*	315	2,782
Estimated Discharge Temperature, °F.	275	347
Compressor Model	18-OIB	30-OIB

*BHP guaranteed with tolerance of $\pm 4\%$ for design point only.

Add 1-1/2% for losses through gear increasor.

PRICING

Date: June 24, 1991

ITEM NO. 1: Toluene Flash Overhead Compressor

The price for one (1) Model 18-OIB Single Stage Centrifugal Compressor, complete with equipment indicated in this proposal, less motor, is..... \$241,900.00.

A 350 HP electric motor is required.

ITEM NO. 2:

The price for one (1) Model 30-OIB Single Stage Centrifugal Compressor, complete with equipment indicated in this proposal, less motor, is..... \$284,300.00.

A 3000 HP electric motor is required.

Adder prices for Electric Motors:

<u>Motor</u>	<u>HP</u>	<u>Type</u>	<u>Classification</u>	<u>Voltage</u>	<u>RPM</u>	<u>Price</u>
	350	TEFC	CL 1, GR D, DIV 1	4000	1800	\$ 22,250
	350	X-Proof	CL 1, GR D, DIV 1	4000	1800	\$ 30,330
	3000	WP-II	CL 1, GR D, DIV 2	4000	1800	\$ 86,650
	3000	TEFC	CL 1, GR D, DIV 2	4000	1800	\$121,200

F.O.B. Point of Manufacture -- no freight included.

Delivery is estimated at 32 - 34 weeks from receipt of purchase order with release to manufacture.

Complete engineering drawing submittals are estimated at 10 - 12 weeks from receipt of purchase order.

The following attached forms apply to this proposal:

General Terms of Sale	GTS-5001
Schedule of Rates	TS-5000-1
General Terms of Sale - Technical Services	TS-5000-2
Cancellation Charges Policy	CP-5004
OSHA Supplement	OSHA-5003
Price Adjustment Clause	PA1-5000

PRICE ADJUSTMENT CLAUSE

ROOTS**DRESSER**

NOTE: This clause applies only to contracts that are based on the normal manufacturing schedule of the Roots Operations of Dresser Industries, Inc.

A. GENERAL POLICY

1. Prices stated herein on equipment manufactured by Seller that can be factory scheduled for shipment within six months from date of order will be firm priced based on prices in effect at time of booking.
2. All units that are factory scheduled or customer requested for shipment beyond six months from date of order will be subject to price in effect at time of shipping for pricebook products or in accordance to terms of section B for non-pricebook products.
3. All parts will be subject to price in effect at time of shipment.
4. Any customer-caused delays from the originally scheduled shipping date will automatically place the order on "price in effect" status.
5. Any significant surcharges on buy out items will be passed along to the customer at net.

B. FOR NON-PRICEBOOK PRODUCTS

The final price is subject to adjustment to compensate for changes in Seller's material and labor costs from the "Base Index Month". In no event will the final price be less than the contract price. This adjustment shall be determined from Bureau of Labor Statistics data as herein provided.

1. DEFINITIONS

For the purpose of this provision, the following definitions apply.

- a. The "Labor Index" shall be the Average Hourly Earnings Index for the Blower and Fans Industry (SIC 3564) as determined and reported monthly by the Bureau of Labor Statistics, U.S. Department of Labor.
- b. The "Materials Index" shall be "Foundry and Forge Shop Products" (W.P.I. Code No. 1015) as determined and reported monthly by the Bureau of Labor Statistics, U.S. Department of Labor.
- c. The "Base Index Month" shall be the month that the proposal is issued.
- d. The "Basic Labor Index" shall be the "Labor Index" for the "Base Index Month."
- e. The "Basic Material Index" shall be the "Material Index" for the "Base Index Month."

2. ADJUSTMENTS FOR COSTS

- a. For the purpose of price adjustment, 10% of the contract price shall be fixed, 55% of the contract price and of each payment made on account thereof shall be deemed to represent the material content and 35% of the contract price and of each payment made on account thereof shall be deemed to represent the labor content.
- b. The labor and material content shall be adjusted for any upward changes in the respective index. The price adjustment for labor shall be equal to the percent by which the index for the month of actual shipment is greater than the "Base Index Month." The price adjustment for material shall be equal to the percent by which the index for the month equal to $\frac{1}{4}$ of the actual shipment is greater than the "Base Index Month."

3. EXCUSABLE DELAYS

Seller will notify Buyer promptly of any material delay and will specify the revised delivery date as soon as practicable. Seller shall not be liable for delays in delivery or performance or for failure to manufacture, deliver, or perform due to (i) causes beyond its reasonable control, or (ii) acts of God, acts of Buyer, acts of civil military authority, governmental priorities, strikes, or other labor disturbances, floods, epidemics, war, riot, delays in transportation or car shortages, or (iii) inability on account of causes beyond the reasonable control of Seller to obtain necessary materials, labor, components, services, or facilities. In event of any such delay, there will be no termination and the date of shipment shall be extended for a period equal to the time lost by reason of the delay, and the price adjusted from the "Base Index Month" in accordance with Bureau of Labor Statistics described herein.

C. GENERAL

- a. In the event any change in the contract specifications prior to actual shipment results in a change in contract price, the new price shall be considered as having been in effect since the "Base Index Month."
- b. In the event price adjustment is to be applied to a contract involving progress payments, the total adjustment to the contract price will be applied and invoiced on the final payment.
- c. Both labor and material adjustments shall be calculated to the nearest one-tenth of one percent.
- d. Should the Indexes specified in Paragraphs 1a and 1b be discontinued, or should the basis of their calculation be modified, Seller, after consulting with Buyer, shall select other indexes or another method of cost adjustment which, in Seller's judgment, will result in an equitable adjustment of the contract price.
- e. Price increases received from our suppliers of Accessory equipment will be directly passed along, regardless of contract duration, with no further mark-up by Seller.
- f. The final price, as adjusted, will not exceed the authorized price in effect at date of actual shipment and shall be in accordance with such, if any, Economic Stabilization Program requirements and regulations of the Cost of Living Council as may then be applicable.

PERFORMANCE

	<u>Toluene Flash</u>	<u>Toluene Stripper</u>
Gas Handled	Toluene/Butadiene	Toluene/Steam
Barometer, PSIA	14.7	14.7
Flow Rate, #/HR	96,120	143,400
Inlet Pressure, PSIA (at compressor flange)	16.0	16.5
Inlet Temperature, °F.	244	214
Inlet Relative Humidity, %	0	0
Inlet Volume, ACFM (at compressor flange)	8,164	28,941
K Value (Cp/Cv)	1.0726	1.17659
Molecular Weight	90.55	35.74
Compressibility Factor at Inlet . . .	0.971003	0.987914
Discharge Pressure, PSIG	9.0	9.0
Discharge Pressure, PSIA	23.7	23.7
Pressure Rise Across Compressor, PSI	7.7	7.2
Polytropic Head, Ft.-Lb./Lb.	4,800	10,930
Speed, RPM	4,704	5,239
BHP at Compressor Shaft*	315	1,039
Estimated Discharge Temperature, °F.	275	270
Compressor Model	18-OIB	30-OIB

*BHP guaranteed with tolerance of $\pm 4\%$ for design point only.

Add 1-1/2% for losses through gear increasor.

TYPICAL ONLY

ROOTS

DRESSER

PROPOSAL

PERFORMANCE CURVES

RADIAL BLADED IMPELLER (PARAMETER-% SPEED)

GB-3798

PROPOSAL

LUBRICATION SYSTEM

The pressure lubrication system for the Roots centrifugal compressor is completely mounted and piped on the compressor base. The system consists of main and auxiliary oil pumps, single oil cooler, single oil filter, a minimum three (3) minute retention time oil reservoir in the baseplate and all necessary safety switches and gauges.

The oil selected should be a premium grade rust, oxidation and foam inhibited turbine oil.

SYM	Description
A	Main Oil Pump
B	Aux. Oil Pump
C	Oil Cooler
D	Oil Filter
E	Check Valve
F	Relief Valve
G	Foot Valve
H	Thermometer
J	Thermometer
K	Pressure Gauge
L	Switch - Aux. Oil Pump Control
M	Switch - Low Oil Press. Shutdown

ROOTS**DRESSER****PROPOSAL****CROSS SECTION**

Part No.	Part Name	Material
1	Volute Casing	Cast Iron
2	Casing Cover	Cast Iron
3	Inlet Section	Cast Iron
4	Sub-Cover Section	Cast Iron
* 5	Shaft Seal Bushing	Aluminum
6	Inlet Nozzle	Cast Iron
7	Discharge Nozzle	Cast Iron
8	Shaft	Alloy Steel
9	Impeller	Alloy Steel
10	Impeller End Plate	Hot Rolled Steel
11	Soc. Hd. Cap Screw	Steel
12	Lockwasher	Steel
13	Bearing Stand	Cast Iron
14	Bearing Stand Cap	Cast Iron
15	Breather Cap	Steel
* 16	Bearing Sleeve	Ductile Iron & Babbitt
* 17	Bearing Sleeve	Ductile Iron & Babbitt
* 18	Oil Retainer	Aluminum
* 19	Oil Retainer	Aluminum
20	Spacing Ring	Cast Iron
* 21	Thrust Housing Seal	Ductile Iron & Babbitt
22	Shim	Steel
* 23	Thrust Shoe	Kingsbury J-6
24	Leveling Plate	
25	Base Ring	
26	Key	
27	Bearing Stand Support	Steel
28	Bedplate	Steel

*Recommended Spare Parts

ROOTS

DRESSER

PROPOSAL

OUTLINE DRAWING

APPROX. WT. = 18,500 lbs.

All dimensions are approximate.

ROOTS

DRESSER

PROPOSAL

OUTLINE DRAWING

APPROX. WT. = 27,000 lbs.

All dimensions are approximate.

ROOTS**DRESSER****PROPOSAL****NOZZLE ORIENTATION**

Position 1

Position 2

Position 3

Position 4

Position 5

Position 6

Position 7

Position 8

Position 9

Position 10

Position 11

Position 12

Position 13

Position 14

Position 15

Position 16

45° Increment Between Positions.
Viewed from Inlet End.
Other Positions Available on Request.

Performance data outlined in this proposal has been established on the basis of Dresser's design experience. Unless specifically provided for elsewhere herein, this proposal does not include testing to verify hydraulic performance (pressure-volume-horsepower) of the equipment proposed. This or other special testing can be performed as a specific extra for an additional price, provided that available test equipment permits, and the scope of such tests are clearly defined and agreed to by both Dresser and the customer prior to Dresser's start of work on the subject order.

Standard factory mechanical test* referred to herein consists of operating the unit(s) for a period of time (one hour minimum after stabilization) which will sufficiently indicate that the unit(s) is mechanically acceptable in accordance with Dresser engineering standards. During this test, the following data shall be recorded:

1. Duration of test	5. Vibration levels
2. Oil pressure	6. Functional check of
3. Speed	accessory devices
4. Oil temperature	(pressure and tempera-
	ture switches, relief
	valves, etc.)

If, during the test, data indicates adjustments should be made to insure conformance to Dresser's high quality and engineering standards, such necessary adjustments to the equipment shall be made by Dresser prior to shipment, at no extra cost to the customer.

Successful performance of this equipment as measured by the above mechanical test shall be considered as the basis for acceptance by the customer unless otherwise agreed upon in writing by Dresser.

*Dresser reserves the right to conduct all tests with its shop test driver in the event that actual driver's requirements are incompatible with Dresser's test facilities.

PRICING

ROOTS

DRESSER

Date: June 11, 1991

ITEM NO. 1: Toluene Flash Overhead Compressor

The price for one (1) Model 18-OIB Single Stage Centrifugal Compressor, complete with a 350 HP, WP II, 460/60/3 electric motor and other equipment indicated in this proposal is \$259,900.00.

ITEM NO. 2:

The price for one (1) Model 30-OIB Single Stage Centrifugal Compressor, complete with a 1250 HP, WP II, 4000/60/3 electric motor and other equipment indicated in this proposal is \$324,200.00.

F.O.B. Point of Manufacture -- no freight included.

Delivery is estimated at 32 - 34 weeks from receipt of purchase order with release to manufacture.

Complete engineering drawing submittals are estimated at 10 - 12 weeks from receipt of purchase order.

The following attached forms apply to this proposal:

General Terms of Sale	GTS-5001
Schedule of Rates	TS-5000-1
General Terms of Sale - Technical Services	TS-5000-2
Cancellation Charges Policy	CP-5004
OSHA Supplement	OSHA-5003
Price Adjustment Clause	PAI-5000

ROOTS DIVISION
DRESSER INDUSTRIES, INC.
1001 S. Dairy Ashford • Suite 113
Houston, TX 77077
Phone: 713/589-0375 • Fax: 713/589-0468

August 14, 1991

Tensa Services, Inc.
6200 Savoy Drive, Suite 540
Houston, Texas 77036-3323

Attention: Mr. Deepak Shukla

Reference: Steam Compressors for ASRC

Dear Mr. Shukla:

We are pleased to offer our rotary lobed positive displacement blowers for your steam compression application. Our standard RGS-J model is modified to handle steam by adding high temperature seals, special rotor clearances, cylinder insulation, zinc coated shafts, 17-4 PH capscrews and oversized oil cooler.

We have numerous installations similar to yours and can provide an installation list, if required.

Please let me know if there's anything else you need. Thank you for your interest in our products.

Sincerely,

A handwritten signature in cursive script that reads "Brad Anno".

Brad Anno
Sales Representative

BA/jb

Enclosure

ROOTS DIVISION
DRESSER INDUSTRIES, INC.
1001 S. Dairy Ashford, Suite 113
Houston, Texas 77077
U.S.A.

Phone: (713) 589-1858
Fax: (713) 589-0468

PROPOSAL FOR: Tensa Services, Inc.
6200 Savoy Drive, Suite 540
Houston, Texas 77036-3323
Mr. Deepak Shukla

Toluene MVR Application
ASRC - Louisville, Kentucky

ROOTS FILE NO. 91-060-107 REVISION #1

NAME: Brad Anno

DATE: June 24, 1991

SIGNATURE:

Brad Anno

Roots Single Stage Centrifugal Compressors

ROOTS

Over 50 Years of Proven Compressor Performance

Roots introduced rotary positive displacement and vacuum pumps in 1911, in 1934 and began manufacturing single-stage centrifugal compressors in 1931. Along the way, we have perfected the application of our technology to provide you with equipment you can trust to perform efficiently and dependably.

Operates Below First Critical Speed

Roots single-stage centrifugal compressors have a stiff shaft design

which assures an operating speed well below the first critical speed of the shaft. And because the shaft does not pass through critical speeds when starting or stop the compressor, bearings and other components aren't subjected to the high vibrations often found in other compressors.

Low Installation Expense

You can save on installation costs with Roots single-stage compressors because our standard package is delivered complete with compressor,

drive, completely piped integral tube system and base plate with oil sump. This packaging concept significantly reduces installation and start-up costs. Installation normally requires only inlet and discharge piping and utility hook-ups.

Adaptable to Many Drives

The stiff shaft design of Roots centrifugal compressors allows safe operation in most variable speed applications. They can be driven by electric motor, steam turbine, gas or diesel engine. Your local energy cost and requirements will determine the most economical method of drive for your application.

Wide Range of Stable Operation

Roots single-stage compressors have a wide range of stable operation with surge occurring at approximately

50% of design capacity. This can be extended to approximately 30% of design capacity (70% turndown) through the use of adjustable inlet guide vanes.

Broad Range of Applications

A variety of sealing arrangements, impeller configurations and materials of construction permit each compressor to be tailored to your specific requirements.

A few of the many applications for which Roots single-stage centrifugal compressors are serving industry include service at paper mills, food processing plants and utility sites for mechanical vapor recompression. They're serving the chemical processing industries in process air, combustion air and vapor recompression applications, and they're providing aeration air at municipal sewage treatment plants.

Radial Bladed Impeller

(Parameter—
% Speed)

Backward Leaning Impeller

(Parameter—
% Speed)

Radial Bladed Impeller

Adjustable Inlet Guide Vanes

Backward Leaning Impeller

Adjustable Inlet Guide Vanes

High Efficiency Impeller Designs

Open Radial-Bladed Impeller

Open Backward-Bladed Impeller

Closed Backward-Bladed Impeller

The impeller is the most critical element in a centrifugal compressor. The most common impeller configurations are those with blades discharging radially, or backward leaning blades curved away from the direction of rotation. The form of impeller blades influences the head curve developed, efficiency, and stable operating range of the compressor. Depending upon requirements, the impellers may be furnished as either open or closed types and cast or fabricated of various materials. Standard material for impellers is AISI 4130 alloy steel. However, impellers are also available in AISI 410, AISI 316, 15-5 PH stainless steel and titanium.

A Variety of Features for

Rugged Bearings

Horizontally split tilting pad bearings and pivoted shoe thrust bearings carry radial and thrust loads. The thrust bearing maintains the rotor in a fixed axial position.

Optional Inlet Guide Vanes

The use of adjustable inlet guide vanes is the most efficient, commercially feasible method of controlling a constant speed compressor. They adjust the capacity with a minimum loss of efficiency and can increase the stable operating range to approximately 30% of design capacity (70% turndown) and design pressure. This is accomplished by pre-rotation of the gas which reduces the head/capacity characteristics of the machine more efficiently than by pure throttling. The vanes can be either manually or automatically controlled.

Dependable Seals

A Simple Labyrinth Seal is generally used in low pressure air applications or in processes where moderate gas leakage to atmosphere can be tolerated. Normally made of aluminum, stainless steel or babbitt, the seal is horizontally split for easy removal.

A Double Labyrinth Seal With Equalizing Chamber is used to prevent leakage of process gas. The equalizing chamber may be connected to either a buffer gas or ejector system, or may be piped back to the compressor suction. Labyrinth seal is normally made of aluminum, stainless steel or babbitt.

Carbon Ring Seals may be operated dry, buttered with gas or liquid buttered. For dry operation they allow a small leakage of process gas to atmosphere. For

Positive Lubrication

Single stage Roots compressors are offered with completely self-contained lubrication systems that are normally mounted on the compressor base plate. The standard lube system includes main and auxiliary oil pumps, oil

1. Casing
2. Bearings
3. Seal
4. Impeller
5. Shaft
6. Guide Vanes

Dependable Performance

**Tilting Pad
Radial Bearing**

**Tilting Pad
Thrust Bearing**

applications that will not tolerate leakage of process gas to atmosphere, gas, or liquid butted seals are recommended. Both allow a small in-leakage, but no external leakage. When liquid is used as the butter it also serves as a lubricant and coolant for contact between the seal and shaft.

A Positive Oil Film Seal is used in high pressure applications. It permits slight leakage of oil to process, but no leakage of process gas to environment. A helical spring maintains initial contact between the end face of the bushing and mating surface in the seal housing. Labyrinth seal or windbacks can be used. Windbacks are recommended for more effective prevention of seal oil flow into the process gas.

**Simple
Labyrinth Seal**

**Double Labyrinth Seal
With Equalizing Chamber**

Carbon Ring Seal

Oil Film Seal

filter, and reservoir to provide lubrication for the compressor, driver and gear set. Special options to meet individual requirements or preferences can be supplied. Note: Separate console tube system are available upon request.

SYM DESCRIPTION

- A Main Oil Pump
- B Aux. Oil Pump
- C Oil Cooler
- D Oil Filter
- E Check Valve
- F Relief Valve
- G Foot Valve
- H Thermometer
- I Thermometer
- J Pressure Gauge
- K Switch-Aux. Oil Pump Control
- L Switch-Low Oil Press. Shutdown
- M High Oil Temperature Switch

Performance

Backward Leaning Impeller

Radial Bladed Impeller

Dimensions

SIZE OIB	INLET CFM	TYPICAL MOTOR HP	A	B	C	APPROX. NET WT. LBS.
12	4700	250	60	55	130	13770
14	6500	300	65	60	135	16150
16	8500	400	80	72	140	18520
20	13000	600	92	85	144	21940
24	19000	800	89	72	179	23370
30	30000	1250	95	80	190	27070
36	42000	1750	105	100	204	42980
42	58000	2250	108	100	222	49060
48	76000	3000	120	115	240	60230
54	96000	4000	140	140	250	67450
60	118000	4500	165	165	275	146390
66	145000	6000	170	170	280	165230
72	200000	7500	180	190	300	182870

All specifications subject to change without notice.

NOTES: 1. All dimensions and weights are approximate.

2. Alternate discharge nozzle positions available.

For Higher Temperature and / or Higher Pressure Applications

The single-stage OIB/HIP centrifugal compressor manufactured by Roots is a high pressure/high temperature version of the OIB single-stage compressor with construction material changes necessary for higher pressures and temperature capabilities.

It also is adaptable to electric motor, steam turbine, gas or diesel engine drivers, and has a wide range of stable operation. Sealing arrangements, impeller configurations and construction materials are designed to meet your specific requirements.

Roots OIB/HIP compressors are designed for capacities from 500 to 100,000 CFM with discharge pressures to 600 PSIG, or working temperatures to 900° F.

Other Roots Centrifugal Compressors

CVS Centrifugal Vacuum Exhausters . . . capacities from 15,000 to 65,000 CFM, vacuums to 25" Hg.

Single-stage Integral Gearing Centrifugal Compressors . . . capacities from 3,800 to 50,000 CFM, pressures to 30 PSIG.

H Multi-stage Centrifugal Compressors . . . capacities from 5,000 to 100,000 CFM, working pressures to 200 PSIG.

ROOTS

ROOTS DIVISION
DRESSER INDUSTRIES, INC.
1001 S. Dairy Ashford, Suite 113
Houston, Texas 77077
U.S.A.

Phone: (713) 589-1858
Fax: (713) 589-0468

PROPOSAL FOR: Tensa Services, Inc.
6200 Savoy Drive, Suite 540
Houston, Texas 77036-3323
Mr. Deepak Shukla

Steam Compressors for ASRC

ROOTS FILE NO. 91-060-110

NAME: Brad Anno

DATE: August 14, 1991

SIGNATURE:

Brad Anno

LIST OF EQUIPMENT - NORMAL OPERATION ONLY*

ROOTS

DRESSER

- (1) Roots Model 1428 RGS-J Steam Compressor with pressure lubrication, oil cooler, oil filter, mechanical seals, and compressor casing insulating jacket.
- (1) Auxiliary oil pump and motor.
- (1) Electric Motor: 350 HP, 460/60/3, 1800 RPM
- (1) Speed reducing gearbox.
- (2) Drive coupling with guards.
- (1) Equipment baseplate common to above components.
- (1) Inlet silencer.
- (1) Discharge silencer.
- (1) Inlet expansion joint.
- (1) Discharge expansion joint.
- (1) Discharge check valve.
- (1) Instrument Protective Package consisting of:
 - Low oil pressure switch
 - High oil temperature switch
 - High discharge temperature switch
 - Inlet pressure switch
 - Differential pressure switch
 - Differential temperature switch
 - Local base mounted panel.
- (1) Roots standard Mechanical Run and Performance Test.

* IF 30 PSIA DISCHARGE IS REQUIRED. A ROOTS MODEL 1821 RGS-J MUST BE USED WITH A 500 HP MOTOR.

PERFORMANCE

ROOTS

DRESSER

	<u>1428</u>	<u>1821</u>
	<u>Design</u>	<u>Alternate Condition</u>
Gas Handled	Steam	Steam
Molecular Weight	18	18
K Value (Cp/Cv)	1.32	1.32
Barometer, PSIA	14.7	14.7
Inlet Pressure, PSIA	15.3	15.3
Inlet Temperature, °F.	214	214
Inlet Volume, (14.7 PSIA, 68°F.) LB/HR . . .	13,036	13,036
Inlet Volume, ACFM ($\pm 4\%$)	5612	5612
Discharge Pressure, PSIA	24.0	30.0
Discharge Pressure, PSIG	9.3	15.3
Pressure Rise Across Blower, PSI	8.7	14.7
Maximum Allowable Pressure Rise, PSI	15.4	15.4
Estimated Discharge Temperature, °F.	335	252
Blower Speed, RPM	1017	800
BHP at Blower Shaft ($\pm 4\%$)	295	486
Maximum Allowable Blower Speed, RPM	1030	800
Approximate WR^2 at Blower Shaft, LB.-Ft. ² .	380	872
Water Injection Required at Inlet	Dry	3.0 GPM

ROOTS® RGS-J Industrial Blowers

- discharge pressures to 24 PSIG
- vacuums to 16" Hg
- flows to 28,000 CFM

ROOTS

IMPELLING QUALITY

Exclusive Whispair® design reduces wear, vibration and noise

Conventional blowers are buffeted up to 120 times a second with shock waves traveling at the speed of sound. The resulting pressure pulses and vibrations rob power and shorten the life of every bearing, gear and other drive train component.

But RAS-J blowers and RGS-J gas pumps have a solution to the problem. Roots' exclusive Whispair® jet design helps equalize pressure pulses, reducing shock wave intensity by up to 50%. Here's what this reduced vibration means to the user:

Longer bearing life

Less shock transmitted through the impellers means approximately **20% longer bearing life**. Other components suffer less stress, too.

Lower energy consumption

Whispair's jet design controls backflow and channels air pressure in the direction of impeller rotation. The result is an extra "push" that **reduces the power required to drive the impellers**.

Pressure pulses per shaft revolution

Lower noise

Pressure pulses are also the major source of blower and gas pump noise. The pressure equalizing effect of the Whispair design **reduces noise by approximately 5 dBA**.

Typical blower/gas pump noise curve

New double ring locking device on timing gears eliminates locking pins and keyways.

RAS-J Whispair Blower

RGS-J Whispair

1. Cylinder and headplates

All units are available in either horizontal or vertical flows. Cylinders and headplates are precision machined grey iron, with cast ribs for improved strength and heat transfer. **All RAS-J blowers and RGS-J gas pumps incorporate a wrap-around plenum design and feature Roots' exclusive Whispair jet.**

2. Impellers

Made from **ductile iron** with a tensile strength of 60,000 PSI, impellers are statically and dynamically balanced.

3. Shafts

Impeller shafts are **alloy steel forgings**, flange-connected to the impeller bodies with high-tensile socket head capscrews. Labyrinth seals minimize air leakage in RAS-J blowers; RGS-J gas pumps feature face-type mechanical seals to prevent gas leakage.

4. Bearings

Long-life, double-row spherical roller bearings support the shaft assemblies and control axial location of the impellers at the thrust end. An inboard bearing **minimizes drive shaft stress** on 1000 J through 1400 J frame size, V-belt driven blowers and gas pumps.

5. Timing gears

All timing gears feature a **double taper ring locking device** that offers easy adjustment and makes shaft-weakening keyways and locking pins unnecessary. These wide-faced spur gears are made to AGMA standards and are **carburized and ground** to a hardness of 58-60 Rc.

6. Lubrication

Both RAS-J blowers and RGS-J gas pumps offer a positive pressure lubrication system which can **extend bearing life by up to 50%**. This system is entirely self-

spair Gas Pump

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contained and includes an integral drive oil pump, distribution piping, gearbox oil sump, oil cooler, pressure gauge, relief valve and low oil pressure safety switch. The RAS-J blower is also available with an energy-saving splash lubrication system in place of the pressure system.

Each unit tested, certified

Every RAS-J blower and RGS-J gas pump is tested at the factory to guarantee that each unit meets performance specifications. **Test procedures include a complete flow test at full speed and pressure**, as well as vibration measurement at three different performance levels.

RAS-J Whispair Blowers

RGS-J Whispair Gas Pumps

Dimensions

FRAME SIZE	PRESSURE LUBE							SPLASH LUBE							INLET	DISCH.
	HORIZONTAL FLOW		VERTICAL FLOW		BOTH		MAX. WEIGHT (LBS.)	HORIZONTAL FLOW		VERTICAL FLOW		BOTH		MAX. WEIGHT (LBS.)		
	O	P	O	P	C	C'		O	P	O	P	C	C'			
1009J	34.75	28.50	28.75	36.00	39.25	48.63	2110	34.75	28.50	28.75	30.75	33.50	42.38	2050	10	8
1012J	34.75	28.50	28.75	36.00	42.25	51.13	2280	34.75	28.50	28.75	30.75	36.50	45.38	2200	10	8
1016J	34.88	28.50	28.75	36.00	46.75	55.63	2510	34.88	28.50	28.75	30.75	41.00	49.88	2400	12	10
1018J	34.88	28.50	28.75	36.00	49.00	57.88	2590	34.88	28.50	28.75	30.75	43.25	52.13	2450	12	10
1021J	34.88	28.50	28.75	36.00	51.25	60.13	2690	34.88	28.50	28.75	30.75	45.50	54.38	2550	14	12
1024J	34.88	28.50	28.75	36.00	54.25	63.13	3110	34.88	28.50	28.75	30.75	48.50	57.38	3000	14	12
1030J	34.88	28.50	28.75	36.00	60.25	69.13	3660	34.88	28.50	28.75	30.75	54.50	63.38	3500	16	14
1212J	40.50	33.00	33.13	40.00	44.75	49.06	3165	40.50	33.00	33.13	36.75	40.06	44.38	3100	12	10
1216J	40.50	33.00	33.13	40.00	48.75	53.06	3575	40.50	33.00	33.13	36.75	44.06	48.38	3400	14	12
1220J	40.50	33.00	33.13	40.00	52.75	57.06	3795	40.50	33.00	33.13	36.75	48.06	52.38	3650	16	14
1222J	40.50	33.00	33.13	40.00	55.25	59.31	3990	40.50	33.00	33.13	36.75	50.56	54.88	3800	16	14
1225J	40.50	33.00	33.13	40.00	57.75	62.06	4185	40.50	33.00	33.13	36.75	53.06	57.38	4000	16	14
1228J	40.50	33.00	33.13	40.00	61.25	65.31	4345	40.50	33.00	33.13	36.75	56.56	60.88	4150	18	16
1236J	40.50	33.00	33.13	40.00	68.75	73.06	4875	40.50	33.00	33.13	36.75	64.06	68.38	4650	20	18
1414J	47.25	38.50	38.00	45.25	50.75	56.56	4820	47.25	38.50	38.00	43.00	45.13	50.94	4600	14	12
1418J	47.25	38.50	38.00	45.25	54.75	60.56	5130	47.25	38.50	38.00	43.00	49.13	54.94	4900	14	12
1422J	47.25	38.50	38.00	45.25	58.75	64.56	5460	47.25	38.50	38.00	43.00	53.13	58.94	5200	16	14
1425J	47.25	38.50	38.00	45.25	61.25	67.06	5700	47.25	38.50	38.00	43.00	55.63	61.44	5300	18	16
1428J	47.25	38.50	38.00	45.25	64.25	70.06	5940	47.25	38.50	38.00	43.00	58.63	64.44	5650	18	16
1431J	47.25	38.50	38.00	45.25	67.75	71.44	6220	47.25	38.50	38.00	43.00	62.13	67.94	5900	18	16
1435J	47.25	38.50	38.00	45.25	71.25	77.06	6500	47.25	38.50	38.00	43.00	65.63	71.44	6200	20	18
1442J	47.25	38.50	38.00	45.25	78.25	84.06	7090	47.25	38.50	38.00	43.00	72.63	78.44	6750	24	20
1616J	53.75	44.50	43.25	51.00	48.31	—	6185	53.75	44.50	43.25	49.50	48.31	—	5700	14	12
1620J	53.75	44.50	43.25	51.00	52.31	—	6465	53.75	44.50	43.25	49.50	52.31	—	6000	16	14
1625J	53.75	44.50	43.25	51.00	57.31	—	6800	53.75	44.50	43.25	49.50	57.31	—	6300	20	18
1627J	53.75	44.50	43.25	51.00	59.31	—	7135	53.75	44.50	43.25	49.50	59.31	—	6600	20	18
1630J	53.75	44.50	43.25	51.00	62.31	—	7480	53.75	44.50	43.25	49.50	62.31	—	6850	20	18
1633J	53.75	44.50	43.25	51.00	65.31	—	7830	53.75	44.50	43.25	49.50	65.31	—	7250	24	20
1639J	53.75	44.50	43.25	51.00	71.31	—	8370	53.75	44.50	43.25	49.50	71.31	—	7800	24	20
1643J	53.75	44.50	43.25	51.00	75.31	—	8580	53.75	44.50	43.25	49.50	75.31	—	8000	30	24
1648J	53.75	44.50	43.25	51.00	80.31	—	8790	53.75	44.50	43.25	49.50	80.31	—	8200	30	24
1821J	59.25	49.50	48.00	56.00	57.31	—	8440	59.25	49.50	48.00	54.00	57.31	—	7800	18	16
1824J	59.25	49.50	48.00	56.00	60.31	—	8770	59.25	49.50	48.00	54.00	60.31	—	8100	20	16
1827J	59.25	49.50	48.00	56.00	63.31	—	9190	59.25	49.50	48.00	54.00	63.31	—	8400	20	16
1830J	59.25	49.50	48.00	56.00	66.31	—	9610	59.25	49.50	48.00	54.00	66.31	—	8850	24	20
1833J	59.25	49.50	48.00	56.00	69.81	—	10030	59.25	49.50	48.00	54.00	69.81	—	9300	24	20
1841J	59.25	49.50	48.00	56.00	77.31	—	10450	59.25	49.50	48.00	54.00	77.31	—	9750	30	24
1845J	59.25	49.50	48.00	56.00	81.31	—	10870	59.25	49.50	48.00	54.00	81.31	—	10100	30	24
1849J	59.25	49.50	48.00	56.00	85.31	—	11170	59.25	49.50	48.00	54.00	85.31	—	10400	30	26
1854J	59.25	49.50	48.00	56.00	90.31	—	11470	59.25	49.50	48.00	54.00	90.31	—	10650	30	26
2022J	66.13	54.50	52.75	61.25	61.13	—	10660	66.13	54.50	52.75	61.25	61.13	—	9800	25	16
2026J	66.13	54.50	52.75	61.25	65.13	—	11120	66.13	54.50	52.75	61.25	65.13	—	10250	28	18
2033J	66.13	54.50	52.75	61.25	72.13	—	12130	66.13	54.50	52.75	61.25	72.13	—	11230	24	20
2037J	66.13	54.50	52.75	61.25	76.13	—	13130	66.13	54.50	52.75	61.25	76.13	—	11800	30	24
2040J	66.13	54.50	52.75	61.25	78.63	—	13630	66.13	54.50	52.75	61.25	78.63	—	12450	30	24
2044J	66.13	54.50	52.75	61.25	82.63	—	14130	66.13	54.50	52.75	61.25	82.63	—	13100	30	24
2050J	66.13	54.50	52.75	61.25	88.63	—	14850	66.13	54.50	52.75	61.25	88.63	—	13800	30	26
2055J	66.13	54.50	52.75	61.25	93.63	—	15340	66.13	54.50	52.75	61.25	93.63	—	14300	36	30
2060J	66.13	54.50	52.75	61.25	98.63	—	15830	66.13	54.50	52.75	61.25	98.63	—	14750	36	30

1. All dimensions are in inches and are approximate

2. Drive shaft location is dependent upon frame size.
1000J through 1400J frame sizes—Drive shaft is located on the thrust end of the unit and is shown by solid heavy lines.
1600J through 2000J frame sizes—Drive shaft is located on the gear end of the unit and is shown by dotted lines.

Performance specifications

FRAME SIZE	SPEED RPM	4 PSI		6 PSI		8 PSI		10 PSI		12 PSI		15 PSI		20 PSI		MAX. PRESS. RISE	MAX. VAC. IN. HG.
		CFM	BHP	CFM	BHP	CFM	BHP	CFM	BHP	CFM	BHP	CFM	BHP	CFM	BHP		
1009J	1800	2007	85	1961	84	1922	82	1887	81	1856	80	1814	157	1687	185	24.4	16
1012J	1800	2676	87	2615	92	2562	117	2516	141	2475	166	2418	203	2249	240	18.3	16
1016J	1800	3752	86	3680	120	3621	154	3568	188	3543	205					13.3	16
1018J	1800	4266	85	4185	134	4117	173	4057	211							11.7	16
1021J	1800	4781	105	4690	148	4614	191	4546	235							10.4	16
1024J	1800	5461	117	5358	167	5271	216									9.2	16
1030J	1800	6708	142	6552	204											7.3	15
1212J	1500	3238	82	3174	111	3120	141	3072	170	3028	200	2970	244	2797	289	22.0	16
1216J	1500	4354	102	4268	142	4195	182	4130	221	4072	261	3993	320			16.5	16
1220J	1500	5508	122	5418	171	5342	221	5275	270	5214	320					13.2	16
1222J	1500	6193	134	6092	190	6006	245	5931	301							11.7	16
1225J	1500	6892	147	6779	209	6684	270	6600	332							10.5	16
1228J	1500	7857	164	7728	235	7619	305									9.2	16
1236J	1500	9912	201	9749	290											7.3	15
1414J	1300	4680	116	4592	158	4518	200	4453	243	4394	285	4315	349	4243	412	21.2	16
1418J	1300	5976	139	5864	193	5770	247	5687	302	5611	356	5510	437			16.6	16
1422J	1300	7357	162	7243	228	7146	294	7061	360	6985	425					13.7	16
1425J	1300	8184	177	8057	250	7950	323	7855	397	7770	470					12.2	16
1428J	1300	9156	195	9014	276	8894	358	8789	440							11.0	16
1431J	1300	10300	215	10140	307	10005	399									9.8	16
1435J	1300	11455	236	11277	338	11127	440									8.8	16
1442J	1300	13741	277	13527	399											7.3	15
1616J	1130	5879	144	5772	197	5683	250	5604	303	5533	356	5436	436	5349	515	22.0	16
1620J	1130	7343	170	7210	236	7099	303	7000	369	6911	435	6791	535			17.6	16
1625J	1130	9184	203	9018	286	8878	369	8755	452	8644	535					14.0	16
1627J	1130	10049	217	9900	306	9774	396	9663	485	9563	575					13.0	16
1630J	1130	11162	236	10996	336	10856	435	10733	535							11.7	16
1633J	1130	12275	256	12093	366	11939	475	11804	586							10.6	16
1639J	1130	14511	296	14296	426	14114	555									9.0	16
1643J	1130	15995	323	15758	465	15558	608									8.2	16
1648J	1130	17861	356	17596	515											7.3	15
1821J	1000	8658	203	8507	278	8380	356	8268	434	8165	512	8029	629	7905	746	18.8	16
1824J	1000	9902	222	9729	312	9584	401	9455	490	9339	579	9182	713			16.5	16
1827J	1000	11127	245	10933	345	10769	445	10625	545	10485	646					14.6	16
1830J	1000	12521	267	12341	378	12190	490	12056	601	11936	713					13.2	16
1833J	1000	13978	293	13777	417	13608	542	13455	666							11.7	16
1841J	1000	17108	348	16863	501	16656	653									9.6	16
1845J	1000	18781	378	18512	545	18285	713									8.8	16
1849J	1000	20454	408	20161	590	19914	772									8.0	16
1854J	1000	22541	445	22218	646											7.3	15
2022J	900	10357	236	10191	327	10051	420	9927	513	9816	606	9664	745	9528	884	19.6	16
2026J	900	12197	268	12001	377	11836	486	11691	596	11559	705	11381	869			16.6	16
2033J	900	15606	325	15400	464	15226	602	15073	740	14934	878					13.0	16
2037J	900	17468	358	17237	513	17042	668	16870	823							11.7	16
2040J	900	18632	379	18386	544	18178	709	17995	874							11.0	16
2044J	900	20494	412	20223	593	19994	775	19793	957							10.0	16
2050J	900	23290	462	22982	668	22723	874									8.8	16
2055J	900	25619	503	25280	730											7.9	16
2060J	900	27948	544	27579	792											7.3	15

Notes: 1. Pressure ratings are based on inlet air or gas at standard temperature of 68°F, ambient pressure of 14.7 psia and specific gravity of 1.0.

2. All specifications subject to change without notice.

ROOTS

DRESSER

Dresser Industries, Inc.
ROOTS DIVISION

SPECIFICATIONS

Roots RGS-J Whispair

heavy duty

rotary positive gas pumps

Frames 1000J thru 2000J

USER BENEFITS

PEAK-TO-PEAK PRESSURE PULSE

TYPICAL GAS PUMP NOISE CURVE

LOWER GAS PULSATION – Whispair gas pumps operate with up to 50% less pressure pulsation than conventional gas pumps due to the pressure equalizing effect of the Whispair jet design. In conventional gas pumps, as the impeller opens up to the outlet port, the higher pressure gas in the discharge line rapidly expands into the lower pressure pocket formed by the impeller and the gas pump case. The resulting shock wave strikes the advancing surface of the impeller at sonic velocity. Four pressure pulses occur during each revolution transmitting shock loads to the gears and bearings.

LONGER BEARING LIFE – The pre-pressurization of the low pressure pocket through the Whispair jet smooths the pulsations and results in less shock being transmitted through the impellers to the bearings, resulting in approximately 20% longer bearing life.

LOWER VIBRATION – The reduction in the magnitude of the pressure pulsation results in smoother operation.

LOWER NOISE – The pressure pulses, inherent in the rotary-lobe design, are also the major source of gas pump noise. The rapid backflow of gas into the gas pump from the discharge line, four times per revolution, results in high noise levels in the conventional gas pump. The Whispair jet controls the backflow of gas into the gas pump, reducing noise by approximately 5 dBA.

HORSEPOWER – As the impeller passes the Whispair jet port, pressurized gas channeled in the direction of rotation strikes the backside of the impeller. The gas jet imparts energy to the impeller, aiding rotation and reducing the power required to drive the gas pump.

PRESSURE PULSES

Vertical or horizontal flow models are available. On horizontal flow units, the bottom shaft is extended for driving, and either right or left side discharge may be ordered. Vertical flow units have the right shaft extended for driving, and either top or bottom discharge may be ordered.

Available accessories include a baseplate for the gas pump and driver, V-belt or coupling drive with guard, bypass regulator, bypass cooler, inlet and discharge silencers, check valve, lube oil heater, auxiliary lube oil pump and expansion joints.

BASIC WHISPERS

RGS-J series Whispair gas pumps are heavy duty units for continuous service featuring a proprietary design that reduces noise, pulsation, and horsepower levels over conventional gas pumps. An exclusive wrap-around plenum and Whispair jet eliminate rapid backflow of gas into the gas pump from the dis-

charge area - a major problem with conventional gas pumps.

CASING - The gas pump casing is of one piece close-grained cast iron construction with separate headplates. The casing is suitably ribbed to prevent distortion under the most severe operating conditions and incorporates the Roots Whispair feature for re-

duced pulsation, noise and horsepower levels.

IMPELLERS - The impellers are made from ductile iron with a tensile strength of 60,000 PSI. They are statically and dynamically balanced by removing metal from the impeller body, and operate without liquid seals or lubrication.

SHAFTS - The gas pump shafts are alloy steel forgings flange connected to the impeller body

with high-tensile socket head capscrews. Self-adjusting face type mechanical seals are used at each bearing to prevent gas leakage.

SEAL SLEEVES - A seal sleeve is used under the drive shaft lip seal to prevent shaft wear. The sleeve is made of hard-chromed 300 series stainless steel with a hardness of 60 Rc.

TIMING GEARS - The impellers are timed by a pair of accurately machined forged steel gears that operate in an oil bath. The wide-faced spur gears are manufactured to AGMA standards, and are carburized and ground with a hardness of 58-60 Rc. The gears are secured to the shafts with a taper locking device providing an easily adjustable and releasable mechanical shrink fit. No shaft-weakening keyways or locking pins are required.

BEARINGS - The impeller/shaft assemblies are supported at each end by double row spherical roller bearings designed for long life. The thrust end bearings are fixed to control the axial location of the impeller assembly in the unit. An inboard bearing is used on 1000J thru 1400J frame size V-belt driven gas pumps to minimize drive shaft stresses.

LUBRICATION - The bearings and gears are lubricated by a positive pressure lubrication system completely mounted and piped on the gas pump unit. The lube system consists of an integral direct-driven oil pump, distribution piping, oil sump in the bottom of the gear housing, suction strainer, relief valve, oil pressure gauge, low oil pressure safety switch and oil cooler. Bearing life is extended by up to 50% through the use of cooled, pressurized lubrication.

TESTING - Each Roots rotary gas pump is given a complete mechanical run and one-point flow test at full speed and pressure to ensure mechanical integrity and verify performance. The units are operated at elevated pressure rise for a minimum of one hour after temperatures have stabilized. Flow, pressure and temperature readings are logged during the test, and each gas pump must meet suitable vibration levels in three different planes before being certified as acceptable.

FRAME SIZE	SPEED RPM	4 PSI		6 PSI		8 PSI		10 PSI		12 PSI		15 PSI		18 PSI		MAX. PRESS. RISE	MAX. VAC. IN. HG.
CFM	BHP	CFM	BHP	CFM	BHP	CFM	BHP	CFM	BHP	CFM	BHP	CFM	BHP	CFM	BHP		
1009J	1800	2007	55	1961	74	1922	92	1887	111	1856	129	1814	157	1687	185	24.4	16
1012J	1800	2676	67	2615	92	2562	117	2516	141	2475	166	2418	203	2249	240	18.3	16
1016J	1800	3752	86	3680	120	3621	154	3568	188	3543	205	3520	222			13.3	16
1018J	1800	4266	95	4185	134	4117	173	4057	211							11.7	16
1021J	1800	4781	105	4690	148	4614	191	4546	235							10.4	16
1024J	1800	5461	117	5358	167	5271	216									9.2	16
1030J	1800	6708	142	6552	204											7.3	15
1212J	1500	3238	82	3174	111	3120	141	3072	170	3028	200	2970	244	2797	289	22.0	16
1216J	1500	4354	102	4268	142	4195	182	4130	221	4072	261	3993	320			16.5	16
1220J	1500	5508	122	5418	171	5342	221	5275	270	5214	320					13.2	16
1222J	1500	6193	134	6092	190	6006	245	5931	301							11.7	16
1225J	1500	6892	147	6779	209	6684	270	6600	332							10.5	16
1228J	1500	7857	164	7728	235	7619	305									9.2	16
1236J	1500	9912	201	9749	290											7.3	15
1414J	1300	4680	116	4592	158	4518	200	4453	243	4394	285	4315	349	4243	412	21.2	16
1418J	1300	5976	139	5864	193	5770	247	5687	302	5611	356	5510	437			16.6	16
1422J	1300	7357	162	7243	228	7146	294	7061	360	6985	425					13.7	16
1425J	1300	8184	177	8057	250	7950	323	7855	397	7770	470					12.2	16
1428J	1300	9156	195	9014	276	8894	358	8789	440							11.0	16
1431J	1300	10300	215	10140	307	10005	399									9.8	16
1435J	1300	11455	236	11277	338	11127	440									8.8	16
1442J	1300	13741	277	13527	399											7.3	15
1616J	1130	5879	144	5772	197	5683	250	5604	303	5533	358	5436	436	5349	515	22.0	16
1620J	1130	7343	170	7210	236	7099	303	7000	369	6911	435	6791	535			17.6	16
1625J	1130	9184	203	9018	286	8878	369	8755	452	8644	535					14.0	16
1627J	1130	10049	217	9900	306	9774	396	9663	485	9563	575					13.0	16
1630J	1130	11162	236	10996	336	10856	435	10733	535							11.7	16
1633J	1130	12275	256	12093	366	11939	475	11804	586							10.6	16
1639J	1130	14511	296	14296	426	14114	555									9.0	16
1643J	1130	15995	323	15758	465	15558	608									8.2	16
1648J	1130	17861	356	17596	515											7.3	15
1821J	1000	8658	203	8507	278	8380	356	8268	434	8166	512	8029	629	7905	746	18.8	16
1824J	1000	9902	222	9729	312	9584	401	9455	490	9339	579	9182	713			16.5	16
1827J	1000	11127	245	10933	345	10769	445	10625	545	10495	646					14.6	16
1830J	1000	12521	267	12341	378	12190	490	12056	601	11936	713					13.2	16
1833J	1000	13978	293	13777	417	13608	542	13455	666							11.7	16
1841J	1000	17108	348	16863	501	16656	653									9.6	16
1845J	1000	18781	378	18512	545	18285	713									8.8	16
1849J	1000	20454	408	20161	590	19914	772									8.0	16
1854J	1000	22541	445	22218	646											7.3	15
2022J	900	10357	236	10191	327	10051	420	9927	513	9816	606	9664	745	9528	884	19.6	16
2026J	900	12197	268	12001	377	11836	486	11691	596	11559	705	11381	869			16.6	16
2033J	900	15606	325	15400	464	15226	602	15073	740	14934	878					13.0	16
2037J	900	17488	358	17237	513	17042	668	16870	823							11.7	16
2040J	900	18632	379	18386	544	18178	709	17995	874							11.0	16
2044J	900	20494	412	20223	593	19994	775	19793	957							10.0	16
2050J	900	23290	462	22982	668	22723	874									8.8	16
2055J	900	25619	503	25280	730											7.9	16
2060J	900	27948	544	27579	792											7.3	15

Ratings based on inlet gas at standard temperature of 68° F, ambient pressure of 14.7 psia and specific gravity of 1.0.
All specifications subject to change without notice.

DRESSER INDUSTRIES, INC.
ROOTS DIVISION
900 WEST MOUNT STREET, CONNERSVILLE, INDIANA 47331
TELEPHONE: 317/827-9200

S-5319

March, 1989

All specifications subject to change without notice

1. GENERAL

A. Seller's prices are based on these sales terms, and (i) this document together with any additional writings signed by Seller shall represent the final, complete and exclusive statement of the agreement between the parties and may not be modified, supplemented, explained or waived by parol evidence, Buyer's purchase order, a course of dealing, Seller's performance or delivery, or in any other way except in writing signed by an authorized representative of Seller, and (ii) these terms are intended to cover all activity of Seller and Buyer hereunder, including sales and use of products, parts and work and all related matters (references to products include parts and references to work include construction, installation and start-up). Any reference by Seller to Buyer's specification and similar requirements are only to describe the products and work covered hereby and no warranties or other terms therein shall have any force or effect. Catalogs, circulars and similar pamphlets of the Seller are issued for general information purposes only and shall not be deemed to modify the provisions hereof.

B. The agreement formed hereby and the language herein shall be subject to the laws in effect on the date hereof of the state in which any order resulting from this Proposal is accepted.

2. TAXES

Any sales, use or other similar type taxes imposed on this sale or on this transaction are not included in the price. Such taxes shall be billed separately to the Buyer. Seller will accept a valid exemption certificate from the Buyer if applicable; however, if an exemption certificate previously accepted is not recognized by the governmental taxing authority involved, and the Seller is required to pay the tax covered by such exemption certificate, Buyer agrees to promptly reimburse Seller for the Taxes paid.

3. CONTRACT PERFORMANCE, INSPECTION AND ACCEPTANCE

A. Unless Seller specifically assumes installation, construction or start-up responsibility, all products shall be finally inspected and accepted within thirty (30) days after receipt at point of delivery. Products not covered by the foregoing and all work shall be finally inspected and accepted within thirty (30) days after completion of the applicable work by Seller. All claims whatsoever by Buyer (including claims for shortage) excepting only those provided for under the WARRANTY and PATENTS Clauses hereof must be asserted in writing by Buyer within said thirty (30) day period or they are waived. If this contract involves partial performance, all such claims must be asserted within said thirty (30) day period for each partial performance. There shall be no revocation of acceptance. Rejection may be only for defects substantially impairing the value of products or work and Buyer's remedy for lesser defects shall be those provided for under the WARRANTY Clause.

B. Shipping dates are approximate and are based upon prompt receipt of all necessary information. Seller shall not be responsible for nonperformance or delays in performance occasioned by any causes beyond Seller's reasonable control, including, but not limited to, labor difficulties, delays of vendors or carriers, fires, governmental actions and material shortages. Any so occasioned shall effect a corresponding extension of Seller's performance dates which are, in any event, understood to be approximate. In no event shall Buyer be entitled to incidental or consequential damages for late performance or a failure to perform.

4. RISK OF LOSS

Full risk of loss (including transportation delays and losses) shall pass to the Buyer upon delivery of products to the f.o.b. point or if Seller consents to a delay in shipment beyond the contract date at the request of the Buyer, upon notification by the Seller that the products are manufactured.

5. TITLE

The title to and property in all apparatus sold hereunder and any substitutions or additions thereto and the right to possession thereof whether attached to realty or otherwise shall not pass from the Seller until all payments as herein set forth have been fully made by the Buyer in cash. Upon failure to make any payment as herein provided, the whole purchase money and any note or security given on account thereof shall forthwith become due and payable and the Seller may immediately enter the premises where the said apparatus is located and take possession of and remove the same as its personal property and may retain any or all partial payments already received as a rental charge for the use of the said apparatus and material without affecting any further or other claims which it may have against the Buyer. The Buyer agrees to do all acts necessary to perfect and maintain such right and title in the Seller.

6. WARRANTY

A. Seller warrants that its products and parts when shipped and its work (including installation, construction and start-up) when performed will meet all applicable specifications and other specific product and work requirements (including those of performance), if any, of this agreement, will be of good quality and will be free from defects in material and workmanship. All claims for defective products or parts under this warranty must be made in writing immediately upon discovery and, in any event, within one (1) year from start-up or eighteen (18) months from shipment of the applicable item, whichever occurs first. Defective items must be held for Seller's inspection and returned to the original f.o.b. point upon request. THE FOREGOING IS EXPRESSLY IN LIEU OF ALL OTHER WARRANTIES WHATSOEVER, EXPRESS, IMPLIED AND STATUTORY, INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS.

B. Upon Buyer's submission of a claim as provided above and its substantiation, Seller shall at its option either (i) repair or replace its product, part or work at the original f.o.b. point of delivery, or (ii) refund an equitable portion of the purchase price.

C. The warranty specified herein shall apply to this contract, but it is specifically understood that products sold hereunder are not warranted for operation with erosive or corrosive fluids or those which may tend to buildup within the product quoted. No product or part shall be deemed to be defective by reason of failure to resist erosive or corrosive action of any fluid and Buyer shall have no claim whatsoever against Seller therefore nor for problems resulting from buildup of material within the unit.

D. The foregoing is Seller's only obligation and Buyer's exclusive remedy for breach of warranty, and except for gross negligence, willful misconduct and remedies permitted under the CONTRACT PERFORMANCE, INSPECTION AND ACCEPTANCE and the PATENTS Clause hereof, the foregoing is Buyer's exclusive remedy hereunder by way of breach of contract, tort or otherwise. In no event shall Buyer be entitled to incidental or consequential damages. Any action for breach of this agreement must commence within two (2) years after the cause of action has accrued.

7. PATENTS

Seller agrees to assume the defense of any suit for infringement of any United States patents brought against Buyer to the extent such suit charges infringement of an apparatus or product claim by Seller's product in and of itself, provided (i) said product is built entirely to Seller's design, (ii) Buyer notifies Seller in writing of the filing of such suit within ten (10) days after the service of process thereof, and (iii) Seller is given complete control of the defense of such suit, including the right to defend, settle and make changes in the product for the purpose of avoiding infringement. Seller assumes no responsibility for charges of infringement of any process or method claims, unless infringement of such claims is the result of following specific instructions furnished by Seller.

8. TERMS OF PAYMENT

A. Unless other terms are specified, all payment shall be in U.S. dollars. All shipments, unless otherwise specified, shall be F.O.B. manufacturer's plant. If delivery is delayed by Buyer, date of readiness for delivery shall be deemed date of delivery for payment purposes. If manufacture is delayed by Buyer, a payment shall be due based upon purchase price and percentage of completion. Balance payable in accordance with terms stated herein.

B. For contracts totalling less than \$100,000 U.S. dollars, all payment shall become due thirty (30) days after shipment.

C. For contracts totalling \$100,000 U.S. dollars and greater, special progress payments, as offered by Seller, shall apply. In cases where special terms are not proposed, final payment shall become due thirty (30) days after shipment.

(a) In the event any equipment is ready for shipment prior to the scheduled date, any payment not due in accordance with the above terms shall immediately become due and payable upon notification by Seller to Buyer that the equipment is ready for shipment.

(b) If shipments are delayed by Buyer for any cause whatsoever or are delayed by Seller for any cause whatsoever beyond Seller's control, payments shall become due and payable from the date of notification by Seller and the equipment is ready for shipment.

D. Seller may, at its option, upon Buyer's default in payment hereunder, charge Buyer with any cost incurred by Seller incidental to its collection efforts including without limitation, reasonable attorney's fees and court costs.

E. A service fee equal to 2% percent per month shall be charged on all arrearages not received by the specified due date in order to recover costs and damages incurred as a result of the delay in payment.

9. LIMITATION OF LIABILITY

In no event shall Seller be liable for special, indirect or consequential damages whether for breach of contract, breach of warranty, tort or otherwise. The Seller's liability on any other claim for loss or liability arising out of or connected with this contract, or the manufacture, sale, delivery, resale, or use of any apparatus covered by this contract (including but not limited to loss or liability arising from breach of contract), shall in no case exceed the unit price of such apparatus or part thereof involved in the claim, except as provided in the paragraph entitled 'Patents'.

SCHEDULE OF RATES

A. For services involving DOMESTIC locations. Buyer shall pay for such services at the following rates:

1. Field Service Representative	2. Engineering Personnel
Monday thru Friday - except holidays:	Monday thru Friday - except holidays:
First 8 hours \$640	First 8 hours \$872
All over 8 hours \$120/hour	All over 8 hours \$163/hour
Saturday:	Saturday:
All hours \$120/hour	All hours \$163/hour
Sunday and locally recognized holidays:	Sunday and locally recognized holidays:
All hours \$120/hour	All hours \$163/hour
3. Emergency Work - The minimum time off for a person during any 24-hour period must be 8 consecutive hours.
 4. Travel time will be charged at the specified based rates for up to a maximum of 8 hours per day for each day of travel on domestic assignments. Monday through Saturday, from the Field Service Representative's or Engineering Personnel's residence (or other point of origin) to jobsite and return to his point of origin. The charge for travel on Sundays and holidays will be at the specified over-time rate applicable for Engineers or Field Service Representatives.
 5. Standby Time - Any waiting time at the jobsite Monday through Friday when the person is available to work shall be regarded as time actually worked, even though the services are not actually utilized, and will be charged at the 8-hour daily rate.
 6. Engineering equipment charges and instrument rental as quoted.

B. For services involving FOREIGN locations, all payments shall be in U.S. funds unless otherwise agreed. Buyer shall pay for such services at the following rates:

1. Field Service Representative	2. Engineering Personnel
Per 8-hour day \$823	Per 8-hour day \$1,007
Next 4 hours \$154/hour	Next 4 hours \$189
3. Travel time will be charged at the specified 8-hour per day minimum. All travel time (8 hours maximum) on Sundays and U.S. holidays will be twice the daily rate when leaving basing point.
 4. These rates apply from date of departure home base to date of return home base. Service personnel assignments will not exceed 60 continuous days. Rotation of Service personnel will be at Buyer's expense.
 5. Engineering equipment charges and instrument rental as quoted.

C. Expenses

1. Meals, lodging, and incidental expenses will be charged as cost incurred.
2. Transportation to and from the city nearest the jobsite, plus local transportation (rental car or company car) will be charged at cost. Mileage from personal car will be allowed at the rate of 26¢ per mile.
3. Outside incidental services will be priced at cost plus 10%.

DRESSER INDUSTRIES, INC., ROOTS DIVISION

GENERAL TERMS OF SALE - TECHNICAL SERVICES

DRESSER INDUSTRIES, INC. (HEREINAFTER CALLED "SELLER" IN RENDERING ANY SERVICE DOES SO UNDER THE INSTRUCTIONS OF THE CUSTOMER (HEREINAFTER CALLED "BUYER"). BUYER IS AT ALL TIMES IN COMPLETE CARE, CUSTODY AND CONTROL OF ALL MACHINERY, EQUIPMENT AND ADJACENT PREMISES.

1. GENERAL

A. SCOPE Seller's Terms shall apply only to its sale of advisory services and procedures, incidental to the installation, overhaul, inspection or conversion of Buyer's equipment as such terms shall be hereinafter defined, wherein such work shall (a) be performed by Buyer's personnel under its sole care, custody and control, or (b) by Seller's personnel under the direction and control of Buyer's personnel.

For the purposes of this section, (1) "installation" shall mean the installation of Buyer's equipment at its intended operational location (including, without limitation, such equipment's on-site testing and operational start-up); (2) "overhaul" shall mean the inspection of same and replacement of all parts and components in Seller's opinion of marginal serviceability; (3) "inspection" shall mean the visual or device-assisted examination of Buyer's equipment at its operational location; (4) "modification" shall mean the making of minor alterations to Buyer's equipment, with view to improving its serviceability within original specifications (normally with improvements in "the state of the art" since equipment's original delivery); and (5) "conversion" shall mean the making of major alterations to same with view to enhancing its performance beyond original operating specifications. These Terms shall not apply to Seller's sale of Factory or Shop services incidental to its repair, overhaul, modification, conversion or revamp of Buyer's equipment at Seller's Factory or Shop or Seller's sale of parts for any purpose, which are covered under separate Terms of Sale.

B. Seller's prices are based on these sales terms and (i) this document, together with any additional writings signed by Seller, shall represent the final, complete and exclusive statement of the agreement between the parties and may not be modified, supplemented, or explained or waived by parol evidence, Buyer's purchase order, a course of dealing, Seller's performance, or in any other way except in writing signed by an authorized representative of Seller, and (ii) these terms are intended to cover all activity of Seller and Buyer hereunder. Any reference by Seller to Buyer's specifications and similar requirements are only to describe the services covered hereby and no warranties or other terms therein shall have any force or effect. Catalogs, circulars and similar pamphlets of Seller are issued for general information purposes only and shall not be deemed to modify the provisions thereof.

C. The agreement formed hereby and the language herein shall be construed and enforced under the laws of the State of Indiana, U.S.A.

2. TAXES

Any sales, use or other similar type taxes imposed on this transaction are not included in this price. Such taxes shall be itemized separately to Buyer. Seller will accept a valid exemption certificate from Buyer if applicable, however, if an exemption certificate previously accepted is not recognized by the governmental taxing authority involved and Seller is required to pay the tax covered by such exemption certificate, Buyer agrees to promptly reimburse Seller for the taxes paid.

3. CONTRACT PERFORMANCE, INSPECTION AND ACCEPTANCE

A. All services shall be finally inspected and accepted promptly upon completion thereof and before Seller's employees leave Buyer's premises. All claims whatsoever by Buyer, excepting only those provided for under the WARRANTY AND LIMITATION OF LIABILITY Clause hereof, must be asserted in writing by Buyer before Seller's employees leave Buyer's premises or they are waived. If this agreement involves partial performances, all such claims must be asserted before such leaving, as to each partial performance. There shall be no revocation of acceptance.

Rejection may be only for defects substantially impairing the value of the services and Buyer's remedy for lesser defects shall be that provided for under the WARRANTY AND LIMITATION OF LIABILITY Clause.

B. Seller shall not be responsible for nonperformance or delays in performance occasioned by any causes beyond Seller's reasonable control, including but not limited to labor difficulties, delays of vendors or carriers, fire, governmental actions and material shortages. Any delays so occasioned shall effect a corresponding extension of Seller's performance dates which are in any event understood to be approximate. In no event shall Buyer be entitled to incidental or consequential damages for late performance or a failure to perform.

NOTICE Dresser Industries, Inc. values highly the confidence and good will of its customers and suppliers. We offer our products and services only on their merit, and we expect our customers to judge and purchase our products and services solely on the basis of quality, price, delivery and service. This Dresser Corporate policy applies to all relationships with our customers and suppliers.

4. WARRANTY AND LIMITATION OF LIABILITY

A. Seller warrants that its services when furnished will meet all specific requirements of this agreement, will be of good quality and will be responsibly rendered. All claims for defective services under this warranty must be made in writing immediately upon discovery and, in any event, within 90 days from the furnishing of the applicable service. Damaged items must be held for Seller's inspection. EXCEPTION ONLY WARRANTY OF TITLE. THE FOREGOING IS EXPRESSLY IN LIEU OF ALL OTHER WARRANTIES WHATSOEVER, EXPRESS, IMPLIED AND STATUTORY, INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS.

B. Upon Buyer's submission of a claim as provided above and its substantiation, Seller shall, at its option, refund an equitable portion of this price.

C. The foregoing is Seller's only obligation and Buyer's exclusive remedy for breach of warranty and, except for gross negligence, willful misconduct and remedies permitted under the PERFORMANCE, INSPECTION AND ACCEPTANCE Clauses hereof, the foregoing is Buyer's exclusive remedy hereunder by way of breach of contract, tort, including negligence and strict product liability or other theories. In no event shall Buyer be entitled to incidental or consequential damages. Any action for breach of this agreement must be commenced within one (1) year after the cause of action has accrued.

5. BUYER'S RESPONSIBILITY

A. Seller's employees shall have free and unobstructed access to the site of the work. Buyer shall preserve and adequately maintain parts and tools necessary to the completion of Seller's work, and Buyer shall furnish safe and proper working conditions and safe storage for Seller's property related to Seller's services during the term of its need therefor. When delays in the work are caused by Buyer, the time and expense caused by the delay will be charged to Buyer. Buyer shall furnish all necessary cranes, tools, parts, material, supplies, steam, electricity, gas, oil, water, and other material and supplies required to repair and operate the machinery. Seller shall not be responsible for any material or supplies furnished by Buyer or for workmanship, acts or omissions of the employees, subcontractors or agents of Buyer. Buyer understands Seller's employees' responsibility is limited to furnishing technical advice and such responsibility does not extend to supervision of Buyer's employees, subcontractors or agents.

B. Buyer understands and agrees, with respect to the performance of Seller or its employees or representatives of active services, that such employees or representatives, in the course of such work shall be treated as Buyer's servants in all respects, and that Buyer shall be solely responsible therefore without the liability of Seller therefore in any respect.

6. CHARGES

A. Rates quoted are subject to adjustment without notice to conform to Seller's published rates in effect at the time service is performed.

B. Invoices are due for payment upon receipt. A service charge of 1 1/2% per month (18% per annum) from the date of invoice will be charged on all unpaid balances, six (6) days after date of invoice. Such service charge payments shall not waive any other Seller's rights, but shall be cumulative.

C. Seller's personnel will provide Buyer's representative at the jobsite one copy of his weekly time sheet. A ten percent (10%) charge to the Seller's actual hourly billing for the week(s) in question will be made if any copies of expense sheets or copies of receipts are required by Buyer.

D. For services involving foreign locations, all payments shall be in U.S. funds unless otherwise agreed.

E. Travel and living expenses will be priced at cost.

F. Outside incidental services and material will be priced at cost plus 15%.

DRESSER INDUSTRIES, INC.
ROOTS BLOWER OPERATION
900 WEST MOUNT ST., CONNERSVILLE, INDIANA 47331

CANCELLATION CHARGES POLICY

In the event that purchaser cancels this contract for any reason after receipt at the factory and prior to shipment, the following cancellation charges will be applied:

ITEMS	CHARGES
1. STANDARD (RESTOCKABLE) 8" GEAR DIAMETER & SMALLER ROTARY BLOWERS OR GAS PUMPS & RENEWAL PARTS: BASIS	
A. Within 30 days of purchase order	No Charge
B. After 30 days	15%
2. ALL OTHER ROOTS PRODUCTS (INCLUDING 8" GEAR DIAMETER AND SMALLER PACKAGES), REPAIRS OR PARTS: BASIS	
A. Within 30 days of purchase order	10%
B. After 30 days	On straight line basis of 10% at 30 days to 100% at 30 days prior to scheduled shipment.

3. MAJOR PURCHASED ITEMS:	Charges presented by Roots' vendor(s) plus 15%

NOTE:

A minimum charge of \$75 will apply to any cancellation for other than category 1.A.

OSHA SUPPLEMENT TO PROPOSALS AND ORDER ACKNOWLEDGEMENTS

ROOTS**DRESSER**

Customer Name _____
Roots Proposal Number and Date _____
Customer Order Number and Date _____
Roots Order Number and Date _____

The following outlines Roots' position with respect to furnishing equipment in compliance with the Williams-Steiger Occupational Safety and Health Act of 1970. Roots expressly limits statements of compliance to only those standards as set forth below which are in effect on the date of this order.

Of this Act, we recognize only the following four (4) areas which apply to us as a supplier.

NOISE: (Subject G, Section 1910.95)

OSHA incorporates the Walsh-Healey Act as its standard for acceptable noise levels in the actual operating environment. In view of this Act applying to allowable noise level as a function of exposure time irrespective of the environmental conditions or distance from the noise source, Roots will not accept responsibility for compliance since we obviously lack control of those factors.

However, upon request, Roots will provide estimated noise levels for our equipment, and we will consider reviewing and negotiating specific conditions under which we can guarantee compliance.

DRIVE GUARDS: (Subpart O, Section 1910.219)

Drive guards, when furnished by Roots, will comply with the requirements of OSHA

However, Roots accepts no responsibility to furnish guards if not specified as part of the customer's purchase order.

Rotating components of equipment furnished by Roots will not be color-coded per OSHA requirements as this remains the responsibility of the user, as does the furnishing of warning signs, tags, etc.

ELECTRICAL: (Subpart S)

All electrical apparatus furnished by ROOTS will comply with OSHA provided that applicable information (including enclosure requirements) is supplied us by the customer.

For explosion-proof enclosures, we must be provided with the NEC (National Electrical Code) classification of the hazardous areas in which the equipment is to be installed.

AIR RECEIVERS: (Subpart M, Section 1910.169)

Air receivers for purpose of compliance with OSHA are defined by Roots as silencers, receivers, separators or aftercoolers to be installed in the system where operation above 15 psig is required. The compressor itself is not considered an air receiver for purposes intended herein.

Safety valves, indicating and control devices furnished by Roots will be in compliance with OSHA.

Under no circumstances will Roots be responsible for interpreting equipment requirements under OSHA merely on the basis of customer's specified intended service, or blanket notation that all supplied equipment must meet OSHA requirements.

Any representations or warranties herein are subject to the Warranty and Limitation of Liability provision contained in Roots' Proposal and/or Order Acknowledgement.

Signed _____ Date _____

NOTE:

When using this form in conjunction with a customer order acknowledgement, type "Form OSHA-5003 attached" on face of acknowledgement, attaching Form OSHA-5003, and place copy of Form OSHA-5003 in internal records.

PRICE ADJUSTMENT CLAUSE

ROOTS**DRESSER**

NOTE: This clause applies only to contracts that are based on the normal manufacturing schedule of the Roots Operations of Dresser Industries, Inc.

A. GENERAL POLICY

1. Prices stated herein on equipment manufactured by Seller that can be factory scheduled for shipment within six months from date of order will be firm priced based on prices in effect at time of booking.
2. All units that are factory scheduled or customer requested for shipment beyond six months from date of order will be subject to price in effect at time of shipping for pricebook products or in accordance to terms of section B for non-pricebook products.
3. All parts will be subject to price in effect at time of shipment.
4. Any customer-caused delays from the originally scheduled shipping date will automatically place the order on "price in effect" status.
5. Any significant surcharges on buy out items will be passed along to the customer at net.

B. FOR NON-PRICEBOOK PRODUCTS

The final price is subject to adjustment to compensate for changes in Seller's material and labor costs from the "Base Index Month". In no event will the final price be less than the contract price. This adjustment shall be determined from Bureau of Labor Statistics data as herein provided.

1. DEFINITIONS

For the purpose of this provision, the following definitions apply.

- a. The "Labor Index" shall be the Average Hourly Earnings Index for the Blower and Fans Industry (SIC 3564) as determined and reported monthly by the Bureau of Labor Statistics, U.S. Department of Labor.
- b. The "Materials Index" shall be "Foundry and Forge Shop Products" (W.P.I. Code No. 1015) as determined and reported monthly by the Bureau of Labor Statistics, U.S. Department of Labor.
- c. The "Base Index Month" shall be the month that the proposal is issued.
- d. The "Basic Labor Index" shall be the "Labor Index" for the "Base Index Month."
- e. The "Basic Material Index" shall be the "Material Index" for the "Base Index Month."

2. ADJUSTMENTS FOR COSTS

- a. For the purpose of price adjustment, 10% of the contract price shall be fixed, 55% of the contract price and of each payment made on account thereof shall be deemed to represent the material content and 35% of the contract price and of each payment made on account thereof shall be deemed to represent the labor content.
- b. The labor and material content shall be adjusted for any upward changes in the respective index. The price adjustment for labor shall be equal to the percent by which the index for the month of actual shipment is greater than the "Base Index Month." The price adjustment for material shall be equal to the percent by which the index for the month equal to 3/4 of the actual shipment is greater than the "Base Index Month."

3. EXCUSABLE DELAYS

Seller will notify Buyer promptly of any material delay and will specify the revised delivery date as soon as practicable. Seller shall not be liable for delays in delivery or performance or for failure to manufacture, deliver, or perform due to (i) causes beyond its reasonable control, or (ii) acts of God, acts of Buyer, acts of civil military authority, governmental priorities, strikes, or other labor disturbances, floods, epidemics, war, riot, delays in transportation or car shortages or (iii) inability on account of causes beyond the reasonable control of Seller to obtain necessary materials, labor, components, services, or facilities. In event of any such delay, there will be no termination and the date of shipment shall be extended for a period equal to the time lost by reason of the delay, and the price adjusted from the "Base Index Month" in accordance with Bureau of Labor Statistics described herein.

C. GENERAL

- a. In the event any change in the contract specifications prior to actual shipment results in a change in contract price, the new price shall be considered as having been in effect since the "Base Index Month."
- b. In the event price adjustment is to be applied to a contract involving progress payments, the total adjustment to the contract price will be applied and invoiced on the final payment.
- c. Both labor and material adjustments shall be calculated to the nearest one-tenth of one percent.
- d. Should the indexes specified in Paragraphs 1a and 1b be discontinued, or should the basis of their calculation be modified, Seller, after consulting with Buyer, shall select other indexes or another method of cost adjustment which, in Seller's judgment, will result in an equitable adjustment of the contract price.
- e. Price increases received from our suppliers of Accessory equipment will be directly passed along, regardless of contract duration, with no further mark-up by Seller.
- f. The final price, as adjusted, will not exceed the authorized price in effect at date of actual shipment and shall be in accordance with such, if any, Economic Stabilization Program requirements and regulations of the Cost of Living Council as may then be applicable.

CROSS SECTION
RGS-J BLOWER

ROOTS

- 1. One Piece Cylinder
- 2. Impellers and Shafts
- 3. Headplates
- 4. Double Row, Spherical Bearings
- 5. Wide Face, Spur Timing Gear

- 6. Self Contained Pressure Lubrication System
- 7. Self Adjusting, Face-Type Mechanical Seals
- 8. Self-Contained Oil Pump
- 9. Oil Cooler

The pressure lubrication system for Roots blowers and gas pumps is completely mounted and piped on the unit. The lube system consists of an integral direct driven oil pump, distribution piping, oil sump in the bottom of the gear housing, suction strainer, relief valve, pressure gauge, water-cooled oil cooler, and a cartridge type filter for the gas pump. A vent space between the labyrinth and oil seals protect against oil contamination of the gas being handled.

The optional auxiliary oil pump system includes a motor driven oil pump, pressure relief valve, check valve, start/stop pressure switch for motor, and a low oil pressure switch.

Available options include: high oil temperature switch, oil heater, temperature indicator on the cooler discharge, air-cooled oil cooler, dual filters, and dual coolers.

CROSS SECTION
MECHANICAL SEAL

ROOTS

DRESSER

ITEM	PART	STANDARD MATERIAL
1	Floating Seat Ring	Ni-Resist
2	"O" Ring	Viton
3	Sealing Washer	Impregnated Carbon Graphite
4	"O" Ring	Viton
5	Retainer	Plated Steel
6	Springs	Stainless Steel (18-8)
7	Disc	Plated Steel
8	Driving Pin	Stainless Steel (302/3)

RECOMMENDED INSTALLATION DIAGRAM

SINGLE UNIT

1. ROOTS WHISP AIR BLOWER
2. INLET SILENCER
3. DISCHARGE SILENCER
4. INLET STAINLESS STEEL EXPANSION JOINT
5. DISCH. STAINLESS STEEL EXPANSION JOINT
6. BACK PRESSURE REGULATOR
7. BY-PASS VALVE
8. BY-PASS COOLER
9. START-UP VENT VALVE
10. CHECK VALVE
11. INLET WATER SPRAY VALVE
12. DISCH. SILENCER DRAIN
13. BLOWER HEADPLATE DRAIN
14. CASING DRAIN
15. INLET SILENCER DRAIN
16. HIGH WATER LEVEL SWITCH
17. DIFFERENTIAL PRESSURE SWITCH
18. INLET VACUUM SWITCH
19. DISCHARGE PRESSURE SWITCH
20. DISCH. PRESS. GAUGE
21. INLET PRESS./VAC. GAUGE
22. DIFFERENTIAL TEMP. SWITCH
23. TEMPORARY SCREEN

NOTE 1: LINES (12), (13), (15) MUST BE CONTINUOUSLY DRAINED, CONNECTED TO BAROMETRIC SEAL OR AUTOMATIC DRAINAGE SYSTEM. EACH LINE WILL BE UNDER DIFFERENT PRESSURE/VACUUM LEVELS.

INSTALLATION WITH ACCESSORIES
FOR STEAM SERVICE

STANDARD MECHANICAL TEST

A mechanical test will be performed for a minimum of one hour after stabilization at conditions near the design ratings.

After the unit has reached stabilization on the mechanical test, a one point factory flow test using a rotary meter on the inlet will be conducted (except Vj models).

CERTIFIED PERFORMANCE TEST (Available At Price Addition)

Certified performance test in accordance with ASME Power Test Code (latest revision) can be conducted at an additional charge. Volume will be measured by a low pressure nozzle or a rotary positive displacement meter. Power consumption will be measured by a calibrated wattmeter on the input to a calibrated test motor. A test report confirming capacity and power will be furnished complete with data and calculations.

While ASME PTC does not allow for water-sealed vacuum blower performance tests; a test can be performed on the VJ which generally meets the intent of the PTC.

WITNESS TEST

All tests may be witnessed by a representative of the purchaser if the witness is available at the scheduled testing time. A price addition will be required to hold equipment on the test floor awaiting arrival of witness.

ROOTS**DRESSER**

Date: August 14, 1991

price for one (1) 1428 RGS J Steam Compressor, complete with the items listed
in this proposal, less motor, is \$ 81,750.00.

Additional Pricing

500 HP, TEFC, 460/60/3 Motor \$ 10,750.00
500 HP, explosion-proof, 460/60/3 Motor \$ 13,350.00

Prices are Net 30 Days.

Prices are F.O.B. factory, Connersville, Indiana.

Delivery is estimated at 18 - 20 weeks after receipt of order and complete
engineering details with release to proceed with manufacture.

Rated weight is 18,000 lbs.

Operating Condition (30 PSIA Discharge)

price for one (1) 1821 RGS-J Steam Compressor, complete with the items listed
in this proposal, less motor, is \$107,500.00.

Additional Pricing

500 HP, TEFC, 460/60/3 Motor \$ 28,850.00
500 HP, explosion-proof, 460/60/3 Motor \$ 41,200.00

Following attached forms apply to this proposal:

General Terms of Sale	GTS-5001
Schedule of Rates	TS-5000-1
General Terms of Sale - Technical Services	TS-5000-2
Cancellation Charges Policy	CP-5004
OSHA Supplement	OSHA-5003
Price Adjustment Clause	PA1-5000

ROOTS

DRESSER

1. GENERAL

A. Seller's prices are based on these sales terms, and (i) this document together with any additional writings signed by Seller shall represent the final, complete and exclusive statement of the agreement between the parties and may not be modified, supplemented, explained or waived by parol evidence, Buyer's purchase order, a course of dealing, Seller's performance or delivery, or in any other way except in writing signed by an authorized representative of Seller, and (ii) these terms are intended to cover all activity of Seller and Buyer hereunder, including sales and use of products, parts and work and all related matters (references to products include parts and references to work include construction, installation and start-up). Any reference by Seller to Buyer's specification and similar requirements are only to describe the products and work covered hereby and no warranties or other terms therein shall have any force or effect. Catalogs, circulars and similar pamphlets of the Seller are issued for general information purposes only and shall not be deemed to modify the provisions hereof.

B. The agreement formed hereby and the language herein shall be subject to the laws in effect on the date hereof of the state in which any order resulting from this Proposal is accepted.

2. TAXES

Any sales, use or other similar type taxes imposed on this sale or on this transaction are not included in the price. Such taxes shall be billed separately to the Buyer. Seller will accept a valid exemption certificate from the Buyer if applicable; however, if an exemption certificate previously accepted is not recognized by the governmental taxing authority involved, and the Seller is required to pay the tax covered by such exemption certificate, Buyer agrees to promptly reimburse Seller for the Taxes paid.

3. CONTRACT PERFORMANCE, INSPECTION AND ACCEPTANCE

A. Unless Seller specifically assumes installation, construction or start-up responsibility, all products shall be finally inspected and accepted within thirty (30) days after receipt at point of delivery. Products not covered by the foregoing and all work shall be finally inspected and accepted within thirty (30) days after completion of the applicable work by Seller. All claims whatsoever by Buyer (including claims for shortage) excepting only those provided for under the WARRANTY and PATENTS Clauses hereof must be asserted in writing by Buyer within said thirty (30) day period or they are waived. If this contract involves partial performance, all such claims must be asserted within said thirty (30) day period for each partial performance. There shall be no revocation of acceptance. Rejection may be only for defects substantially impairing the value of products or work and Buyer's remedy for lesser defects shall be those provided for under the WARRANTY Clause.

B. Shipping dates are approximate and are based upon prompt receipt of all necessary information. Seller shall not be responsible for nonperformance or delays in performance occasioned by any causes beyond Seller's reasonable control, including, but not limited to, labor difficulties, delays of vendors or carriers, fires, governmental actions and material shortages. Any so occasioned shall effect a corresponding extension of Seller's performance dates which are, in any event, understood to be approximate. In no event shall Buyer be entitled to incidental or consequential damages for late performance or a failure to perform.

4. RISK OF LOSS

Full risk of loss (including transportation delays and losses) shall pass to the Buyer upon delivery of products to the f.o.b. point or if Seller consents to a delay in shipment beyond the contract date at the request of the Buyer, upon notification by the Seller that the products are manufactured.

5. TITLE

The title to and property in all apparatus sold hereunder and any substitutions or additions thereto and the right to possession thereof whether attached to realty or otherwise shall not pass from the Seller until all payments as herein set forth have been fully made by the Buyer in cash. Upon failure to make any payment as herein provided, the whole purchase money and any note or security given on account thereof shall forthwith become due and payable and the Seller may immediately enter the premises where the said apparatus is located and take possession of and remove the same as its personal property and may retain any or all partial payments already received as a rental charge for the use of the said apparatus and material without affecting any further or other claims which it may have against the Buyer. The Buyer agrees to do all acts necessary to perfect and maintain such right and title in the Seller.

6. WARRANTY

A. Seller warrants that its products and parts when shipped and its work (including installation, construction and start-up) when performed will meet all applicable specifications and other specific product and work requirements (including those of performance), if any, of this agreement, will be of good quality and will be free from defects in material and workmanship. All claims for defective products or parts under this warranty must be made in writing immediately upon discovery and, in any event, within one (1) year from start-up or eighteen (18) months from shipment of the applicable item, whichever occurs first. Defective items must be held for Seller's inspection and returned to the original f.o.b. point upon request. THE FOREGOING IS EXPRESSLY IN LIEU OF ALL OTHER WARRANTIES WHATSOEVER, EXPRESS, IMPLIED AND STATUTORY, INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS.

B. Upon Buyer's submission of a claim as provided above and its substantiation, Seller shall at its option either (i) repair or replace its product, part or work at the original f.o.b. point of delivery, or (ii) refund an equitable portion of the purchase price.

C. The warranty specified herein shall apply to this contract, but it is specifically understood that products sold hereunder are not warranted for operation with erosive or corrosive fluids or those which may tend to buildup within the product quoted. No product or part shall be deemed to be defective by reason of failure to resist erosive or corrosive action of any fluid and Buyer shall have no claim whatsoever against Seller therefore nor for problems resulting from buildup of material within the unit.

D. The foregoing is Seller's only obligation and Buyer's exclusive remedy for breach of warranty, and except for gross negligence, willful misconduct and remedies permitted under the CONTRACT PERFORMANCE, INSPECTION AND ACCEPTANCE and the PATENTS Clause hereof, the foregoing is Buyer's exclusive remedy hereunder by way of breach of contract, tort or otherwise. In no event shall Buyer be entitled to incidental or consequential damages. Any action for breach of this agreement must commence within two (2) years after the cause of action has accrued.

7. PATENTS

Seller agrees to assume the defense of any suit for infringement of any United States patents brought against Buyer to the extent such suit charges infringement of an apparatus or product claim by Seller's product in and of itself, provided (i) said product is built entirely to Seller's design, (ii) Buyer notifies Seller in writing of the filing of such suit within ten (10) days after the service of process thereof, and (iii) Seller is given complete control of the defense of such suit, including the right to defend, settle and make changes in the product for the purpose of avoiding infringement. Seller assumes no responsibility for charges of infringement of any process or method claims, unless infringement of such claims is the result of following specific instructions furnished by Seller.

8. TERMS OF PAYMENT

A. Unless other terms are specified, all payment shall be in U.S. dollars. All shipments, unless otherwise specified, shall be F.O.B. manufacturer's plant. If delivery is delayed by Buyer, date of readiness for delivery shall be deemed date of delivery for payment purposes. If manufacture is delayed by Buyer, a payment shall be due based upon purchase price and percentage of completion. Balance payable in accordance with terms stated herein.

B. For contracts totalling less than \$100,000 U.S. dollars, all payment shall become due thirty (30) days after shipment.

C. For contracts totalling \$100,000 U.S. dollars and greater, special progress payments, as offered by Seller, shall apply. In cases where special terms are not proposed, final payment shall become due thirty (30) days after shipment.

(a) In the event any equipment is ready for shipment prior to the scheduled date, any payment not due in accordance with the above terms shall immediately become due and payable upon notification by Seller to Buyer that the equipment is ready for shipment.

(b) If shipments are delayed by Buyer for any cause whatsoever or are delayed by Seller for any cause whatsoever beyond Seller's control, payments shall become due and payable from the date of notification by Seller and the equipment is ready for shipment.

D. Seller may, at its option, upon Buyer's default in payment hereunder, charge Buyer with any cost incurred by Seller incidental to its collection efforts including without limitation, reasonable attorney's fees and court costs.

E. A service fee equal to 2% percent per month shall be charged on all amounts not received by the specified due date in order to recover costs and damages incurred as a result of the delay in payment.

9. LIMITATION OF LIABILITY

In no event shall Seller be liable for special, indirect or consequential damages whether for breach of contract, breach of warranty, tort or otherwise. The Seller's liability on any other claim for loss or liability arising out of or connected with this contract, or the manufacture, sale, delivery, resale, or use of any apparatus covered by this contract (including but not limited to loss or liability arising from breach of contract), shall in no case exceed the unit price of such apparatus or part thereof involved in the claim, except as provided in the paragraph entitled 'Patents'.

SCHEDULE OF RATES

A. For services involving DOMESTIC locations, Buyer shall pay for such services at the following rates:

<p>1. Field Service Representative
 Monday thru Friday - except holidays:
 First 8 hours \$640
 All over 8 hours \$120/hour</p> <p>Saturday:
 All hours \$120/hour</p> <p>Sunday and locally recognized holidays:
 All hours \$120/hour</p> | <p>2. Engineering Personnel
 Monday thru Friday - except holidays:
 First 8 hours \$872
 All over 8 hours \$163/hour</p> <p>Saturday:
 All hours \$163/hour</p> <p>Sunday and locally recognized holidays:
 All hours \$163/hour</p> |
|---|--|
3. Emergency Work - The minimum time off for a person during any 24-hour period must be 8 consecutive hours.
 4. Travel time will be charged at the specified based rates for up to a maximum of 8 hours per day for each day of travel on domestic assignments. Monday through Saturday, from the Field Service Representative's or Engineering Personnel's residence (or other point of origin) to jobsite and return to his point of origin. The charge for travel on Sundays and holidays will be at the specified overtime rate applicable for Engineers or Field Service Representatives.
 5. Standby Time - Any waiting time at the jobsite Monday through Friday when the person is available to work shall be regarded as time actually worked, even though the services are not actually utilized, and will be charged at the 8-hour daily rate.
 6. Engineering equipment charges and instrument rental as quoted.

B. For services involving FOREIGN locations, all payments shall be in U.S. funds unless otherwise agreed. Buyer shall pay for such services at the following rates:

<p>1. Field Service Representative
 Per 8-hour day \$823
 Next 4 hours \$154/hour</p> | <p>2. Engineering Personnel
 Per 8-hour day \$1,007
 Next 4 hours \$189</p> |
|---|---|
3. Travel time will be charged at the specified 8-hour per day minimum. All travel time (8 hours maximum) on Sundays and U.S. holidays will be twice the daily rate when leaving basing point.
 4. These rates apply from date of departure home base to date of return home base. Service personnel assignments will not exceed 60 continuous days. Rotation of Service personnel will be at Buyer's expense.
 5. Engineering equipment charges and instrument rental as quoted.

C. Expenses

1. Meals, lodging, and incidental expenses will be charged as cost incurred.
2. Transportation to and from the city nearest the jobsite, plus local transportation (rental car or company car) will be charged at cost. Mileage from personal car will be allowed at the rate of 26¢ per mile.
3. Outside incidental services will be priced at cost plus 10%.

DRESSER INDUSTRIES, INC., ROOTS DIVISION

GENERAL TERMS OF SALE - TECHNICAL SERVICES

DRESSER INDUSTRIES, INC. (HEREINAFTER CALLED "SELLER" IN RENDERING ANY SERVICE DOES SO UNDER THE INSTRUCTIONS OF THE CUSTOMER (HEREINAFTER CALLED "BUYER") BUYER IS AT ALL TIMES IN COMPLETE CARE, CUSTODY AND CONTROL OF ALL MACHINERY, EQUIPMENT AND ADJACENT PREMISES.

1. GENERAL

A. SCOPE Seller's Terms shall apply only to its sale of advisory services and procedures, incidental to the installation, overhaul, inspection or conversion of Buyer's equipment as such terms shall be hereinafter defined, wherein such work shall (a) be performed by Buyer's personnel under its sole care, custody and control, or (b) by Seller's personnel under the direction and control of Buyer's personnel.

For the purposes of this section, (1) "installation" shall mean the installation of Buyer's equipment at its intended operational location (including, without limitation, such equipment's on-site testing and operational start-up); (2) "overhaul" shall mean the inspection of same and replacement of all parts and components in Seller's opinion of marginal serviceability; (3) "inspection" shall mean the visual or device-assisted examination of Buyer's equipment at its operational location; (4) "modification" shall mean the making of minor alterations to Buyer's equipment, with view to improving its serviceability within original specifications (normally with improvements in "the state of the art" since equipment's original delivery); and (5) "conversion" shall mean the making of major alterations to same with view to enhancing its performance beyond original operating specifications. These Terms shall not apply to Seller's sale of Factory or Shop services incidental to its repair, overhaul, modification, conversion or revamp of Buyer's equipment at Seller's Factory or Shop or Seller's sale of parts for any purpose, which are covered under separate Terms of Sale.

B. Seller's prices are based on these sales terms and (i) this document, together with any additional writings signed by Seller, shall represent the final, complete and exclusive statement of the agreement between the parties and may not be modified, supplemented, or explained or waived by parol evidence, Buyer's purchase order, a course of dealing, Seller's performance, or in any other way except in writing signed by an authorized representative of Seller, and (ii) these terms are intended to cover all activity of Seller and Buyer hereunder. Any reference by Seller to Buyer's specifications and similar requirements are only to describe the services covered hereby and no warranties or other terms therein shall have any force or effect. Catalogs, circulars and similar pamphlets of Seller are issued for general information purposes only and shall not be deemed to modify the provisions thereof.

C. The agreement formed hereby and the language herein shall be construed and enforced under the laws of the State of Indiana, U.S.A.

2. TAXES

Any sales, use or other similar type taxes imposed on this transaction are not included in this price. Such taxes shall be itemized separately to Buyer. Seller will accept a valid exemption certificate from Buyer if applicable, however, if an exemption certificate previously accepted is not recognized by the governmental taxing authority involved and Seller is required to pay the tax covered by such exemption certificate, Buyer agrees to promptly reimburse Seller for the taxes paid.

3. CONTRACT PERFORMANCE, INSPECTION AND ACCEPTANCE

A. All services shall be finally inspected and accepted promptly upon completion thereof and before Seller's employees leave Buyer's premises. All claims whatsoever by Buyer, excepting only those provided for under the WARRANTY AND LIMITATION OF LIABILITY Clause hereof, must be asserted in writing by Buyer before Seller's employees leave Buyer's premises or they are waived. If this agreement involves partial performances, all such claims must be asserted before such leaving, as to each partial performance. There shall be no revocation of acceptance.

Rejection may be only for defects substantially impairing the value of the services and Buyer's remedy for lesser defects shall be that provided for under the WARRANTY AND LIMITATION OF LIABILITY Clause.

B. Seller shall not be responsible for nonperformance or delays in performance occasioned by any causes beyond Seller's reasonable control, including, but not limited to, labor difficulties, delays of vendors or carriers, fire, governmental actions and material shortages. Any delays so occasioned shall effect a corresponding extension of Seller's performance dates, which are, in any event, understood to be approximate. In no event shall Buyer be entitled to incidental or consequential damages for late performance or a failure to perform.

NOTICE Dresser Industries, Inc. values highly the confidence and good will of its customers and suppliers. We offer our products and services only on their merit, and we expect our customers to judge and purchase our products and services solely on the basis of quality, price, delivery and service. This Dresser Corporate policy applies in all relationships with our customers and suppliers.

4. WARRANTY AND LIMITATION OF LIABILITY

A. Seller warrants that its services when furnished will meet all specific requirements of this agreement, will be of good quality, and will be responsibly rendered. All claims for defective services under this warranty must be made in writing immediately upon discovery and, in any event, within 90 days from the furnishing of the applicable service. Damaged items must be held for Seller's inspection. EXCEPTION ONLY WARRANTY OF TITLE. THE FOREGOING IS EXPRESSLY IN LIEU OF ALL OTHER WARRANTIES WHATSOEVER, EXPRESS, IMPLIED AND STATUTORY, INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS.

B. Upon Buyer's submission of a claim as provided above and its substantiation, Seller shall, at its option, refund an equitable portion of this price.

C. The foregoing is Seller's only obligation and Buyer's exclusive remedy for breach of warranty and, except for gross negligence, willful misconduct and remedies permitted under the PERFORMANCE, INSPECTION AND ACCEPTANCE Clauses hereof, the foregoing is Buyer's exclusive remedy hereunder by way of breach of contract, tort, including negligence and strict product liability or other theories. In no event shall Buyer be entitled to incidental or consequential damages. Any action for breach of this agreement must be commenced within one (1) year after the cause of action has accrued.

5. BUYER'S RESPONSIBILITY

A. Seller's employees shall have free and unobstructed access to the site of the work. Buyer shall preserve and adequately maintain parts and tools necessary to the completion of Seller's work, and Buyer shall furnish safe and proper working conditions and safe storage for Seller's property related to Seller's services during the term of its need therefor. When delays in the work are caused by Buyer, the time and expense caused by the delay will be charged to Buyer. Buyer shall furnish all necessary cranes, tools, parts, material, supplies, steam, electricity, gas, oil, water, and other material and supplies required to repair and operate the machinery. Seller shall not be responsible for any material or supplies furnished by Buyer or for workmanship, acts or omissions of the employees, subcontractors or agents of Buyer. Buyer understands Seller's employees' responsibility is limited to furnishing technical advice and such responsibility does not extend to supervision of Buyer's employees, subcontractors or agents.

B. Buyer understands and agrees, with respect to the performance of Seller or its employees or representatives of active services, that such employees or representatives in the course of such work shall be treated as Buyer's servants in all respects, and that Buyer shall be solely responsible, therefore without the liability of Seller therefore in any respect.

6. CHARGES

A. Rates quoted are subject to adjustment without notice to conform to Seller's published rates in effect at the time service is performed.

B. Invoices are due for payment upon receipt. A service charge of 1 1/2% per month (18% per annum) from the date of invoice will be charged on all unpaid balances, sixty (60) days after date of invoice. Such service charge payments shall not waive any other Seller's rights, but shall be cumulative.

C. Seller's personnel will provide Buyer's representative at the jobsite one copy of his weekly time sheet. A ten percent (10%) charge to the Seller's actual hourly billing for the week(s) in question will be made if any copies of expense sheets or copies of receipts are required by Buyer.

D. For services involving foreign locations, all payments shall be in U.S. funds unless otherwise agreed.

E. Travel and living expenses will be priced at cost.

F. Outside incidental services and material will be priced at cost plus 10%.

DRESSER INDUSTRIES, INC.
ROOTS BLOWER OPERATION
900 WEST MOUNT ST. CONNERSVILLE, INDIANA 47331

CANCELLATION CHARGES POLICY

In the event that purchaser cancels this contract for any reason after receipt at the factory and prior to shipment, the following cancellation charges will be applied:

ITEMS	CHARGES
1. STANDARD (RESTOCKABLE) 8" GEAR DIAMETER & SMALLER ROTARY BLOWERS OR GAS PUMPS & RENEWAL PARTS: BASIS	
A. Within 30 days of purchase order	No Charge
B. After 30 days	15%
2. ALL OTHER ROOTS PRODUCTS (INCLUDING 8" GEAR DIAMETER AND SMALLER PACKAGES), REPAIRS OR PARTS: BASIS	
A. Within 30 days of purchase order	10%
B. After 30 days	On straight line basis of 10% at 30 days to 100% at 30 days prior to scheduled shipment.

3. MAJOR PURCHASED ITEMS:	Charges presented by Roots' vendor(s) plus 15%

NOTE:

A minimum charge of \$75 will apply to any cancellation for other than category 1.A.

OSHA SUPPLEMENT TO PROPOSALS
AND ORDER ACKNOWLEDGEMENTS

ROOTS

DRESSER

Customer Name _____
Roots Proposal Number and Date _____
Customer Order Number and Date _____
Roots Order Number and Date _____

The following outlines Roots' position with respect to furnishing equipment in compliance with the Williams-Steiger Occupational Safety and Health Act of 1970. Roots expressly limits statements of compliance to only those standards as set forth below which are in effect on the date of this order.

Of this Act, we recognize only the following four (4) areas which apply to us as a supplier.

NOISE: (Subject G, Section 1910.95)

OSHA incorporates the Walsh-Healey Act as its standard for acceptable noise levels in the actual operating environment. In view of this Act applying to allowable noise level as a function of exposure time irrespective of the environmental conditions or distance from the noise source, Roots will not accept responsibility for compliance since we obviously lack control of those factors.

However, upon request, Roots will provide estimated noise levels for our equipment, and we will consider reviewing and negotiating specific conditions under which we can guarantee compliance.

DRIVE GUARDS: (Subpart O, Section 1910.219)

Drive guards, when furnished by Roots, will comply with the requirements of OSHA

However, Roots accepts no responsibility to furnish guards if not specified as part of the customer's purchase order.

Rotating components of equipment furnished by Roots will not be color-coded per OSHA requirements as this remains the responsibility of the user, as does the furnishing of warning signs, tags, etc.

ELECTRICAL: (Subpart S)

All electrical apparatus furnished by ROOTS will comply with OSHA provided that applicable information (including enclosure requirements) is supplied us by the customer.

For explosion-proof enclosures, we must be provided with the NEC (National Electrical Code) classification of the hazardous areas in which the equipment is to be installed.

AIR RECEIVERS: (Subpart M, Section 1910.169)

Air receivers for purpose of compliance with OSHA are defined by Roots as silencers, receivers, separators or aftercoolers to be installed in the system where operation above 15 psig is required. The compressor itself is not considered an air receiver for purposes intended herein.

Safety valves, indicating and control devices furnished by Roots will be in compliance with OSHA.

Under no circumstances will Roots be responsible for interpreting equipment requirements under OSHA merely on the basis of customer's specified intended service, or blanket notation that all supplied equipment must meet OSHA requirements.

Any representations or warranties herein are subject to the Warranty and Limitation of Liability provision contained in Roots' Proposal and/or Order Acknowledgement.

Signed _____ Date _____

NOTE:

When using this form in conjunction with a customer order acknowledgement, type "Form OSHA-5003 attached" on face of acknowledgement, attaching Form OSHA-5003, and place copy of Form OSHA-5003 in internal records.

PRICE ADJUSTMENT CLAUSE

ROOTS**DRESSER**

NOTE: This clause applies only to contracts that are based on the normal manufacturing schedule of the Roots Operations of Dresser Industries, Inc.

A. GENERAL POLICY

1. Prices stated herein on equipment manufactured by Seller that can be factory scheduled for shipment within six months from date of order will be firm priced based on prices in effect at time of booking.
2. All units that are factory scheduled or customer requested for shipment beyond six months from date of order will be subject to price in effect at time of shipping for pricebook products or in accordance to terms of section B for non-pricebook products.
3. All parts will be subject to price in effect at time of shipment.
4. Any customer-caused delays from the originally scheduled shipping date will automatically place the order on "price in effect" status.
5. Any significant surcharges on buy out items will be passed along to the customer at net.

B. FOR NON-PRICEBOOK PRODUCTS

The final price is subject to adjustment to compensate for changes in Seller's material and labor costs from the "Base Index Month". In no event will the final price be less than the contract price. This adjustment shall be determined from Bureau of Labor Statistics data as herein provided.

1. DEFINITIONS

For the purpose of this provision, the following definitions apply.

- a. The "Labor Index" shall be the Average Hourly Earnings Index for the Blower and Fans Industry (SIC 3564) as determined and reported monthly by the Bureau of Labor Statistics, U.S. Department of Labor.
- b. The "Materials Index" shall be "Foundry and Forge Shop Products" (W.P.I. Code No. 1015) as determined and reported monthly by the Bureau of Labor Statistics, U.S. Department of Labor.
- c. The "Base Index Month" shall be the month that the proposal is issued.
- d. The "Basic Labor Index" shall be the "Labor Index" for the "Base Index Month."
- e. The "Basic Material Index" shall be the "Material Index" for the "Base Index Month."

2. ADJUSTMENTS FOR COSTS

- a. For the purpose of price adjustment, 10% of the contract price shall be fixed, 55% of the contract price and of each payment made on account thereof shall be deemed to represent the material content and 35% of the contract price and of each payment made on account thereof shall be deemed to represent the labor content.
- b. The labor and material content shall be adjusted for any upward changes in the respective index. The price adjustment for labor shall be equal to the percent by which the index for the month of actual shipment is greater than the "Base Index Month." The price adjustment for material shall be equal to the percent by which the index for the month equal to $\frac{3}{4}$ of the actual shipment is greater than the "Base Index Month."

3. EXCUSABLE DELAYS

Seller will notify Buyer promptly of any material delay and will specify the revised delivery date as soon as practicable. Seller shall not be liable for delays in delivery or performance or for failure to manufacture, deliver, or perform due to (i) causes beyond its reasonable control, or (ii) acts of God, acts of Buyer, acts of civil or military authority, governmental priorities, strikes, or other labor disturbances, floods, epidemics, war, riot, delays in transportation or car shortages, or (iii) inability on account of causes beyond the reasonable control of Seller to obtain necessary materials, labor, components, services, or facilities. In event of any such delay, there will be no termination and the date of shipment shall be extended for a period equal to the time lost by reason of the delay, and the price adjusted from the "Base Index Month" in accordance with Bureau of Labor Statistics described herein.

C. GENERAL

- a. In the event any change in the contract specifications prior to actual shipment results in a change in contract price, the new price shall be considered as having been in effect since the "Base Index Month."
- b. In the event price adjustment is to be applied to a contract involving progress payments, the total adjustment to the contract price will be applied and invoiced on the final payment.
- c. Both labor and material adjustments shall be calculated to the nearest one-tenth of one percent.
- d. Should the Indexes specified in Paragraphs 1a and 1b be discontinued, or should the basis of their calculation be modified, Seller, after consulting with Buyer, shall select other indexes or another method of cost adjustment which, in Seller's judgment, will result in an equitable adjustment of the contract price.
- e. Price increases received from our suppliers of Accessory equipment will be directly passed along, regardless of contract duration, with no further mark-up by Seller.
- f. The final price, as adjusted, will not exceed the authorized price in effect at date of actual shipment and shall be in accordance with such, if any, Economic Stabilization Program requirements and regulations of the Cost of Living Council as may then be applicable.

Appendix A-4

VENDOR QUOTE

Basket Strainers and Knock Out Drum

Otto York

OTTO YORK

OTTO H. YORK COMPANY, INC.

October 24, 1991

Mr. Deepak Shukla
Tensa Services, Inc.
6200 Savoy Drive
Suite 540
Houston, Texas 77036

Dear Deepak:

Sorry for the delay, our engineering department has been inordinately busy. We have reviewed your project for ASRC and offer the following proposal.

1. Retrofit the existing strainers to better remove liquids and crumb.
2. Install suction side knockout drum to remove remaining liquids and solids to protect the compressor. The vessel would be carbon steel with a design pressure of 25 psig.

Budget Price:

Retrofit of strainer:	\$ 2,250.00 per strainer
Compressor knockout drum:	\$35,000.00

Deepak, I will be in Louisville sometime in November or early December. If it is appropriate, perhaps we can visit the plant together so I can get a better feel for what they are dealing with.

I look forward to your reply.

Sincerely,

OTTO H. YORK COMPANY, INC.

Steven E. Spardel
Houston Regional Sales

SES:gt

Appendix B

CALCULATION OF STEAM COST

The cost of steam for this facility is complicated by the fact that the site uses a simple cycle cogeneration to let down 135,000 (lbs/hr) of steam at 300 psig and 555 (°F) to 30 psig, before the steam is injected in the stripper (Figure B-1). The cost of 30 psig steam is estimated as follows:

Cost of Steam generated at 300 psig (\$/1000 lb.)	= 3.47
Power Generated from Steam (KWH/lb.)	= 1/26.18*
	= 0.03819
Power Generated from 1000 lb. of Steam (<u>KWH</u>)	= 0.0381 x 1000
1000 lb.	= 38.19
Cost Savings from letting down 1000 lb. of Steam through turbine(<u>KWH</u> x <u>\$</u>)	= 38.19 x 0.0376
1000 lb. K	= 1.436 (\$/1000 lb.)
Cost of 3000 PSIG Steam (Including Credit for Cogenerated Power)	= 3.47 (\$/1000 lb.)
	- 1.436 (\$/1000 lb.)
	= 2.034/1000 lb.

*From Turbine data sheet

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CULATION OF STEAM COST

st of steam for this facility is complicated by the fact that the site uses a simple
ogeneration to let down 135,000 (lbs/hr) of steam at 300 psig and 555 (°F) to 30
efore the steam is injected in the stripper (Figure B-1). The cost of 30 psig
s estimated as follows:

Steam generated at 300 psig (\$/1000 lb.)	= 3.47
Generated from Steam (KWH/lb.)	= 1/26.18*
	= 0.03819
Generated from 1000 lb. of Steam (<u>KWH</u>)	= 0.0381 x 1000
1000 lb.	= 38.19
ings from letting down 1000 lb.	= 38.19 x 0.0376
through turbine(<u>KWH</u> x <u>\$</u>)	= 1.436 (\$/1000 lb.)
1000 lb. K	
000 PSIG Steam (Including Credit for	
ated Power)	= 3.47 (\$/1000 lb.)
	- 1.436 (\$/1000 lb.)
	= 2.034/1000 lb.

rbine data sheet