MARKET INVESTIGATION FOR SURFACE SUPPLIED DIVING AIR COMPRESSORS

U.S. Army Belvoir Research, Development
and Engineering Center
Ft. Belvoir, VA 22060-5606

Contract No. DAAK70-89-D-0016, Task 0002
FINAL REPORT

Phillips Cartner & Co., Inc.
700 N. Fairfax St.
Alexandria, VA 22314

12 June 1990

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This paper reports the findings of a market investigation for air compressors that might be suitable for U.S. Army surface supplied diving operations. The goals of the survey and report were to determine whether it was necessary to develop a prototype compressor or whether there were commercial compressors suitable to Army needs. The report documents the effort and the results. Several commercial compressors were found that would fulfil Army needs and recommendations were made regarding those compressors and an appropriate surface supplied diving air system based on those compressors as the primary air supply.

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STUDY GIST - MARKET INVESTIGATION FOR SURFACE SUPPLIED DIVING AIR COMPRESSORS.

PRINCIPAL FINDINGS

1. It was found that commercial low pressure air compressors exist that will fulfil U.S. Army requirements for providing surface supplied diving air. Two compressors were located. These are the Rix Industries Model 2JS2B-300 medium pressure compressor and the Hamworthy Engineering, Ltd. Model 3TH-190W70 compressor. Of these machines the Rix model most closely matches the requirement of the Army.

2. It was found that there is very little quantitative Reliability and Maintainability data available for any compressors.

3. Low pressure compressor technology has not changed appreciably in the past 10 years.

MAIN ASSUMPTIONS

1. A low pressure compressor was superior to a high pressure. This was decided due to the inherent increase in reliability associated with the low pressure compressor.

PRINCIPAL LIMITATIONS

1. Limited response by industry to the market investigation questionnaires.

2. Extremely small amount of Reliability and Maintainability data available for quantitative analysis and comparison of compressors.

SCOPE OF EFFORT

This investigation searched the commercial markets for air compressors that could be considered for U.S. Army surface supplied diving operations. The primary focus was on compressor manufacturers. Foreign and domestic manufacturers were consulted regarding their products. Also, in the course of the investigation Army personnel and commercial diving companies were interviewed concerning equipment they use and their opinions of that equipment.

OBJECTIVE

The first objective was to determine if there were any commercial compressors available that would fulfil U.S. Army needs or whether a prototype compressor should be built. The second objective was to determine which of the qualified compressors best fulfilled Army requirements and propose a system configuration for primary and emergency air for diving operations.

BASIC APPROACH

A questionnaire for industry was developed in coordination with and approved by representative at U.S. Army, Ft. Belvoir, Belvoir VA, Belvoir Research, Development and Engineering Center and U.S. Army Engineer School. In conjunction with the questionnaire development, an announcement was placed in the Commerce Business Daily (CBD) to help in compiling a list of interested vendors. In addition to CBD responders a list of appropriate companies to contact was developed using the Thomas Register and some in-house contacts. After the completed questionnaires were returned follow up calls were made to gather and refine the data collected. In addition to the questionnaires, interviews with Army personnel and Commercial diving companies were conducted.

REASON FOR PERFORMING THE INVESTIGATION

This study was conducted because the Quincy compressors built by the Quincy Compressor Division of Colt Industries and used by the U.S. Army since the mid-1970's are nearing the end of their usable life. State of the art technology is not being utilized and one of the goals of this investigation was to determine if there are compressors that do a better job than the Quincies.

IMPACT OF THE INVESTIGATION

It was found that compressor technology hasn't appreciably changed since the Quincy compressors first came into service, but it was determined that a new compressor system would be beneficial. The current system requires two full compressors to supply primary diving air during operations. This causes problems due to the increase in the number of spares and increased logistical support necessary to support two compressors. This investigation has identified potential compressors that can support Army requirements with only one unit.

SPONSOR

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SURFACE SUPPLIED DIVING AIR COMPRESSOR
MARKET INVESTIGATION

1.0 EXECUTIVE SUMMARY

Phillips Cartner & Co., Inc. has, at the request of the U.S. Army, surveyed the commercial market for surface supplied diving air compressor that is operationally suitable for military use.

The Army specified the use of a questionnaire that was to be coordinated and approved by the Government in accordance with CDRI, AOOM, Type I. The objective being to determine whether to build a prototype compressor or prepare a purchase description for limited quantity procurement.

In addition to the questionnaire administered to commercial vendors, Phillips Cartner interviewed personnel at Ft. Eustis, Virginia and commercial diving companies in order to develop a more comprehensive set of criteria.

Two compressors were found that met U.S. Army criteria. These are the Rix Industries Model 2JS2B-300 medium pressure compressor and the Hamworthy Engineering, Ltd. Model 3TH-190W70. Of these two, it was determined that the Rix model most closely matches the requirements and goals of the Army.

2.0 INTRODUCTION AND BACKGROUND

2.1 GENERAL

This document details the efforts and results of an extensive investigation of commercially available surface supplied diving air compressors.

The study was conducted by Phillips Cartner & Co., Inc. under contract number DAAK70-89-D-0016, Task 0002 with the U.S. Army Belvoir Research, Development and Engineering Center, Ft. Belvoir, Virginia, in accordance with Standard Operating Procedure (SOP) Number 70-2.

Mr. Henry Schaefer was the Project Engineer for the U.S. Army. Mr. Les Sonnenmark was the Program Manager for Phillips Cartner & Co., Inc.

2.2 SCOPE

In order to thoroughly evaluate the commercial market for air compressors to be considered for U.S. Army surface supplied diving operations, Phillips Cartner consulted three sources of information:

- o Army personnel were interviewed regarding the equipment that is presently in use by them.
- o Commercial diving companies were interviewed regarding equipment used by them to perform operations similar to those of the Army.
- o Compressor manufacturers were interviewed regarding equipment manufactured by them and its applicability to Army requirements.

Information gained from these three sources enabled Phillips Cartner to establish a comprehensive set of criteria with which to evaluate and compare the products of the candidate companies.

2.3 BACKGROUND

The U.S. Army units conduct underwater operations using surface-supplied divers air systems. System requirements and diving limitations are in accordance with those in the U.S. Navy Diving Manual volume 1.

Surface supplied air diving operations include those forms of diving in which air is supplied from the surface to the diver by a flexible hose. Mobility is a key ingredient to the success of the Army's operations; the entire system must be readily transportable.

The 250 psig air compressor manufactured by the Quincy Compressor Division of Colt Industries has been the standard diving air compressor used by the Army since the mid-1970's. The characteristics of this machine are listed in Table 1.

The Army's current inventory is over 15 years old. As they approach the end of their usable life, they present certain problems.

- o State-of-the-art technology is not in use because the units are outdated.
- o Maintenance and repair of the units are hindered due to the lack of spare parts.

The results of this study will be used to make a decision on whether to build a prototype compressor or prepare a purchase description (PD) for limited quantity procurement with minimum acceptable risk.

Table 1.

Compressor: Manufacturer	Quincy Compressor, Colt Ind.
Type	Two-stage reciprocating
Model	W5120
Configuration	VEE
High-pressure cylinders	2
Low-pressure cylinders	2
Stroke	4 in.
Bore, high-press. cylinder	3.25 in.
Bore, low-press. cylinder	6.0 in.
Piston displacement	123 cfm at 940 rpm
Maximum operating pressure	250 psig
Rated Flow	97.3 scfm at 940 rpm @ 250psig
Length	28.5 in.
Width	35 in.
Height	31 in.
Weight	970 lbs.
Crankcase oil capacity	10 qts, 1 pt

3.0 APPROACH

In accordance with the work order issued by the U.S. Army, Phillips Cartner prepared a questionnaire in coordination with and approved by representatives at U.S. Army, Ft. Belvoir, Virginia, Belvoir Research, Development and Engineering Center and U.S. Army Engineer School. The questionnaire included sections to cover three areas of information specified by the Army.

- o The specific requirements that would be used by the Army to evaluate the suitability of each commercially manufactured air compressor.

- o Details addressing the background, configuration and use of the current system, i.e., environmental requirements, noise limits, air quality and transportability.

- o Market information to be provided by each vendor surveyed regarding their product. This included items such as compression method, capability, pressure, sizing, environmental limitation, RAM data and references.

At the same time the questionnaire was being developed, an announcement was placed in the Commerce Business Daily (CBD) to begin to compile a list of interested vendors. This announcement was also developed with the approval of representatives of the U S. Army. In addition to soliciting interested vendors through the CBD, a list of appropriate companies was generated using the Thomas Register and some in-house contacts.

Twenty seven (27) companies responded to inquiries. These companies were mailed a copy of the questionnaire to be completed. Included in the package sent to each company, was a copy of the purchase description presently used by the Army. This was

included for reference. Please note that a copy of the questionnaire, the CBD announcement and the purchase description will be found in Appendix (A) of this document.

Five (5) companies responded to the mailed questionnaire. These responses were followed up by calls in an effort to refine and expand upon the given information. A list of the five responding companies will be found in Appendix (B) of this document.

In conjunction with efforts to gather information from potential commercial suppliers, Phillips Cartner determined that an extensive assortment of criteria should be developed to determine which commercially available air compressor would most closely fit the requirements specified by the Army. This was accomplished by interviewing U.S. Army Master Divers at Ft. Eustis, Virginia regarding their evaluations of compressors presently in use; commercial diving companies were interviewed regarding compressors used now and in the past for operations similar to those of the Army.

4.0 SUMMARY OF RESULTS

4.1 GENERAL

This section will discuss the results of the vendor questionnaires, interviews with U.S. Army personnel and commercial diving companies.

In addition, the U.S. Army has shown particular interest in the feasibility of replacing twin compressors of low pressure flow rates with a single intermediate or high pressure flow rate compressor. Accordingly, Phillips Cartner also interviewed Army personnel and commercial diving companies concerning their opinions on such a substitution.

4.2 U.S. ARMY PERSONNEL

Phillips Cartner contacted Master Divers at Ft. Eustis, Virginia. Discussion concerning the value of the Quincy/Lister engine compressor combination, presently used by the Army, generally indicated that the divers were not satisfied with the equipment. The complaints regarding the system consistently addressed the effectiveness of the Lister engine.

It should be noted, however, that according to MSG. Hienbach, U.S. Army Chief Diving Supervisor of the U.S. Army Engineer School at Ft. Leonardwood, Missouri, it is difficult to do an extensive evaluation of the Quincy W5120 due to the fact that there is only a small number of units fielded.

As previously indicated, the Army personnel were interviewed as to their preference for either twin compressors of low pressure or a single compressor with intermediate or high flow rate. The divers generally were not in favor of substituting a single compressor for twin compressors. They expressed concern that failure of a single unit would put

operations totally out of commission. If two units were in use and one unit failed, deep dives would be halted but shallow dives could continue.

It was concluded, however, that the increased number of spares, tools and the necessary logistic support required for two compressors was too great; and that since the majority of diving operations conducted by the Army are shallow, one compressor would be a more feasible solution.

Discussion concerning the use of low pressure compressors versus the use of high pressure compressors indicated that most divers would support the use of low pressure compressors. Overall, they felt that low pressure compressors offer greater reliability and ease of maintenance.

4.3 COMMERCIAL DIVING COMPANIES

Five commercial diving companies were interviewed concerning the type of compressors that were used for surface supported diving operations similar to those of the Army. A list of the companies interviewed will be found in Appendix (B) of this document.

The requirements of the commercial companies did not exactly match Army requirements. The U.S. Army has indicated that it is interested in acquiring equipment that will support three divers with a continuous flow of 6 ACFM each at a maximum depth of 250 FSW. Commercial diving companies typically do not send more than one or two men down using one compressor; and they use flasks of high pressure air as part of the primary air supply. Dives at maximum depths (190 feet) typically do not exceed eight hours. Consequently, the divers can be fully supported with bottled air while the compressor is dedicated to filling bottles that are not in use.

Each of the five companies interviewed indicated that they use, almost exclusively, the Quincy compressor/Lister engine combination. The model most commonly used is the Quincy 390. The companies have been replacing their Quincy W5120 models with this slightly smaller model. The reasons cited are their higher reliability and ease of repair. However, it should be noted that Quincy has not published any reliability/maintenance data, therefore, it is not possible to substantiate claims made by the commercial diving companies with quantitative data.

4.4 COMPRESSOR VENDORS

The following companies responded to the questionnaire and forwarded information concerning compressors they would recommend for use by the Army:

1. Atlas Copco - Model LT12-435
2. Bauer - Model SMART (Safe Mobile Air Rapid Transporter) Module 1-5
3. Hamworthy - Model 3TH 190W70 & 4TH 275W100
4. Ingersoll-Rand - Model IR105D Compressor/Purifier with 6R80-100 comp. block
5. Rix Industries - Model 2JS2B-300 Medium Pressure

This section will develop recommendation criteria; each company and their suggested compressor will be discussed individually; and the compressors will be compared to each other.

4.4.1 RECOMMENDATION CRITERIA

1. The Army requires that an acceptable diving compressor will support diving operations to 250 feet sea water (FSW). At this depth the pressure is 112 psig. The primary diving gear that this system will support is the Deep Sea Diving Equipment Set (Mark 12). This requires minimal overbottom pressure. The minimum manifold pressure requirement

is driven by the umbilical hose length and the depth. For a 600 foot hose at 250 FSW the minimum manifold pressure is 200 psig. This was calculated using methods from the U.S. Navy Diving Manual, Volume 1.

The Army also uses the Superlite 17B diving equipment, and this requires a minimum manifold pressure of 112 psig + 135 psig overbottom pressure for a total of 250 psig. The system is not required to support the Superlite, but this information is provided for reference.

2. 18 ACFM at 250 FSW is considered a fixed requirement that must be met without the use of bottled high pressure air.

To determine the minimum required F.A.D. (free air displacement) necessary to meet the Army requirements for 18 ACFM at 250 FSW and to fill a 236 cubic foot recompression chamber to 165 FSW the following calculations and assumptions were used. These assumed inlet conditions were used because they are standard gas conditions and are used by manufacturers for reference. The bottom temperature was chosen because of the Army's need for cold water diving capability.

Atmospheric air:

1. Pressure 14.7 psi (1 Atmosphere)
2. Temperature 60F or 520R

Bottom conditions:

1. Pressure 250 FSW gage or 126.7 psi absolute
   (14.7 + 250FSW/2.24FSW/psi)
2. Temperature 30F or 490R

Recompression Chamber:

1. Pressure 165 FSW or 88.125 psi absolute
2. Temperature 60F

Basic Equation: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

For diving needs:

For 18 ACFM @ 250 FSW (V_1 is the required F.A.D.) $= \frac{P_2T_1V_2}{P_1T_2} = \frac{126.7*520*18}{14.7*490} = 165$ FAD CFM

For the recompression chamber:

To pressurize a 236 Ft^3 chamber to 88.4 PSIA in three (3) minutes $\frac{236}{3} = 78.7$ CFM

$V_1 = \frac{P_2T_1V_2}{P_1T_2} = \frac{88.4*78.7}{14.7} = 473$ FAD CFM

The compressors that were investigated were not capable of this. The F.A.D. requirement to pressurize the chamber is outside the range of any compressor evaluated and high pressure air flasks are considered a necessary option for making up the difference between compressor output and need.

3. An emergency backup supply of air is required for surface air supplied diving. Optional ways to supply backup air include an identical backup compressor or flasks of high pressure air. A backup compressor involves problems in the areas of transportation, maintenance, spares, size and initial expense. The Army currently has, as part of its standard diving equipment list, two 20 CFM FAD 5000 psig compressors. These compressors with the addition of bottles of high pressure air will constitute an adequate

backup supply that is lighter, smaller and more reliable than a full backup, low pressure, high volume compressor.

A logical backup procedure is to determine a minimum number of flasks to be filled before the dive. If the main compressor goes out, the two 20 CFM FAD 5000 psig compressors would come on line. These compressors would fill the flasks with high pressure air as they were depleted. The divers would use the flasks and not need to directly tap off the compressor.

The amount of air (SCF Standard Cubic Feet) necessary to bring three divers up was calculated for 250 FSW and 190 FSW. The following assumptions were made:

1. Each diver needs 4.5 ACFM
2. Ascent rate is 60 FPM
3. At 250 FSW (Extreme exposure dive) the divers bottom time is the maximum covered by the U.S. Navy Diving Manual Air Decompression Tables. (240 Minutes)
4. At 190 FSW the bottom time was assumed to be the maximum time allowable that is not considered extreme exposure. (40 Minutes)

These calculations do not take into consideration the temperature of the water at the decompression stops. At 250 FSW, three divers who have had a maximum bottom time of 240 minutes, need 38,820 SCF to decompress and surface. At 190 FSW the three divers, after maximum bottom time of 40 minutes, need 2,232 SCF of air.

The calculations to identify the minimum number of flasks of air that are necessary for a backup supply for both dives are as given in Appendix (D). The following is a summary of the results of those calculations.

1. 250 FSW, No compressor, 85 flasks
2. 250 FSW, 1 compressor, 38 flasks
3. 250 FSW, 2 compressors, 12 flasks

4. 190 FSW, No compressor, 5 flasks
5. 190 FSW, 1 compressor, 1 flasks
6. 190 FSW, 2 compressors, will have excess air equivalent 4.2 flasks.

The amount of air (SCF) needed to bring the chamber to pressure (165 FSW) is 1183 SCF. This assumes that the chamber starts at standard conditions. These calculations will be found in Appendix (D) of this document.

4.4.2 VENDORS

Each of the five vendors and the compressors recommended are discussed in this section. This information is listed alphabetically and not in order of preference.

It became evident during the interview and evaluation process that the compressor industry and related technology has not changed appreciably in the last 20 years. The Quincy W5120s which began production nearly 20 years ago are still being produced and used by some in the commercial industry. However, there is little or no repair/maintenance data available for any of the compressors reviewed. Where it is available, it will be cited. A comparative chart of compressors is included at the end of this section. Copies of vendor literature will be found in Appendix (C) of this document.

Atlas Copco - Model LT12-435 compressor. Information on filtration equipment, storage bottles and controls was not provided. The compressor is a reciprocating, oil lubricated, medium pressure unit. It produces air at 435 psig at 42 CFM FAD. This compressor will support diving operations only if four compressors are grouped together or if Hp bottles are used as a supplement. Neither of these two solutions is acceptable according to U.S. Army requirements.

Bauer - SMART (Safe Mobile Air Rapid Transporter) Module 1-5 with a Lister diesel engine. It is a high pressure compressor delivers air between 1280 and 5000 psig at a flow rate of 36 to 60 CFM FAD. This is well below the required minimum flow for single compressor surface supported diving.

Hamworthy Engineering Ltd. - Model 3TH-190W70 and the Model 4TH-275W100. The Model 3TH-190W70 is a three stage compressor that operates at 1000 psig at a flow rate of 177 CFM FAD. The Model 4TH-275W100 is a four stage machine that operates at 5000 psig and 177 CFM FAD. Both of these compressors meet the flow requirements set by the Army. Both are reciprocating, oil lubricated, water cooled units. Engines were not specified by Hamworthy except for minimum horsepower requirements. The high pressure unit requires 160 Hp and 86 USG (United States Gallons) of cooling water per minute. The lower pressure unit requires 130 Hp and 55 (USG) of cooling water per minute.

A potential problem with the Hamworthy unit is the fact that it is British and is built to British standards with metric dimensions and fittings. However, the assembly of the full compressor, purification, control units would take place in the United States. Therefore, all piping/materials used on the outside of the compressor would be supplied at the appropriate U.S. Standards.

Hamworthy has indicated that they should be able to supply the entire diving package at a weight of 7500 lbs.

Ingersoll-Rand - Model IR105D compressor/purifier with an Ingersoll-Rand 6R80-100 compressor block, a 124 horsepower Perkins Model T-6-3544 diesel engine and an Ingersoll-Rand Model 50LB12 air purification system. The approximate weight of this diving package is 8000 lbs. This compressor produces 100 CFM FAD at 5000 psig. This

is below Army requirements. It would require two compressors together to meet the minimum required flow. In addition, this is a high pressure compressor and more prone to failure.

Rix Industries - Models 2JS4B-150 and 2JS2B-300. These are reciprocating, oil free compressors. The high pressure model provides only 100 CFM FAD at 5000 psig. This is insufficient for Army requirements. This unit would, however, be capable of filling Hp bottles quickly. The medium pressure model produces air from 125 to 500 psig at flows of up to 250 CFM FAD. This compressor fully meets Army requirements. In addition, it is on the "Approved for Navy Use" list. The basic unit weighs 4500 lbs. With the addition of a radiator, it weighs 6000 lbs. Filtration equipment is not necessary with either of these units because they are not oil lubricated. The drawback for this unit would be the high price. At $150,000 per copy, it is the most expensive package investigated.

AIR COMPRESSOR COMPARATIVE CHART

Specs	Quincy (current)	Atlas Copco	Bauer
Model	W5120	LT12-435	SMART (Safe M Air Rapid Tra Module 1-5, W
Type	2 Stage Reciprocate Low pressure	Reciprocating Medium pressure	High pressure or Horizontal
Capacity/Vol.	97.3 CFM FAD	42 CFM FAD	36-60 CFM F
Pressure	250 PSIG	435 PSIG	1280-5000 P
Drive, Fuel-type	Diesel	Diesel engine, V belt drive	Diesel/elect hydraulic co
Cooling	not addressed	Air cooled	Air cooled
Storage flasks	not addressed	Min. of 44 cu.ft. at 65 minutes to press.	Module #4/5, System & bott holder, 6000
Filter System	non-coalescing filters	to be determined	Securus purif panel. 57000- cu.ft.
Control Panel	not addressed	to be determined	Module #3, In control panel
Dimensions	not addressed	76"L x 45"W x 39"H	W/O trailer 84"L x 43"W x
Weight	6585 lbs	1225 lbs.	W/O trailer 3200 lbs.
Environmental Limitations	Temp. -25 - 120 degF	Temp. 32-110 deg F. 88 dBA	Temp. 32-110
Air Quality	not addressed	Reference test perf. at NCSC on equip.	Securus purif panel
Packaging	skid mounted	to be determined	skid/truck/or trailer mount
Brake Horse power	25	20	15
Delivery time	not addressed	150 days	120 days
Cost	not addressed	Compressor: 22K receiver, storage, controls & filter, extra	Storage 20K Compress/air 28-55K

(1)

Atlas Copco	Bauer	Hamworthy Engineering	Ingersoll-R
LT12-435	SMART (Safe Mobile Air Rapid Transporter) Module 1-5, W/Lister	3TH 190W70	IR105D comp/pu 6R80-100 Comp.
Reciprocating Medium pressure	High pressure, Vert. or Horizontal Pos.	Medium pressure, horizon. reciprocat.	high pressure
42 CFM FAD	36-60 CFM FAD	177 CFM FAD	addressed in I· diving comp. ci
435 PSIG	1280-5000 PSIG	1000 PSIG	up to 6000 PS
iesel engine, V elt drive	Diesel/electric/ hydraulic comb.	Diesel of choosing	Perkins Model T-6-3544 dies·
Air cooled	Air cooled	Water cooled	Air cooled
n. of 44 cu.ft. at minutes to press.	Module #4/5, air stor System & bottle holder, 6000 DOT	6000 DOT cylinders	Main: 6 6000 D· Reserve: 3 600
o be determined	Securus purification panel. 57000-424000 cu.ft.	Dominick Hunter HP-A0-40-HE30	Purification m· 50LB12
o be determined	Module #3, Instrument control panel	to be determined	addressed in · 6315
'L x 45"W x 39"H	W/O trailer 84"L x 43"W x 60"H	144"L x 84"W x 64"H	120"L x 60"W x
1225 lbs.	W/O trailer 3200 lbs.	Max. 7500 lbs.	8000 lbs.
mp. 32-110 deg F. 88 dBA	Temp. 32-110 deg F.	Temp 0-113 deg F. 85 dBA	Temp 32-110 d· 104 dBA
ference test perf. NCSC on equip.	Securus purification panel	Model HP 130	Model 50LB12 A· purification s·
o be determined	skid/truck/or 4 wheel trailer mount	skid mounted	skid mounted
20	15	Min. 113	124
150 days	120 days	120 days	90 days
pressor: 22K eiver, storage, trols & filter, tra	Storage 20K Compress/air purif. 28-55K	86K per package	120K per packa

	Hamworthy Engineering	Ingersoll-Rand	Rix Industries
ile porter) ister	3TH 190W70	IR105D comp/purifier 6R80-100 Comp. block	2JS2B-300
Vert. os.	Medium pressure, horizon. reciprocat.	high pressure	medium pressure, reciprocating
	177 CFM FAD	addressed in I-R diving comp. chart	up to 250 CFM FAD
;	1000 PSIG	up to 6000 PSIG	up to 500 PSIG
:/ .	Diesel of choosing	Perkins Model T-6-3544 diesel	Diesel W/ V belt drive
	Water cooled	Air cooled	Water cooled
· stor ·	6000 DOT cylinders	Main: 6 6000 DOT's Reserve: 3 6000 DOTs	low pressure stage
tion 000	Dominick Hunter HP-A0-40-HE30	Purification model 50LB12	Particulate filter
ument	to be determined	addressed in dwg. 6315	not addressed
"H	144"L x 84"W x 64"H	120"L x 60"W x 81"H	57"W x 78"L x 81"H
	Max. 7500 lbs.	8000 lbs.	5500 lbs.
F.	Temp 0-113 deg F. 85 dBA	Temp 32-110 deg F. 104 dBA	85 dBA @ 3'
tion	Model HP 130	Model 50LB12 Air purification system	Oil free breathing air
wheel	skid mounted	skid mounted	floor mount preferred not required
	Min. 113	124	113
	120 days	90 days	180 days
·if.	86K per package	120K per package	150K per package

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 GENERAL

This section will present the conclusions and recommendations developed as a result of this study. In addition to recommendations on the type of compressor that should be used, it will make recommendations on which specific compressor should be further investigated and what the next appropriate steps in this investigation should be.

5.2 CONCLUSIONS

The Army's two requirements for an air compressor systems for surface supplied diving are:

- o It must supply 18 ACFM at 250 FSW.
- o It must be capable of pressurizing a 236 cubic foot recompression chamber to 165 FSW in three minutes. Flasks of high pressure air are allowable in the pressurizing chamber.

It was concluded from discussions with Army personnel and commercial diving companies that a single compressor with a higher volumetric output is a superior alternative to two compressors, each of lower output, matching the single compressor output. This conclusion is based on the ability to reduce the stock of parts and spares and the reduced logistics support necessary for the single compressor.

There were no compressors investigated that had sufficient capacity to pressurize the chamber in the required three minutes, therefore it is necessary to use high pressure flasks for this task.

Backup air for divers can be supplied by air from high pressure flasks that are filled by the Army's existing 20 CFM FAD compressors. Please refer to section 4.4.2 "Recommendation Criteria" for calculations on the minimum number of flasks required for backup.

It was found that low pressure compressors would be preferable to high pressure compressors because they are more reliable.

It was also found that there is not a significant advantage to either oil lubed or oil free compressors. The oil free design does not require the same filtration equipment and its associated maintenance, however, the oil free design is expected to be less reliable than the oil lubed equipment. This qualitative information applies to the compressor only.

If a filtration system is attached, it will necessarily have its own reliability and maintenance problems that need to be included with the reliability/maintainability data for the oil lubed compressor. Whether the total reliability of the oil free system is lower than the oil lubed system cannot be quantitatively determined. The U.S. Navy includes both designs on its approved list of compressors.

5.3 RECOMMENDATIONS

Two companies were found to have air compressors that fulfilled the Army's requirements. Hamworthy Engineering, Ltd. offers Model 4TH-275W70, and Rix Industries offers their Model 2JS4B-300 medium pressure compressor.

Phillips Cartner more recommends the Rix Industries compressor as the primary air supply for surface supplied diving air. The recommended backup system would use the currently owned 5000 psig compressors along with high pressure air flasks. The two major reasons for recommending the Rix Model are:

- o It is manufactured in the United States to U.S. standard dimensions.
- o It is currently on the U.S. Navy "Approved for Use" list for surface supplied diving air.

Figure 2. details a preliminary recommended surface supplied diving air system configuration. It includes the basic compressor, engine, volume tank, recompression chamber, high pressure air flasks and high pressure compressors for emergency backup as well as room for tools, hoses, fuel and controls. This recommendation is driven by the need to meet flow and pressure requirements with a high degree of technical feasibility. Further refinement of this system will be done during the preparation of a purchase description document.

The Hamworthy compressor, as previously noted, is built to metric standards and would therefore be a special maintenance item. In addition, it is not presently on the Navy's "Approved for Use" list. However, the Hamworthy compressor is less costly and is potentially more reliable due to the fact that it is oil lubricated. As noted before, though, this higher reliability only applies to the compressor part of the system and does not take into account the filtration side.

The compressors offered by Atlas Copco, Bauer and Ingersoll-Rand lacked sufficient capacity to fulfill the requirements of the Army.

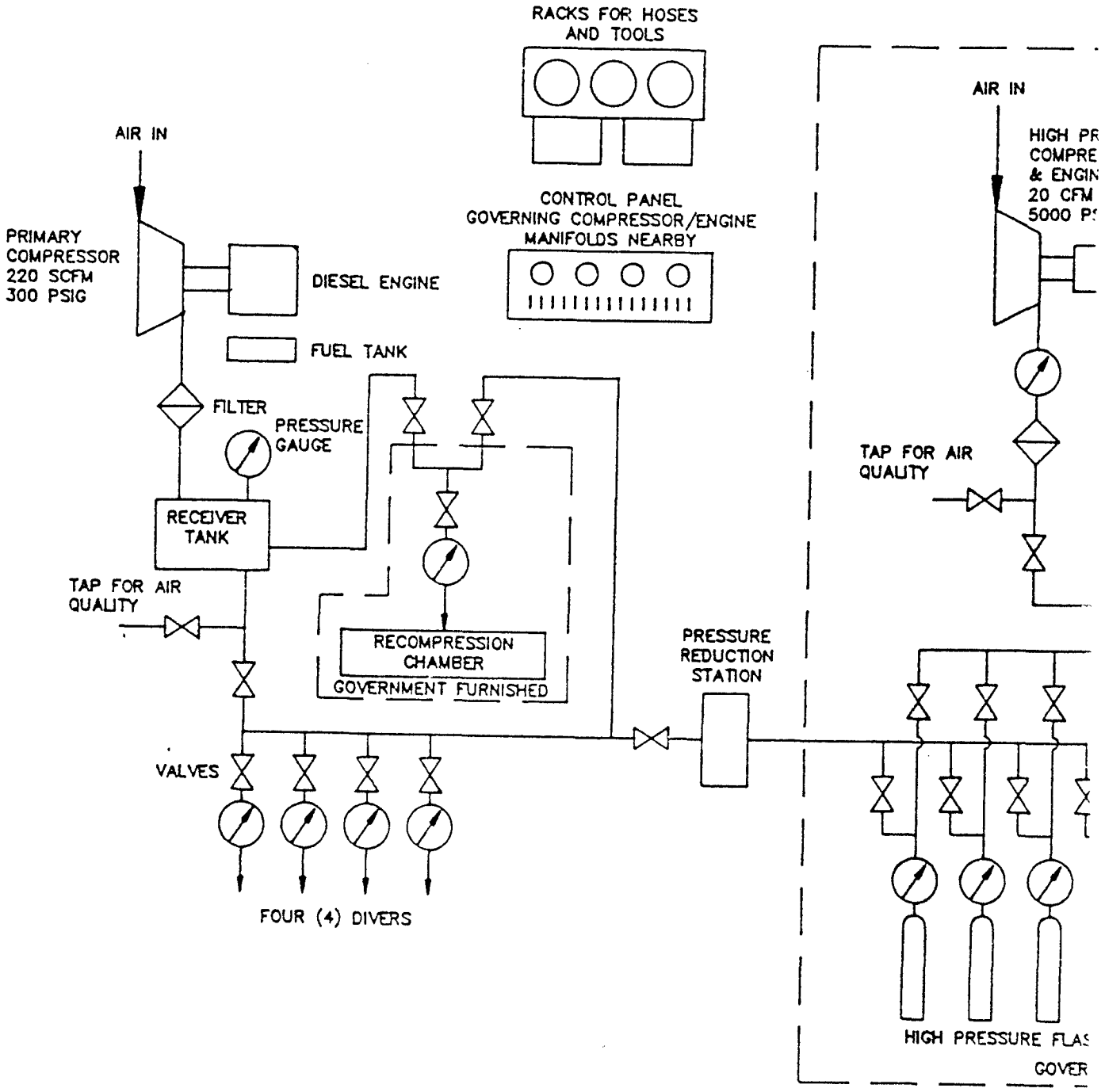
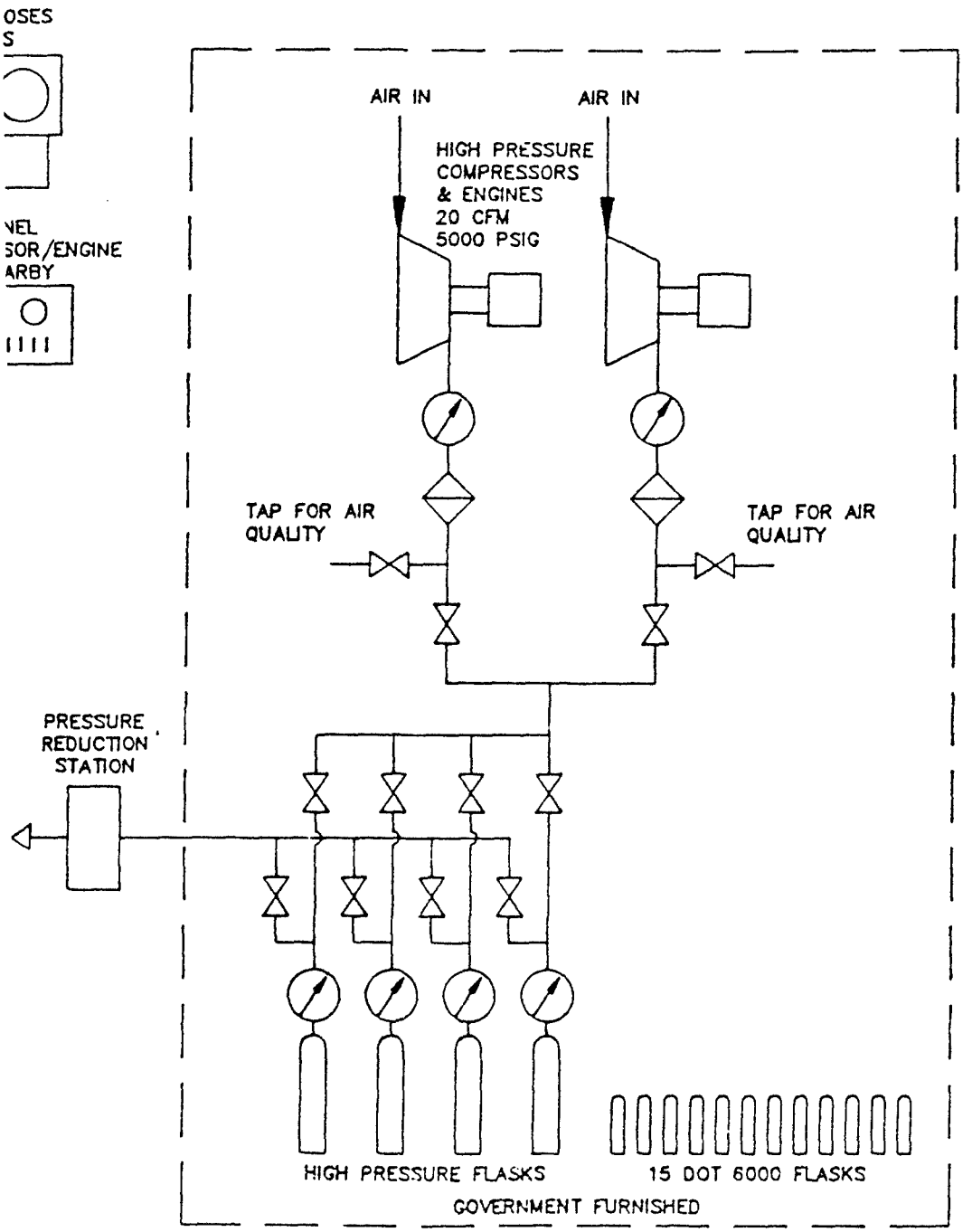


FIGURE 2
PRELIMINARY RECOMMENDED SYSTEM CONFIGURATION



URE 2
)ED SYSTEM CONFIGURATION

5.4 CONTINUATION

The objective of this survey was to determine whether it would be more practical to develop a prototype compressor or update the current purchase description tailoring it for existing, state-of-the-art compressors. It is Phillips Cartner's opinion, based on its findings, that it is not necessary to develop a prototype compressor. It has been determined that the required product is available. If a more quantitative basis is needed for a decision, the next step would be to purchase one copy of each compressor and test each one.

APPENDIX (A)

Questionnaire, CBD Announcement, Old P.D. and Navy ANU List Excerpt

MARKET SURVEY FOR DIVING AIR COMPRESSOR

This package consists of the Army's current requirements, i.e., what we are looking to accomplish, description of diving air compressors presently in use needing upgrade or replacement, and a list of compressor characteristics specifically of interest. Manufacturer/vendor response to the Army should include, but not be limited to, all products that may be appropriate to requirements and referenced characteristics below.

1.0 REQUIREMENTS. The Army would like to evaluate what is commercially available on the market for a diving air compressor. The market survey is being conducted to gather and compile vendor information to eventually prepare a document for procurement.

The air compressor is intended to provide clean, dry, breathable compressed air to support surface-supplied diving equipment and a portable recompression chamber used to treat diving-related injuries.

The requirement for capacity/volume is as follows:

- o 18 acfm at 250 feet of seawater (fsw) and/or
- o pressurize a 236 cubic foot recompression chamber to an equivalent pressure of 165 fsw within 3 minutes and maintain for 40 hours

The current requirement for pressure is as follows:

- o support surface to 250 fsw with and without using a pressure reducer
- o compressor operating pressure may be 0 - 5000 psig with reduction station operations for diver's air supply

The Army is interested in the possibilities of the following:

- o replacing low pressure (0-500 psig) compressors with intermediate (500-1000 psig) or high pressure (1000-5000 psig) ones,
- o using one compressor vs. the two compressors in use now

2.0 BACKGROUND. The Army presently uses a diving air compressor skid mounted package to provide clean, dry, breathable compressed air to support surface-supplied diving equipment and a portable recompression chamber used to treat diving-related injuries. This compressor skid mounted package is used aboard various service craft, for pier-side and field operations.

Configuration/Use:

Currently, two compressors, each 88.5 cfm at 0-200 psig capabilities, support three divers at 250 fsw and pressurize a portable 236 cubic foot recompression chamber to the equivalent pressure of 165 fsw. These units are similar to the Navy's Flyaway Diving System (FADS). The difference between the two systems are:

- o Flow rate
- o Filtration
- o Type of performance specificaiton required for actual purchase of units

Present Inventory:

The Army's systems are over fifteen years old and there are numerous units in use world-wide.

Problems:

- o Linking and transporting of the two units together for proper use
- o Current technology is not being used as the units are out-dated
- o Maintenance and repair of units is hindered due to lack of spare parts

A copy of the Purchase Description (PD) for the current acquisition, titled Compressor Unit, Diesel-Engine Driven, 88.5 CFM, 200 psig, is enclosed for reference

the vendor can provide to up-grade the current system. Please do not respond with comments on revising the PD. It is the intent of the Army to have a unit(s) which meets the requirements but has the minimum physical characteristics, i.e. weight and length.

Important characteristics to note:

Environmental requirements:

- o - 25 degrees F to 125 degrees F
- o salt air use and storage
- o operable aboard service craft in open ocean conditions
- o skid mounted for use along piers, lakes, and rivers

Noise Limits:

The noise produced by the system shall conform to MIL-STD-1474 requirements, with the exception of MIL-STD-1474, 5.2, 5.3, and 5.4, and 4.4 when tested in accordance with 4.5.2.4.2. The provisions of MIL-STD-1474, 4.3 and 4.4 shall apply if and only if MIL-STD-1474, 5.1.1.2 procedures have been pursued and documented to the satisfaction of the contracting officer and written permission to exceed the 85 dB(A) limit is obtained from the procuring activity.

Air quality:

Each system shall have an air sampling test performed to insure that the quality of compressed air produced by the system meets air purity standards for compressed air in accordance with NAVSEA 0994-LP-001-9010, chapter 6, section 6.8.1.2. (Grade "C" air). The air samples shall be taken from the discharge valve of the slide-out receiver, transportable receiver for the run-in and operator's controls test, and from the downstream side of the filter system for the endurance test.

Transportability:

The system, in its transport configuration, shall be transportable by highway, rail, marine, and air modes.

- o maximum size: 8 ft. by 8 ft. by 20 ft.
- o maximum weight: 10,000 lbs at a 5-ton cargo requirement; 7,500 lbs desirable
- o rail: unit(s) in their transport configuration shall withstand the rail impact test specified in MIL-STD-810
- o Units should be sling/forklift transportable

Fuel tank:

The tank shall have a capacity for not less than 8 hours of continuous compressor operation at rated capacity and pressure. The fuel shall be of diesel and/or JP-8 only in accordance with MIL-T-83133.

3.0 MARKET SURVEY INFORMATION. The Army is interested in what is currently available for an off-the-shelf purchase and what components the vendor offers which are preferably better then what already is in use. Please provide manufacturers/vendor informatoin on diving air compressor packages to include, but not be limited to, the following characteristics:

a. MODEL

Do you have experience with breathable air compressor diving packages? Do you have a compressor that satisfies the requirement as an off-the-shelf buy?

b. TYPE

What type of compressor do you offer? Piston, rotary screw, reciprocating booster?

c. CAPABILITY

d. PRESSURE

e. COMPRESSOR PRIME-MOVER

f. FUEL - Diesel and/or JP8 required; reference MIL-T-83133

g. COOLING SYSTEM

h. STORAGE FLASKS - size, pressure storage units, material?

i. FILTER SYSTEM - micron size?

j. SYSTEM PIPING - standards constructed to and materials?

k. CONTROL PANEL - instrumentation and controls?

l. DIMENSION AND WEIGHTS - transportability?

m. ENVIRONMENTAL LIMITATIONS - storage and operation?

n. AIR QUALITY - output?

o. NOISE LEVEL - output and what features have been added/done to reduce noise levels?

p. PACKAGING DESCRIPTION AND ACCESORIES

q. INSTRUCTION, PARTS MANUALS AND DRAWING COSTS

r. AVAILABILITY

s. ESTIMATED PRICE AND DELIVERY

t. MAINTAINABILITY - field and shop? What are estimated maintenance/spare parts costs per year?

u. REFERENCES - The Army is interested in seeing the diving compressor and associated equipment in use. Please provide a list of companys/users that you have sold the equipment to.

43 Pumps and Compressors - Potential Sources Sought

US Army Belvoir Research, Development and Engineering Center, STRBE-FMT Contruction, Rail and Diving Team Directorate, Fort Belvoir, VA 22060-5606

43 – DIVING AIR COMPRESSOR POC John Leary, Attn: STRBE-FMT, 703/774-5581. Investigating sources for a possible future procurement of a Diving Air Compressor System for supporting surface - supplied diving and portable recompression chamber operations. The objective is to gather the information necessary to prepare a document for quantity procurement. Those interested in acquiring greater detail about this survey, i.e., background information and current requirements as well as providing information w/i two weeks of this announcement: John Leary, US Army Belvoir Research, Development and Engineering Center, STRBE-FMT, Fort Belvoir, VA 22060-5606. Tel 703/774-5581. The information will only be accepted on a no-cost or obligation basis. Proprietary information will be appropriately protected. Foreign sources are welcome. (243)

PD 4310-0039A
16 August 1989
SUPERSEDING
PD 4310-0039

PURCHASE DESCRIPTION

COMPRESSOR UNIT,

DIESEL-ENGINE DRIVEN,

88.5 CFM (2.5 CMM), 200 PSIG (1380 KPA)

1. SCOPE

1.1 Scope. This purchase description covers a skid mounted, 88.5 cfm (2.5 cmm), 200 psig (1380 kPa), diesel-engine-driven divers air compressor with low pressure volume/storage tanks. The Authorized for Navy Use (ANU) equipment list, NAVSEA INST 10560.2, should be used when procuring the air compressor portion of the system and repair/replacement parts thereto. No variation or substitute from the ANU list is permitted due to the critical life support nature of the unit.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

VV-F-800	- Fuel Oil, Diesel.

MILITARY

MIL-V-173	- Varnish, Moisture- and Fungus-Resistant (for Treatment of Communications, Electronic, and Associated Equipment).
MIL-P-514	- Plates, Identification, Instruction and Marking, Blank.
MIL-T-704	- Treatment and Painting of Material.
MIL-L-2104	- Lubricating Oil, Internal Combustion Engine, Tactical Service.
MIL-L-2105	- Lubricating Oil, Gear, Multi-Purpose.
MIL-H-2815	- Hose Assemblies, Rubber, Divers Breathing Air and Gas Supply.

MIL-F-3541 - Fittings, Lubrication.
MIL-C-3600 - Compressors, Rotary, Power-Driven: and Compressors Reciprocating, Power-Driven: Air and Gas (Except Oxygen and Refrigerant), Packaging of.

DISTRIBUTION STATEMENT A. Approved for public release, distribution is unlimited.

MIL-G-10924 - Grease, Automotive and Artillery.
MIL-B-11040 - Belt, V: Engine Accessory Drive.
MIL-P-14105 - Paint, Heat Resisting (from Steel Surfaces).
MIL-D-16791 - Detergent, General Purpose (Liquid, Nonionic).
MIL-L-17331 - Lubricating Oil, Steam Turbine and Gear, Moderate Service.
MIL-H-17672 - Hydraulic Fluid, Petroleum, Inhibited.
MIL-G-23827 - Grease, Aircraft and INstrument, Gear and Actuator Screw.
MIL-V-24109 - Valve, Globe, Angle, Quick Change Cartridge Trim, High Pressure (H-P) Hydraulic and Pneumatic (Sizes 1/8 - 1-1/4 Inches).
MIL-V-24578 - Valve, Globe, Pressure Instrument, Stem Test Connection, Union End.
MIL-C-46168 - Coating Aliphatic Polyurethane, Chemical AGent Resistant.
MIL-H-52471/2 - Hose Assemblies, Rubber; Hydraulic Pressure Type; Type 100R2.
MIL-T-83133 - Turbine Fuel, Aviation, Kerosene Type, Grade JP-8.

STANDARDS

FEDERAL

FED-STD-H28 - Screw Thread Standards for Federal Service.

MILITARY

MIL-STD-129 - Marking for Shipment and Storage.
MIL-STD-130 - Identification Marking of U.S. Military Property.
MIL-STD-209 - Slinging and Tiedown Provisions for Lifting and Tying down Military Equipment.
MIL-STD-642 - Identification, Marking of Combat and Tactical Transport Vehicles.
MIL-STD-810 - Environmental Test Methods and Engineering Guidelines.
MIL-STD-838 - Lubrication of Military Equipment.
MIL-STD-1410 - Methods for Selection of Industrial Engines for End Item Application.

MIL-STD-1472	- Human Engineering Design Criteria for Military Systems.
MIL-STD-1474	- Noise Limits for Army Material.
MIL-STD-1791	- Design for Internal Aerial Delivery In Fixed Wing Aircraft.
MS35000	- Batteries, Storage, Lead-Acid, Waterproof.

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, (ATTN; NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those in effect on the date of the solicitation.

NAVSEA INSTRUCTION 10560.2 (NAVSEAINST 10560.2)	- Diving Equipment Authorized for Navy Use.
NAVSEA 0994-LP-001-9010	- U.S. Navy Diving Manual (Vol 1)
NAVSEA 0910-LP-312-4600	- U.S. Navy Diving and Manned Hyperbaric Systems Safety Certification Manual.
NEDUINST 7121.A	- Organizational Level Cleaning Procedure for Air and Oxygen Systems.

(Applications for copies should be addressed to the Superintendent of Documents, US Government Printing Office, Washington, D.C. 20402.)

DEPARTMENT OF AGRICULTURE

Forest Service Standard 5100-1

(Application for copies should be addressed to the Forest Service, US Department of Agriculture, P.O. Box 2417, Washington, DC 20013.)

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)

29CFR Part 1910, 212a

(Application for copies should be addressed to Bureau of National Affairs, 1231 25th Street NW, Washington, DC 20037).

2.2 Non-Government publications. The following document(s) form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD

adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

Boiler and Pressure Vessel Code, Section VIII, Division 1, Unfired Pressure Vessels. Performance Test Code PTC-9- Displacement Compressor, Vacuum Pumps, and Blowers.

(Applications for copies should be addressed to the American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017).

AMERICAN TRUCKING ASSOCIATION (ATA)

Summary of Size and Weight Limit.

(Application for copies should be addressed to the Department of State Laws, American Trucking Association, Inc., 2200 Mill Road, Alexandria, VA 22314-4654).

AMERICAN WELDING SOCIETY (AWS)

AWS D1.1 - Structural Welding Code - Steel.
AWS D1.2 - Structural Welding Code - Aluminum.

(Applications for copies should be addressed to the American Welding Society, 550 NW LeJune Road, P.O. Box 351040, Miami FL 33135).

ASSOCIATION OF AMERICAN RAILROADS (AAR)

Loading and Tie Down Requirements.

(Application for copies should be addressed to the Association of American Railroads, American Railroads Building, 50 F Street, NW, Washington, DC 20001).

INTERNATIONAL ROAD FEDERATION

Limits of Motor Vehicle Sizes and Weights.

(Application for copies should be addressed to the International Road Federation, 1023 Washington Building, Washington, DC 20005).

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

J492 - Rivets and riveting.
J614 - Dipstick Marking.

(Applications for copies should be addressed to the Society of Automotive Engineers, 400 Common Wealth Drive, Warrendale, PA 15096).

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

Rule 442 - Usage of Solvents.

(Application for copies should be addressed to the South Coast Air Quality Management District, 9150 Flair Drive, El Monte, CA 91731).

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, (except for related associated detail specifications, specification sheets or MS standards), the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Description. The compressor (hereafter referred to as the "system" shall consist of the following major components:

a. Air Compressor
   (1) Diesel engine drive
   (2) 12 VDC cranking system
   (3) Dual 12 VDC batteries
   (4) Fuel tank
   (5) Exhaust system with muffler
   (6) Operating instruments and controls
   (7) Compressor
b. Air filtration system
c. Stationary air receiver, 30 gallon (113.5 liter), with pressure relief valve.
d. Slide-out air receiver, 60 gallon (227 liter) with breathing air manifold and pneumofathometers, pressure relief valve, and pressure gauge.
e. Transportable air receiver, 240 gallon (908.5 liter) with breathing air manifold and pneumofathometers, pressure relief valve, and pressure gauge.

3.1.1 System layout. The system shall be fabricated into three separate skid mounted units as follows:

Unit 1	Unit 2	Unit 3
Engine		

Air compressor stationary air receiver slide-out air receiver	Transportable air receiver	Air filtration system

3.1.2 System piping design. The system shall be piped for air flow from the compressor to the stationary 30 gallon (113.5 liter) receiver to the air filtration system to the slide-out receiver and then to the transportable receiver. Both the slide-out receiver and transportable receiver shall contain a manifold for connection of divers deep sea diving hoses. The slide-out receiver and transportable receiver shall both contain as part of each manifold system a pressure relief valve and a pressure gauge. All inlet and outlet openings shall have a cap/plug to prevent contamination permanently affixed to the unit near the opening being capped/plugged.

3.1.3 Frame. Each unit shall be mounted on a heavy duty aluminum skid frame. Frames shall be of open tubular aluminum construction and mounted on aluminum skids of welded construction. The skid frame shall consist of two longitudinal structural shape skids and necessary braces and gussets to prevent frame distortion. Both ends of the skid shall be rounded or beveled to permit sliding and unit 2 shall be provided with a pair of forklift pockets of square tube or inverted U-channel shape, 10 inch (25.4 cm) minimum width. The pockets shall be centered on the skid length, transverse the full width of the unit, and be a minimum of 14 inches and a maximum of 54 inches (137 cm) apart. The pockets shall be labeled "FORKLIFT HERE" in 1 inch high (2.54 cm) letters in accordance with 3.7.1. Slinging and tiedown provisions shall be as specified in 3.18 and 3.19. Unit 1 shall include a top mounted bracket for storing and transporting 600 feet (182.88 m) of umbilical hoses. A waterproof tarp shall be provided for each of the units specified in 3.1.1 and also for slide-out air receiver of unit 1. The tarp shall be supported by the frame in such a manner that water will not collect on the tarp.

3.1.4 Dimensions. Maximum overall dimensions in inches(cm) and weight in pounds (Newtons) of each skid unit shall be as follows:

	Unit 1	Unit 2	Unit 3
Height	86" (218.4 cm)	40" (101.6 cm)	36" (91.4 cm)
Length	97" (246.4 cm)	90" (228.6 cm)	36" (91.4 cm)
Width	60" (152.5 cm)	36" (91.4 cm)	12" (30.5 cm)
Weight	5000 lbs (22241N)	1000 lbs (4448 N)	85 lbs (378 N)

The 5000 pound maximum weight for unit 1 shall include the weight of the umbilical hose and the weight of unit 3.

3.2 Performance. The system shall produce clean, filtered compressed air at rated pressure and capacity with the air intake

filters installed and in ambient temperatures from -25 to +120 °F (-32 to 49 °C).

3.3 First articles. When specified (see 6.2), a sample shall be subjected to first article inspection (see 6.3) in accordance with 4.3).

3.4 Material. Materials not specified shall be selected by the contractor and shall be subject to all provisions of this purchase description.

3.4.1 Material deterioration prevention and control. The system shall be fabricated from compatible materials, inherently corrosion resistant or treated to provide protection against the various forms of corrosion and deterioration that may be encountered in any of the applicable operating and storage environments to which the system may be exposed. Corrosion resistant treatment shall consist of galvanizing or electrodepositing a chromium copper or nickel. This process is to be used only in non-life support components of the system. This process is not to be used in the compressor manifold system, air filtration system or piping system in accordance with instructions in NAVSEA 0910-LP-312-4600.

3.4.2 Dissimilar metals. Dissimilar metals, as defined in MIL-STD-889, shall be electrically insulated from one another to minimize or prevent galvanic corrosion. Insulation may be provided by an insulating barrier such as a corrosion inhibiting sealant conforming to MIL-C-46168 and NAVSEA 0910-LP-312-4600. Protection against corrosion could be also obtained by exclusion of the electrolyte if feasible.

3.4.3 Identification of materials and finishes. The contractor shall identify the specific material, material finish or treatment for use with component and subcomponent, and shall make information available upon request to the contracting officer or designated representative.

3.4.4 Recovered materials. For the purpose of this requirement, recovered materials are those materials which have been collected from solid waste and reprocessed to become a source of raw materials, as distinguished from virgin raw materials. The components, pieces and parts incorporated in the system may be newly fabricated from recovered materials to the maximum extent practicable, provided the system produced meets all other requirements of this purchase description. Used, rebuilt or remanufactured components, pieces and parts shall not be incorporated in the system.

3.5 Environmental requirements.

3.5.1 Operation at extreme temperatures. The system shall operate as specified herein under the following conditions:

3.5.1.1 Low temperature. With a winterization system installed and operating, the system shall start and operate as specified herein for not less than 4 hours at rated capacity in ambient temperature -25 °F (-32 °C) (see 4.5.2.6.1).

3.5.1.2 High temperature. The system unit, either non-winterized or winterized, shall start and operate as specified herein at any ambient temperature up to +120 °F (49 °C) for not less than 8 hours at rated capacity (see 4.5.2.6.2).

3.5.2 Rain and salt/fresh water spray. The system shall start and operate as specified after exposure to 15 minutes of rainfall or salt/fresh water spray at a minimum rate of 3 inches (7.62 cm) per hour directed at all fours sides and top. The system shall operate as specified herein for 15 minutes at no load while the rain or salt/fresh water spray continues to fall at the minimum rate of 3 inches (7.62 cm) per hour (see 4.5.2.7).

3.6 Safety. All parts which are subject to high operation temperatures or which are energized electrically shall be insulated, fully enclosed or guarded when such parts are exposed to contact by personnel, or otherwise create a hazard. All moving parts which ar hazardous to personnel shall be fully enclosed or guarded in accordance with OSHA regulations. Exhaust or discharge from the compressor shall be directed so that they do not endanger personnel or increase the possibility of being introduced into the breathing air system. Protective devices shall not impair the operating functions of the system or restrict the flow of the breathing air system. Sharp edges and projecting points shall be avoided.

3.6.1 Safety devices. Safety devices in accordance with MIL-STD-1410 shall be provided to automatically stop the engine when any of the limiting temperatures or pressures recommended by the engine manufacturer are reached. Switches of the mercury type and those employing a gage needle to activate the safety device shall not be used.

3.7 Human factors.

3.7.1 Human factors engineering. The compressor shall conform to accepted human factors engineering design criteria as described in MIL-STD-1472. Special design emphasis shall be given, but not limited, to general requirements (4), control/display integration (5.1), visual displays (5.2), audio displays 5.3), controls (5.4), labeling (5.5), anthropometry (5.6), design for maintainability (5.9), and hazards and safety (5.13) of MIL-STD-1472, as applicable.

3.7.2 Noise limits. The noise produced by the system shall conform to MIL-STD-1474 requirements, with the exception of MIL-STD-1474, 5.2, 5.3., and 5.4, when tested in accordance with 4.5.2.4.2. The provisions of MIL-STD-1474, 4.3 and 4.4 shall apply if and only if MIL-STD-1474, 5.1.1.2 procedures have been

pursued and documented to the satisfaction of the contracting officer and written permission to exceed the 85 dB(A) limit is obtained from the procuring activity. Hazard signs shall conform to MIL-STD-1474, 4.3, except the sign shall state "HEARING PROTECTION REQUIRED WITHIN (specify) FEET." The sign shall be readable at the distance indicated on the sign.

3.8 Performance characteristics.

3.8.1 Rated capacity. Within five minutes of operation after starting, the system shall deliver breathable air of not less than 88.5 cubic feet per minute (cfm) (2.5 cmm) of free air at a delivery pressure of 200 pounds per square inch gauge (psig) (1380 kPa) (see 6.5.1 and 6.5.3) when operating under all conditions specified herein. The moisture content of the delivered air and air purity standards shall conform to the standards as required in NAVSEA 0994-LP-001-9010 (FM 20-11-1) for divers breathing air.

3.8.2 Endurance. The system shall operate as specified herein for 250 hours when tested in accordance with 4.5.2.5. At the end of this 250 hour period, the decrease in output shall be not more than 0.5 cfm (0.0142 cmm) when delivering air at a pressure of 200 psig (1380 kPa) at rated engine rpm.

3.9 Compression system.

3.9.1 Compressor. The compressor shall be taken from the NAVSEAINST 10560.2 (see 1.1). The compressor shall have an actual cfm flow of 88.5 cfm (2.5 cmm). The compressor shall be lubricated with oil meeting MIL-L-17331 (2190 TEP). A special warning shall be included on the unit. The warning shall prohibit any substitution of oil in accordance with NAVSEA 0994-LP-001-9010 (FM 20-11-1). The compressor shall be provided with a means to unload the compressor when the pressure in the air receiver tanks reaches approximately 210 psig (1448 kPa) and to load the compressor at an air receiver pressure of not less than 180 psig (1241 kPa). The compressor shall be connected to the engine with a belt driven fan type compressor pulley system that shall be included with the compressor.

3.9.2 Pressure vessels. Three receiver tanks having a total of not less than 330 gallons (1250 liters) shall be provided. Receivers and relief valves shall be constructed, stamped, and piped in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Unfired Pressure Vessels. Receiver tanks and system piping shall not be equipped with a means of automatically reducing pressure upon compressor shutdown. Each receiver tank shall be rated at 250 psig (1724 kPa) (minimum) working pressure and proof pressure of 417 psig (2875 kPa) (minimum), equipped with an adjustable spring loaded pressure-relief valve set at 250 psig (1724 kPa), and a pressure gage rated to 300 psig (2069 kPa). A warning plate shall accompany the compressor unit stating "DIVER'S AIR - DO NOT TOUCH."

3.9.2.1 Receiver 1 - stationary. The stationary air receiver shall be firmly attached to the system (unit 1) and shall have a capacity of not less than 30 gallons (114 liters).

3.9.2.2 Receiver 2 - slide-out. The slide-out air receiver shall have a minimum capacity of 60 gallons (227 liters) and shall be mounted on its own skid that is slid into unit 1 during transportation. It shall be easily removable from unit 1 for portable, remote diving operations. The slide-out receiver shall be equipped with manifolds that provide for three pneumofathometer gages, valves and hoses, three valves for attaching deep sea diver's air hoses, a tank pressure gage, a tank pressure relief valve, and a moisture drain valve. Deep sea outlet valves shall be 1-1/16 inch (2.699 cm), 17 internal thread outlet fitting, in accordance with FED-STD-H28. Deep sea inlet valves shall be 1-1/6 inch (2.699 cm), 17 external thread inlet fitting, in accordance with FED-STD-H28. Deep sea inlet valves shall be 1-1/6 inch (2.699 cm), 17 external thread inlet fitting, in accordance with FED-STD-H28. The manifold and valves shall be of ASTM 304 material. A protective enclosure shall be provided to protect all valves, fittings, and gages. A lifting bar shall be provided on both ends of the top section of the frame and on the bottom skids of the frame.

3.9.2.3 Receiver 3 - transportable. Unless otherwise specified (see 6.2), the transportable receiver shall have a capacity of 240 gallons (908.5 liter) and shall be mounted horizontally in its own skid, (unit 2). The transportable receiver shall be equipped with an inlet and outlet manifold that provides for attaching two valves and deep sea diver's air hoses on each manifold; and a pressure relief valve and moisture drain valve. Deep sea outlet valves shall be 1-1/16 inch (2.699 cm), 17 internal thread outlet fitting, in accordance with FED-STD-H28. Deep sea inlet valves shall be 1-1/6 inch (2.699 cm), 17 external thread inlet fitting, in accordance with FED-STD-H28. The manifold and valves shall be of ASTM 304 material.

3.9.3 Pressure tubing and fittings. All pressure tubing and fittings shall have a minimum operating pressure of 250 psig (1724 kPa) and a proof pressure of 417 psig (2875 kPa), they shall be of ASTM 304 material. All tubing and fittings shall be installed to minimize and withstand vibration and allow for thermal expansion. Provision shall be made for relieving pressure to the atmosphere from all lines in the system without disassembly of any fitting or component.

3.9.4 Valves. Manually operated shutoff, isolation, and control service valves shall be of the positive shutoff type and shall be of ASTM 304 material. The valves shall not require more than 60 inch-pounds (6.78 joule) of torque to open or close under a pressure of 200 psig (1380 kPa) and over-torquing to 150 inch-pounds (16.95 joule) shall not damage the valve seats. Valve seats shall be resistant to corrosion and heat damage. All

valves shall be labeled as to function and shall be provided with double-ended arrows indicating the direction of operation and labeled at each end to indicate the functional result (i.e. OPEN, CLOSE) in accordance with 3.7.1. Gage isolation valves shall conform to MIL-V-24578. All other valves installed shall conform to MIL-V-24109.

3.10 Filter system.

3.10.1 Description. The filter system shall utilize non-coalescing filters and particulate filters to remove and reduce the content of moisture, oil mist, and solid particles. The filter system shall trap and drain all liquid condensation and shall reduce oil mist and solid particle content to a level of 5 mg/m^3 maximum. The filter system shall not restrict the actual cfm of the system below 88.5 cfm (2.5 cmm) at any time during operation.

3.10.2 Ratings. The filter system shall have the following minimum ratings and characteristics:

Maximum working pressure:	250 psig (1724 kPa)
Maximum flow rate @ 100 psig:	150 scfm (2.45 cmm)
Maximum flow rate @ 200 psig:	215 scfm (6.09 cmm)
Maximum operating temperature:	120 °F (49 °C)

3.10.3 Components. The filter system shall incorporate all of the following components and design features:

a. Separator/filter - a three micron absolute filter complete with auto drain for removal of solid contaminants and liquid water. The separator/filter shall remove liquid loads up to 25,000 ppm by weight.
b. Particulate filter - a one micron absolute filter complete with auto drain for removal of solid contaminants and liquid water.
c. Oil removal filter - a coalescing type oil removal filter complete with auto drain. Filter cartridge shall be designed to remove oil aerosols and shall have an efficiency 99.999 percent to 0.01 microns.
d. Pressure relief valve, 250 psig (1724 kPa), ASME stamped.
e. Inlet pressure gage, 300 psig (2069 kPa), 2.5 inch (6.35 cm) diameter case.
f. Outlet pressure gage, 300 psig (2069 kPa), 2.5 inch (6.35 cm) diameter case.
g. Differential pressure indicator - to indicate when pressure drop across the filter system requires filter cartridge replacement. The gage shall be color coded green and red. The green portion of the gage shall indicate normal operation, red shall indicate when to change the filter.
h. Two inlet valves, 1/4 turn, ball type - for connection of unit 1 and alternate emergency air, with 1-1/16 inch

(2.699 cm), 17 thread, external fitting in accordance with FED-STD-H28.

i. Two outlet valves, 1/4 turn, ball type - for connection to slide-out receiver (receiver 2) and transportable receiver (receiver 3) with I-1/6 inch (2.699) cm), 17 internal fitting in accordance with FED-STD-H28.

j. ASTM 304 material fittings with minimum pressure rating of 250 psig (1724 kPa).

k. Warning plates mounted on filter unit frame stating "DIVER'S AIR - DO NOT TOUCH."

In compliance with NAVSEAINST 10560.2, note 30, the filter system shall not have sorbent chemical beds. The filter system shall not be required to remove gaseous and vapor phase contaminants such as water vapor, oil vapor, hydrocarbons, or carbon monoxide. The filter system shall not be required to remove tastes and odors associated with gaseous contaminants.

3.10.4 Service and maintenance of filter system. System design shall permit ready access to all items requiring periodic service in the field. Periodic maintenance shall be accomplished with the use of conventional general purpose tools normally associated with diving equipment of this nature. The replacement and adjustment of components and accessories of the filter system shall be accomplished with a minimum of disturbance of system components, piping, or wiring. Operating instructions and replacing of cartridge elements shall be provided on an instruction plate to the frame of the filter unit. Included in the information shall be the required hours between cartridge changes for normal operation. A blank space on the instruction plate shall be provided for the user to record the compressor hourmeter reading of when the filter system cartridges were last changed and the recommended hourmeter reading when the filter system cartridge cartridges are to be changed.

3.11 Drain valves. Drain valves shall be grouped and mounted on a common member of each unit. Drain valve handles shall not extend beyond the exterior of the frame, shall be cool enough to be operable with bare hands, and shall be operable by personnel wearing heavy mitten-type gloves.

3.12 Drive belts. Drive belts shall conform dimensional to RMA Engineering Standards for multiple V-belt drives and shall conform to the material requirements of MIL-B-11040. A means for adjusting belt tension shall be provided.

3.13 Hose assemblies. Hose for hydraulic oil and coolant lines, excluding radiator hose assemblies and breathing air assemblies, shall conform to MIL-H-52471/2. Hose assemblies for breathing air assemblies shall conform to NAVSEAINST 0994-LP-001-9010 (FM 20-11-1).

3.14 Service hose. Three 25-foot (7.62 m) pneumatic hose assemblies conforming to MIL-H-2815, 1/2 inch (1.27 cm) ID, with

deep sea fittings to mate up to the receiver tanks (receiver 2 and 3 [see 3.9.2.2 and 3.9.2.3]) shall be provided. Each hose assembly shall be used to connect unit 1 to unit 2 and unit 3 as required by the diving operation.

3.15 Diesel engine. The contractor shall furnish a electric/manual start diesel engine in accordance with MIL-STD-1410 for application in a class II end item with all the accessories necessary to support the system. For the purpose of selecting the engine, it shall be fully capable of mating up to and operating the compressor selected from NAVSEAINST 10560.2 and meet all compressor cfm requirements without exceeding or requiring additional horsepower as rated for the engine selected. The engine shall be furnished with both a non-electric manual start system and a 24 volt electric cranking and battery charging system; batteries, high coolant temperature control shutdown type, low oil pressure shutdown, and all controls required to operate and monitor engine operating functions. All controls shall be approved by the engine manufacturer and shall be set at the engine manufacturers recommended limits. The battery charging system shall be of the alternator type. The diesel engine shall be capable of operating on diesel fuel conforming to VV-F-800 and JP-8 type fuel conforming to MIL-T-83133 and lubricating oil conforming to MIL-L-2104. The engine shall be equipped with an auxiliary governing control to prevent racing of the engine when the compressor is disengaged.

3.16 Lubrication. All surfaces requiring lubrication shall be provided with a means for lubricating. A dipstick oil-level indicator conforming to SAE J614, a crankcase ventilator, an oil drain, and a pressure switch shall be provided. When the crankcase ventilator is open to the atmosphere, a filter shall be provided to prevent foreign matter from entering the crankcase. The oil drain shall be not less than 3/4 inch (1.905 cm) diameter and shall be located to permit complete drainage of the sump into a suitable container. The pressure switch shall be provided on pressurized lubrication systems to stop the compressor in the event of compressor oil-pressure failure.

3.16.1 Lubricants. The compressor shall operate as specified herein when lubricated with the lubricants as specified in MIL-L17331 (2190 TEP) for temperatures above 20 °F (-7 °C). For temperatures below 20 °F (-7 °C), use lubricants as specified in MIL-H-17672 (2135 TH). No substitutions are allowed. The diesel engine shall operate as specified herein when lubricated with lubricants as state in MIL-STD-838, grease conforming to MIL-G-10924 or MIL-G-23827, and universal gear lubricant conforming to MIL-L-2105 (see 6.4).

3.16.2 Lubrication fittings. Lubrication fittings shall conform to MIL-F-3541, type I, II, or III. Fittings shall be located in a protected position. Accessibility to fittings shall be provided without the removal or adjustment of accessories or parts. Engine housing side panels and plates shall be equipped

with hand-operable, quick-disconnect fasteners and may be removed to provide accessibility to lubrication fittings. Non-removable panels shall be self supporting in the open position in accordance with 3.7.1.

3.16.3 Pressure release device. A pressure release device shall be provided where the use of pressure lubricating equipment will damage grease seals or other parts.

3.16.4 Filling, draining, and checking provisions. Enclosures that contain a reservoir of lubricants for the lubrication of the parts enclosed shall be equipped with dipsticks, check plugs not less than 1/2-inch (1.27 cm) pipe size, or sight gages to determine the level of the lubricant. Each enclosure shall be equipped for filling the enclosure with a lubricant and for draining. The drain outlet shall be located so that removal of the plug will result in complete drainage of the lubricant from the enclosure. Drainage shall be to a container when the compressor is in its normal position. Integral tubes or troughs may be used to convey the lubricant from the drain outlet to a container. Accessibility to the drainplug, the filling means, and the lubricant level checking device shall be provided without the removal of or adjustment of accessories or parts. Compressor housing side panels or plates shall be equipped with hand-operated, quick-disconnect fasteners and may be removed. Non-removable panels shall be self supporting in the open position in accordance with 3.7.1.

3.16.5 Delivery lubrication service. When delivered, all components, except those for which preservatives are specified in 5.2 shall be lubricated. Grease lubrication, including lubrication of sealed bearings, shall be with greases conforming to MIL-G-10924 or MIL-G-23827. Unless otherwise specified herein, all components shall be fitted to the operating level with military oils designated for use in the temperature range as specified herein. Each lubricated component shall be tagged in a conspicuous place to indicate the temperature range and grade of oils and grades of greases used.

3.17 Fungus- and moisture-resistance. The electrical circuitry, including all components except as specified below, shall be protected from the effects of fungus growth and moisture by an overall treatment with varnish conforming to MIL-V-173, composition as specified (see 6.2), with 7 percent salicylamide (by weight) based on the nonvolatile content of the varnish:

a. Components or circuit elements that are inherently fungus and moisture resistant or which are hermetically sealed or are part of the breathing air system need not be treated.
b. Components or circuit elements whose function will be adversely affected by the varnish coating shall not be treated.

When used, the varnish shall be applied by spray, brush, or a combination of both to give a minimum dry-film thickness of 0.001 inch (1 mil) to component or element surfaces previously cleaned and prepared so that the surfaces are free from all foreign matter which would interfere with the adherence or function of the varnish.

3.17.1 Composition. Composition II shall be used only in the case when local air pollution regulations governing the application of varnish precludes the use of composition I. When composition II is used, the contractor shall provide evidence to the Government that the use of composition II is required, and shall certify that the composition II material complies with Rule 442, South Coast Air Quality Management District.

3.18 Slinging attachments. The transportable receiver unit and the compressor unit shall have permanently affixed attachments that comply with MIL-STD-209, class 1 or 3, type IV. The attachments shall be located so that each item can be lifted safely in its normal travel or operation configuration. The provision shall be located so that not less than 1 inch (2.54 cm) clearance is maintained between slings and all exterior parts and shall be fastened to members which will withstand stresses in the amount and direction of pull specified for the provisions without weld failure, permanent deformation, cracking, loosening, or breaking of the provisions or its connecting structural components. Slinging provisions may also be used as tiedown provision when such provisions meet the inch high letters. Combination lift/tiedown points shall be labeled "LIFT/TIEDOWN HERE" in 1 inch high letters.

3.19 Tiedown attachments. Permanently affixed attachments that permit fastening the compressor, transportable receiver and filtration unit to the floor or deck of a transportation medium shall be provided and shall comply with MIL-STD-209, class 2 or 3, type IV and to MIL-STD-1791 for equipment restraint criteria. Tiedown attachments may be also used as lifting attachments when such attachments meet the requirements as specified in 3.18. All slinging/tiedown provisions shall be labeled "LIFT", "TIEDOWN" or LIFT/TIEDOWN" as appropriate, in 1-inch (2.54 cm) high letters.

3.20 Identification marking. The system shall be identified in accordance with MIL-STD-130. The marking shall be applied to the system unit on plates conforming to MIL-P-514, type I, style 1, composition C, of type I, grade A, class 1 material. Plates shall be affixed by screws, bolts, or rivets in a conspicuous location.

3.21 Shipping data plate. Shipping data plates shall be provided and shall conform to MIL-P-514, type III, composition C, of type I, grade A, class 1 material and in addition, shall show the silhouette of unit 1 (with unit 3 attached for transport) and unit 2 in transport position indicating the center of gravity and the location and capacity of the lifting and tiedown attachments.

Plates shall be affixed by screws, bolts, or rivets in a conspicuous protected location.

3.22 Instruction plates. Each unit shall be equipped with instruction plates or diagrams, including warnings and cautions, describing any special or important procedures to be followed in assembling, operating, or servicing the system. Instruction plates shall conform to MIL-P-51, type III, composition C, of type I, grade A, class 1 material. Plates shall be affixed by screws, bolts, or rivets in a conspicuous protected location.

3.22.1 Wind-compressor orientation plate. An instruction plate describing the required compressor's orientation to the prevailing wind. The plate shall read: "NOTICE: LOCATE ENGINE EXHAUST DOWNWIND OF AIR INTAKE." The engine exhaust and air intake shall be prominently labeled.

3.23 Treatment and painting. The portions of the system normally painted, internally and external, shall be cleaned, treated, and painted in accordance with MIL-T-704, type F or G, as applicable. Unless otherwise specified (see 6.2), top coat color shall be camouflage green 383. When specified (see 6.2), the system shall be overcoated in accordance with the Government furnished camouflage patterns with the colors specified in the camouflage patterns. Heat resistant paint conforming to MIL-P-14105 shall be used on parts of the system subjected to a temperature of 400 °F or higher.

3.23.1 Camouflage pattern data. When specified (see 6.2), the contractor shall provide camouflage pattern data.

3.23.2 Government furnished property. When specified (see 6.2), the following property in quantity indicated will be furnished by the Government (see 6.10).

Item No.	Description	Quantity
1	Camouflage paint pattern	As required

3.24 Stenciling. The gross weight of each unit shall be stenciled on each side of the units. Stenciling shall conform to MIL-T-704 using block or stencil-type letters not less than 1 inch (2.54 cm) high. The registration numbers and other markings of the compressor shall be in accordance with MIL-STD-642.

3.25 Toolbox. The system shall be provided with two separate weatherproof toolboxes made of 0.075-inch (0.1905 cm) nominal thickness metal. Each tool box shall have an over-lapping hinged lid which prevents the entry of rain, direct, and POL products. Each lid shall be provided with a fastener of a type that will keep the lid closed when the toolbox is subjected to vibration. Each toolbox shall be fastened to the system in a protected position. Each toolbox shall be of sufficient size to house the operating and maintenance tools that are to be provided by the

contractor. The tools that are to be provided shall be those special tools deemed necessary by the system component unit manufacturer to perform to general support maintenance by the user. Each toolbox shall incorporate a provision for drainage. It is critical that there be two sets of tools, one set is to be used strictly on the breathing air system and is not to be exposed to any POL product expect for what is in the life support side of the compressor, the other set of tools is to be used strictly for the non-life support side of the system. The toolbox containing the breathing air tools shall be labeled "BREATHING AIR SUPPLY TOOLS" in accordance with 3.7.1. The other toolbox shall be labeled "NON-LIFE SUPPORT TOOLS" in accordance with 3.7.1.

3.26 Air induction system. A heavy duty air cleaner and restriction indicator, in accordance with MIL-STD01410, 4.2.11, shall be furnished. The snorkel mast shall be able to extend above the compressor unit to provide sufficient distance from the engine exhaust.

3.27 Exhaust system. The exhaust system shall be designed to present minimum hazard to the operator while starting, operating, or making minor adjustments to the engine or system while the system is running. A low noise muffler shall be provided. Exposed hot areas shall be guarded. Outlet shall be equipped with a raincap, low noise muffler, and a spark arrestor, or a combination muffler, rain cap, spark arrestor. The spark arrestor shall conform to the US Department of Agriculture, Forest Service Standard 5100-1. The total backpressure of the exhaust system shall not exceed the maximum recommended by the manufacturer. Provisions shall be made to easily remove and store portions of the exhaust system extending above the unit frame which may otherwise be damaged or interfere with transporting the system. Provisions shall be made to extend the unit exhaust system not less than 15 fee (457.2 cm) above unit frame. The engine exhaust shall be located as far from the compressor intake as practical. Ducting may be used to increase the separation.

3.28 Fuel tank and quantity indicator. The fuel tank shall have a capacity for not less than 8 hours of continuous compressor operation at rated capacity and pressure. A panel mounted fuel capacity quantity indicator, conforming to 3.7.1, shall be provided. A filler neck assembly shall be provided and shall incorporate a removable strainer and have a chain secured filler cap and a fuel tank cap gasket. The filler opening shall be a minimum of 2.5 inches (6.35 cm). The fuel fill port shall be labeled "DIESEL FUEL OR JP-8 ONLY" in accordance with 3.7.1. Provisions shall be made for connection to an auxiliary fuel supply. A standpipe at least .025 inch (0.0635 cm) above the bottom of the fuel tank shall be incorporated into the fuel tank to prevent entry of direct and foreign matter into the fuel system. Construction and mounting shall be such that vibration, tightening of the mounting devices, or contact with other

components of the engine or system will not cause leaks to develops. The tank and all lines shall be located or positioned to minimize fire hazard or damage resulting from spilling, overflow, damage, or vapor lock at 120 °F (49 °C) ambient temperature.

3.29 Clutch. A clutch for the engagement of the engine to the compressor belt drive shall be furnished and shall be operable from within reach of the engine controls. Provisions shall be made to prevent clutch engagement due to vibration during operation.

3.30 Cranking system. A heavy duty 24-volt cranking system with glow plug type starting aid shall be furnished. Two batteries, conforming to MS35000 shall be furnished. Battery storage provisions shall be included. Provisions to start the engine manually (a non-electric means) by a hand crank pneumatic assist or spring loaded assist start shall also be provided.

3.31 Operating instruments and controls (instrument panel). An instrument panel shall be provided for all engine and compressor instruments and controls. The panel shall be furnished with a dimmer switch controlled illumination for use in darkness in accordance with the Army Secure Lighting Program. All instruments, valves, receiver tanks, and controls shall be labeled in accordance with 3.7.1 with permanently affixed marking plates in accordance with MIL-P-514.

3.32 Engine instruments and controls. The engine shall be equipped with the following instruments and controls:

a. Tachometer.
b. Electric start.
c. Lubricating oil pressure gage.
d. Voltmeter.
e. Hour meter, electric, non-resetable.
f. Fuel gage.
g. Vernier type throttle for precise setting of engine rpm.
h. Engine speed control to prevent racing of engine when compressor is disengaged.

3.33 Compressor instruments and controls. The compressor shall be equipped with the following instruments and controls:

a. Air pressure switch to unload the compressor when the pressure in the stationary air receiver reaches approximately 210 psig (1448 kPa), and to load the compressor at an air pressure of not less than 180 psig (1241 kPa). The air pressure switch shall to be wired to shutdown the diesel engine.

b. High air temperature switch to sound an alarm conforming to 3.7.1 in the event of high discharge air

temperature which may cause the lubricating oil to flash and produce carbon monoxide. Temperature shall be measured at the compressor outlet, prior to the aftercooler.

c. Discharge temperature gage to indicate temperature at the compressor discharge, prior to the aftercooler.

d. Discharge air pressure gage to indicate compressor output. The gage shall be piped in such a way as to permit the operator to tell when the compressor is unloaded.

e. Low pressure rpm unloader to automatically unload the compressor when the diesel engine is at idle.

3.34 System instruments and controls. The pneumatic system shall be equipped with the following instruments and controls:

a. Receiver pressure gage.

b. Low pressure

3.35 Interchangeability. All parts having the same part number shall be functionally and dimensionally interchangeable. Interchangeable parts are defined as two or more parts possessing such functional and physical characteristics as to be equivalent in performance and durability and capable of being exchanged one for the other without alteration of the parts themselves or of adjoining parts except for adjustment, and without selection for fit or performance. Note, no interchanging of similar parts between the compressor/breathing air system and diesel engine/non breathing air system is allowed. There is no exception to this requirement.

3.36 Workmanship. All parts, components, and assemblies of the breathing air system and compressor including castings, forgings, molded parts, stampings, bearings, seals, machined surfaces and welded parts shall be cleaned in accordance with instructions in NEDUINST 7121.A. All components of the system shall be clean and free from sand, dirt, fins, pits, sprues, scales, or any damaging extraneous material. The compressor shall be free of any defect that could hinder or impair its operation or serviceability.

3.37 Fabrication. Steel and aluminum used in the fabrication of the system shall provide original quality surface finish and shall be free from kinks and sharp bends. The forming of the material shall be done by methods that will not cause damage to the metal. Shearing and chipping shall be done neatly and accurately. Corners shall be square and true, and sharp edges and burrs shall be removed. Flame cuttings may be employed of steel, but not of aluminum instead of shearing or sawing. Burned surfaces of flame-cut material shall be ground or machined sufficiently to remove ash and cooling checks. Precautions shall be taken to avoid overheating, and heated metals shall be allowed to cool slowly. All bends of a major character shall be made with metal dies or fixtures to insure uniformity of size and shape. Fabrication standards of ASME Boiler and Pressure Vessel

Code, section VIII, Division 1, Unfired Pressure Vessels, AWS D1.1, AWS D1.2, and OSHA 29 CFR Part 1910, 212a shall be followed by the manufacturer. Any conflicts between the above documents shall be clarified by referring to NAVSEA (0910-LP-312-4600 for clarification.

3.38 Welding. The standards of AWS D1.1 and AWS D1.2 shall be followed for all welding. The surface of parts being welded shall be free of scale, paint, grease, and other foreign matter. Welds shall transmit stress without permanent deformation or failure when the parts connected by the welds are subjected to proof and service loading.

3.39 Bolted connections. Boltholes shall be accurately punched or drilled and shall have burrs removed. Boltholes in structural members subject to variable loads shall be punched or drilled. Washers or lock washers shall be provided where necessary. All bolts, nuts, and screws shall be correctly torqued. Matching thread areas securing bolts or capscrews shall be of sufficient strength to withstand the tensile strength of the bolt.

3.40 Riveted connections. Rivets shall fill the holes completely. The upset rivet head shall be full, neatly made, concentric with the rivet holes, and in full contact with the surface of the member and shall be in accordance with SAE J492.

3.14 Machine work. Tolerances and gages for metal fits shall conform to limitations specified herein.

3.42 Transportability. The system, in its transport configuration, shall be transportable by highway, rail, marine, and air modes. The transport configuration for unit 1 includes the 600 feet of umbilical hoses stored on the top mounted bracket and also unit 3 stored in the transport compartment of unit 1.

3.42.1 Highway. The transport configuration so unit 1 and unit 2 shall individually; be within the dimensions of the M35A2C trucks flatbed; be restrainable using the truck's cargo tiedown provisions; shall not exceed the payload capacity of the M35A2C truck; be transportable in the flat bed of the M35A2C truck without exceeding the legal size and weight limits imposed by the state and North America Treaty Organization (NATO) countries. United States limitations are summarized by the American Trucking Association, Inc. (ATA). The NATO statutory road limitations are available from the International Road Federation (IRF).

3.42.2 Rail. The compressor shall be rail transportable in CONUS and NATO countries without restrictions. The M35A2C and unit 1 combination, when loaded on a 50-inch high rail car, shall meet the dimensional requirements of the Association of American Railroads (AAR) gage. Each unit 1 and 2 in their transport configuration shall withstand the rail impact test specified in MIL-STD-810 without degradation or damage.

3.42.3 Fixed wing aircraft. Unit 1 and 2, in their transport configuration, shall be transportable on a HCU-6/E type 1 pallet (for 463L air cargo handling system). The palletized load shall be transportable on the C05A, C-130, and C-141 aircraft. Criteria for transport in U.S. Air Force cargo aircraft are defined in MIL-STD-1791.

3.42.4 Rotary wing aircraft. In their transport configurations, units 1 and 2 shall be externally air transportable (EAT) by UN-60 helicopters in an environment of 70 °F (21 °C) ambient temperature at an altitude of 2,000 feet (610 m) above sea level for 30 nautical miles (55.6 Km). Units 1 and 2 shall meet the requirements of MIL-STD-209 for helicopter transport.

3.43 Cleaning of life support system. All parts and systems for use with oxygen and compressed air shall be thoroughly cleaned and tested for cleanliness in accordance with the standards for the following publications and procedures: MIL-D-16791 and NEDU Instruction 7121.A. Included in the cleaning procedure shall be the requirement to perform an air purity sampling test after the last step of the cleaning procedure is completed. This shall insure that the parts and systems cleaned meet the exposure limit values for breathing gas as stated in NAVSEA 0994-LP-9010, chapter 5.

3.43.1 Documentation. Documentation for cleaning procedures, air purity sampling test procedures, and results of the first article unit and each production unit shall be furnished in a waterproof plastic holder secured on the inside of the curbside control panel door of each servicing unit. The plastic holder shall be sized to hold at least a 12-month time period of documents.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items must meet all requirements of sections 3 and 5. The inspection set forth in the specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all

products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to acceptance of defective material.

4.2 Classification of inspection. The inspection requirements specified herein are classified as follows:

a. First article inspection (see 4.3).
b. Quality conformance inspection (see 4.4).
c. Inspection comparison (see 4.6).
d. Inspection of packaging (see 4.7).

4.3 First article inspection. Prior to examination and test of the system, the following shall be performed:

a. The system shall be started and operated. Inability of the system to deliver 88.5 cfm (2.5 cmm) of free air at 200 psig (1380 kPa) in less than 5 minutes after starting shall constitute a failure of this test.
b. A schedule of maintenance to be followed during all testing of the first article system shall be furnished. A list of tools required to perform this maintenance shall also be provided.
c. The system shall be lubricated with military oils and greases as specified in 3.16 of this purchase description. Oils and greases shall be those designated for use in the ambient temperature at the place of the test.

4.3.1 Examination. Prior to testing, the system shall be examined for the presence of defects marked "X" in the column 1 of table I. Presence of one or more defects shall be cause for rejection.

4.3.2 Tests. Upon successful completion of the examination specified in 4.3.1, the system shall be subjected to the tests marked "X" in column 1 of table II. Failure of any test shall be cause for rejection.

4.4 Quality conformance inspection.

4.4.1 Inspection. Each system shall be subjected to the examinations in column 2 of the table I and any defect is cause for rejection. Each system shall be submitted to the tests in column 2 of table II. Failure of any test shall be cause for rejection.

4.5 Inspection procedure.

4.5.1 Examination. Examination shall be in accordance with table I.

TABLE I. Examination

First Article 1	Quality Conformance 2	Inspection Comparison 3	Defects 4	Requirements Paragraph(s) 5
x	x	x	Description not as specified.	3.1
x	x	x	System layout not as specified.	3.1.2
x	x	x	System piping design not as specified.	3.1.2
x	x	x	Frame not as specified.	3.1.3
x	x	x	Dimensions not as specified.	3.1.4
x	x	x	Material not as specified.	3.4
x	x	x	Materials not resistant to corrosion and deterioration, or treated to be resistant to corrosion and deterioration of the applicable storage and operating environments.	3.4.1
x	x	x	Dissimilar metals as defined in MIL-STD-889 are not effectively insulated from each other.	3.4.2
x	x	x	Contractor does not have documentation available for identification of materials, material finishes, or treatment.	3.4.3
x	x	x	Used, rebuilt or remanufactured components, pieces, or parts incorporated in the system.	
x	x	x	Safety devices not as specified.	3.6 & 3.6.1
x	x	x	Human factors not as specified.	3.7.1
x	-	-	Noise not as specified.	3.7.2
x	x	x	Maintainability not as specified.	3.7.1
x	x	x	Pressure vessels, tubing, and fittings not as specified.	3.9.2 & 3.9.3
x	x	x	Manually operated valves not as specified.	3.9.4
x	x	x	Air filters not as specified.	3.10 thru 3.10.3
x	x	x	Service and maintenance design of filter system not as specified.	3.10.4
x	x	x	Pressure relief valves not as specified.	3.9.4 & 3.10.3d
x	x	x	Air receiver tanks not as specified.	3.9.2.1 thru

x	x	x	Unloader not as specified.	3.9.1, 3.9.2 & 3.33a
	x	x	Blowdown device not as specified.	3.9.1, 3.33a & 3.34
x	x	x	Frame not as specified.	3.1.3
x	x	x	Drain valves not as specified.	3.9.4, 3.10.3a, b, & c & 3.11
x	x	x	Drive belts not as specified.	3.12
x	x	x	Hose assemblies and fittings not as specified.	3.13
x	x	x	Servicing hose and fittings not as specified.	3.14
x	x	x	Lubrication design not as specified.	3.16
x	x	x	Lubricants not as specified.	3.16.1
x	x	x	Lubrication fittings not as specified.	3.16.2
x	x	x	Pressure release device not as specified.	3.16.3
x	x	x	Filling, draining, and checking provisions not as specified.	3.16.4
x	x	x	Delivery lubrication service not as specified.	3.16.5
x	x	x	Fungus- and moisture-resistance not as specified.	3.17
	x	x	Slinging and tiedown attachments as specified.	3.18 & 3.19
x	x	x	Identification marking not as specified.	3.20
x	x	x	Shipping data plate not as specified.	3.21
x	x	x	Instruction plates not as specified.	3.22
x	x	x	Treatment and painting not as specified.	3.4.2 & 3.23
x	x	x	Stenciling not as specified.	3.24
x	x	x	Tools and toolbox not as specified.	3.25
x	x	x	Air induction system not as specified.	3.26
x	x	x	Exhaust system not as specified.	3.27
x	x	x	Fuel tank not as specified.	3.28
x	x	x	Clutch not as specified.	3.29
x	x	x	Cranking system not as specified.	3.30
x	x	x	Lighting not as specified.	3.31
x	x	x	Control panel not as specified.	3.31 & 3.32
x	x	x	Interchangeability not as specified.	3.35
	x	x	Workmanship not as specified.	3.36

x	x	x	Fabrication not as specified.	3.37
x	x	x	Welding not as specified.	3.38
x	x	x	Bolted connections not as specified.	3.39
x	x	x	Riveted connections not as specified.	3.40
x	x	x	Machine work not as specified	3.41
x	x	x	Transportability not as specified.	3.42
x	x	x	Highway transportability not as specified.	3.42.1
x	x	x	Rail transportability not as specified.	3.42.2
x	x	x	Fixed wing aircraft transportability not as specified.	3.42.3
x	x	x	System not cleaned as specified.	3.43
	x	x	Material not of quality as used on first article.	sect 3
x	x	x	Leaks in coolant, fuel, oil or air lines.	sect 3
x	x	x	Lubricants not as specified.	sect 3
x	x	x	Parts or components missing or do not function.	sect 3
x	x	x	Assembly incorrect or incomplete.	sect 3

4.5.2 Tests. Tests shall be in accordance with table II.

TABLE II. Tests.

First article	Quality Conformance	Inspection Comparison	Tests	Test Para(s)	Requirement Para(s)
1	2	3	4	5	6
:	-	-	System consumption	4.3a	3.9.1, 3.15
:	-	-	Maintenance schedule	4.3b	3.7.1
:	-	-	Lubrication	4.3c	3.16.1
:	-	-	Test conditions	4.5.2.2	3.9, 3.10, 3.15 & 3.6
:	x	x	Air cleanliness	4.5.2.3	3.43 & 3.43.1
:	x	x	Air purity	4.5.2.3	3.10 thru 3.10.3
:	x	x	Run-in	4.5.2.4	3.8.2
:	-	x	Endurance	4.5.2.5	3.8.2
:	-	x	Final performance	4.5.2.5.2	3.8.2
:	-	x	Low temperature	4.5.2.6.1	3.5.1.1
:	-	x	High temperature	4.5.2.6.2	3.5.1.2
:	-	x	Rain, fresh/	4.5.2.7	3.5.2

		salt water spray		
-	x	Tiedown & slinging attachments	4.5.2.8	3.18 & 3.19
-	x	Rail hump	4.5.2.9	3.1 & 3.42.2
-	-	Performance	4.5.2.10	3.8.1
x	x	Hydrostatic	4.7	3.9.3

4.5.2.1 Test log. A first article test log covering the run-in, endurance, cycling, high and low temperature, air purity, storage temperature, lifting and tie down, rail hump test, rain and fresh/salt water spray, and noise shall be established tabulating the appropriate test data. The log shall be prepared by the contractor and shall include all items as listed on two separate sheets of legal size paper. The contractor shall prepare and provide a log for each unit separate from the first article test log that shall provide a record of the run-in and air purity tests. This log shall be identified by serial number and will accompany each unit for certification purposes.

4.5.2.2 Test conditions.

a. Unless otherwise specified herein, sequence of tests is optional with the tester.
b. Only that maintenance established by the contractor and submitted as a schedule prior to the start of testing shall be performed during the test.
c. Safety and human factor considerations shall be evaluated throughout testing.
d. The system shall be started using the electrical cranking system without external assistance (either by adding more batteries - amperage - or by manual/mechanical means).
e. Fuel. All first article tests shall be conducted using JP-8. Quality conformance tests shall be conducted using JP-8 or the appropriate grade of diesel fuel.
f. Clean, test and document the life support system cleanliness as cleaning procedure, or noncompliance of the system in meeting the exposure limit values for breathing gas as stated in NAVSEA 0994-LP-001-9010, chapter 5 shall constitute failure of this test.
g. Run air cleanliness test before run-in and endurance tests.
h. The first article endurance test (see 4.5.2.5) shall be run with the compressor fully treated and painted. It is not necessary to have the camouflage patterns applied for conduction of the endurance test.
i. All quality conformance testing of air purity samples (see 4.5.2.3.1) shall be conducted with the compressor fully treated and painted with the camouflage patterns applied.

4.5.2.3 Air purity. Each system shall have an air sampling test performed to insure that the quality of compressed air produced by the system meets air purity standards for compressed

air in accordance with NAVSEA 0994-LP-001-9010, chapter 5, 6.8.1.2. The air samples shall be taken from the discharge valve of the slide-out receiver, transportable receiver for the run-in and operator's controls test, and from the downstream side of the filter system for the endurance test. The contractor shall provide to the Government copies of the test procedures and test results by serial number of each system to the Government for certification purposes. Failure to conform to the air purity standards of NAVSEA 0994-LP-001-9010, chapter 5 shall constitute failure of this test. The test shall be conducted in accordance to the procedure in 4.5.2.3.1.

4.5.2.3.1 Air purity sampling procedures. Evaluation of the air sampling shall be conducted by an independent laboratory. The test shall be performed during the endurance test every 10 hours and at the end of each run-in test (10 hours). The test procedure for the air sampling and the name of the independent laboratory conducting the evaluation shall be submitted to the Government for review and approval prior to conducting the air sample test.

4.5.2.4 Run-in. The system shall be operated for a run-in period as determined by the contractor but not less than 10 hours of operation, utilizing all operator controls. During the final hour of this test, capacity shall be determined as specified in 4.5.2.4.1. Inability of the system to produce the capacity or meet the performance requirements specified in 3.8.1 and 3.8.2 shall constitute failure of this test.

4.5.2.4.1 Capacity. Capacity shall be determined in accordance with the low pressure nozzle method of the ASME Performance Code for Displacement Compressors, Vacuum Pumps, and Blowers, PTC-9. Capacity may also be calculated from the weight of air delivered in a given time with a constant back pressure of 200 psig, wherein the pressure vessel utilized for weight measurement shall be not less than 1000 cubic inches (16,400 cubic cm), and capacity shall be calculated based on free air at intake conditions.

4.5.2.4.2 Noise level test. Noise levels shall be measured in accordance with MIL-STD-1474 requirements and reported in the format indicated by MIL-STD-1474, figure 7. As a minimum, noise levels shall be measured when equipment is operating under full load. MIL-STD-1474, 5.1.2.1.4 contours shall be taken at not fewer than 12 equal (horizontal) arc increments, one increment shall include data from the noisiest position. The noise level at the typical operating position shall be provided as dB(A) level. Failure to comply with MIL-STD-1474 provisions and 3.7.2 shall constitute failure of this test.

4.5.2.5 Endurance. Conduct the test without shelter and at the climatic conditions existing at the place of testing. The system shall be coupled to its power unit and shall be operated for a total of 250 hours as follows:

a. 200 hours with the system delivering not less than 88.5 cfm (2.5 cmm) of free air at 200 psig (1380 kPa).
b. 25 hours with the system cycling not less than 10 times per hour between the cut-in and cutout pressure of the unloader. The output shall be adjusted so that the pressure will alternately build up to 210 psig (1448 kPa), the system unload, and the pressure drop to 180 psig (1241 kPa), cut-in pressure.
c. 25 hours with the system operating for alternate periods of 10 minutes loaded and 50 minutes unloaded.
d. For the 200 hours of operation specified in a., data listed in 4.5.2.5.1 shall be recorded every 2 hours, and a capacity computation shall be made after every 40 hours of operation. A graph shall be prepared, plotting capacity and corresponding air receiver discharge temperature, taken and logged every 40 hours of operation.
e. At the end of each 25-hour cycling test specified in b. and c., remove the system from cycling operation and operate the system at rated capacity for 1 hours. After 1 hour operation make a capacity computation.
f. Capacity shall be determined utilizing the formula as set forth in 4.5.2.4.1.
g. Endurance tests shall not be credited in less than 2-hour intervals of continuous operation. Intervals of endurance test time of less than 4 hours terminated by malfunction shall not be credited. All test time accrued during other successfully completed tests specified herein shall be credited. Operate all functional controls, including valves, not less than 50 times during the test. All safety devices may be demonstrated independently of system operation. Determine intervals of air filter cartridge change as specified by the air filter cartridge manufacturer.
h. Readings shall be taken only after at least 1 hour of continuous operation. Record appropriate remarks including a record of all stops and adjustments. The amount of lubricants consumed and fuel added during the tests shall be recorded as they are added to the test system.

4.5.2.5.1 Test data.

a. Compressor crankshaft speed, in rpm.
b. Discharge pressure measured at air filter outlet, in psig (kPa).
c. Temperature of air at receiver outlets, in degrees fahrenheit (celsius).
d. Intercooler and aftercooler inlet and outlet surface temperatures, in degrees fahrenheit (celsius). Thermocouples shall be used and shall be located on the cooler inlet and outlet piping as close to the cooler as physically possible.

e. Intercooler and aftercooler pressure, in psig (kPa).
f. Free air delivery rate, in cfm (cmm).
g. Ambient air temperature and pressure, in degrees fahrenheit (celsius) and inches (mm) Hg.
h. Lubricating oil temperatures, in degrees fahrenheit (celsius).
i. Average temperature of air inside system frame, in degrees fahrenheit (celsius).
j. Dew point of delivered air, in degrees fahrenheit (celsius).

4.5.2.5.2 Final performance. Upon completion of 250 hours of testing, repeat the capacity test specified in 4.5.2.4.1.

4.5.2.5.3 Failure criteria. Any of the following shall constitute failure of this test:

a. Failure of any component which will cause inability of the system to perform as specified.
b. Inability of the system to operate as specified in 3.8.
c. Inability of the valves to operate as specified in 3.9.4.
d. A fuel tank capacity less than specified in 3.28.
e. Inability of the unloader to operate as specified in 3.9.1.
f. Inability of the blowdown device to operate as specified in 3.9.1.
g. Inability of the pressure relief valves to operate as specified in 3.9.2.
h. A decrease in the capacity of the system after the final performance test of more than as specified in 3.8.2.
i. Inability of the system to provide air as specified in 4.5.2.3.

4.5.2.6 Environmental

4.5.2.6.1 Low temperature. Expose the system to an ambient temperature of -25 °F (-32 °C) for not less than 4 hours or until all temperatures have been stabilized for at least 1 hour. Start the system and operate under conditions specified at full load for a minimum of 4 hours. While delivery air at 200 psig (1380 kPa) at a compressor crankshaft speed of not less than that used in establishing performance in 4.3a, record the data listed in 4.5.2.4.1 at 15 minute intervals and capacity at the end of each hour. Evidence of malfunction or damage to the compressor, or inability to start and operate as specified shall constitute failure of this test.

4.5.2.6.2 High temperature. Expose the system to an ambient temperature of 120 °F (-32 °C) for 4 hours or until all temperatures have been stabilized for at least 1 hour while at this ambient temperature, start the system and operate at full load for 8 hours, delivering air at 200 psig (1380 kPa) at a

compressor crankshaft speed of not less than that used in establishing performance in 4.3a. Record the data listed in 4.5.2.4.1 at 30-minute intervals during operation of the system. Evidence of malfunction or damage to the system, or inability to start and operate as specified shall constitute failure of this test.

4.5.2.7 Rain, fresh/salt water spray. Subject the system, in operating condition with all components connected together and all panels necessary for operation open, to a simulated rainstorm and fresh water and salt water spray by conducting two separate tests identical except for the water spray used. The first test shall use salt water spray the second test shall use freshwater spray. The test shall be conducted in the following manner: water shall be sprayed onto the system at a minimum rate of 3 inches per hour (6.62 cm/hr) directed simultaneously at all four sides and on top at an angle of approximately 45 degrees from the vertical. The apparatus for producing the spray shall emit water in the form of droplets rather than a fine mist. Expose the system to the spray for 15 minutes not running, and then start and operate the system for 15 minutes at no load while the spray continues. Water leakage into the air cleaners and crankcase or water accumulation on other components which prevents operation of the system at rated capacity and performance standards shall constitute failure of this test.

4.5.2.8 Tiedown and lifting attachments. The system's lifting and tiedown attachments shall be tested in accordance with MIL-STD-209. The maximum shipping weight for unit 1 shall include the weight of the umbilical hoses and the weight of unit 3. Nonconformance to 3.18 and 3.19 or weld failure, permanent deformation, cracking, loosening, or breaking of attachments or its connecting structural components shall constitute failure of this test.

4.5.2.9 Rail impact test. The rail impact/hump test shall be performed at the completion of the 250 hours of endurance testing. The system shall be tested in accordance with MIL-STD-810, rail impact test procedure to show conformance to 3.42.2. Nonconformance to 3.42.2 or inoperability after test shall constitute a failure of the test. During and after the test if any item that is attached or included as an integral part of the test item breaks free, cracks, loosens or shows any sign of permanent deformation as a result of the test shall constitute a failure of the test.

4.5.2.10 Performance

4.5.2.10.1 Performance. The first article system shall be operated continually through 15 minute loaded-unloaded cycles. The unloaded phase of operation shall be not more than 1 minute in duration. The test data specified in 4.5.2.4.1 shall be recorded every 2 hours during loaded operation, and a capacity computation shall be made from every fifth set of data readings.

Inability to meet the requirements of 3.8.1 shall constitute failure of this test.

4.6 Inspection comparison. The Government may select a system at any time during the contract production period and subject these systems to the examination identified by "x" in column 3 of table I and the tests identified by "x" in column 3 of table II to determine conformance to the requirements of this purchase description. The inspection shall be performed by the Government, at a site selected by the Government, on units selected at random from those which have been accepted by the Government and shall not include the previously inspected first article systems. In addition to any test specified as part of the inspection comparison, the Government reserves the right to conduct any and all other tests contained in this purchase description as part of the inspection comparison and failure of such additional tests shall have the same effect as failure of those tests as specified as inspection comparison.

4.6.1 Inspection failure. Failure of an inspection comparison system to meet any requirement specified herein during and as a result of the examination and tests specified in 4.6 shall be cause for rejection of the inspection comparison system(s) and shall be cause for refusal by the Government to continue acceptance of production systems until evidence has been provided by the contractor that corrective action has been taken to eliminate the deficiencies. Correction of such deficiencies shall be accomplished by the contractor at no cost to the Government on systems previously accepted and produced under the contract. Any deficiencies found as a result of the inspection comparison shall be considered prima facie evidence that all systems accepted prior to the completion of the inspection comparison are similarly deficient unless evidence to the contrary is furnished by the contractor and such evidence is acceptable to the contracting officer.

4.7 Hydrostatic. Subject the compressor air system to a hydrostatic pressure of not less than 417 psig (2875 kPa) (5/3 of 250). Hold the test pressure for 90 minutes. Any permanent damage, deformation, or evidence of any leakage shall constitute failure of this test.

4.8 Inspection of packaging. The preservation, packing and marking shall be examined and tested to determine compliance with the applicable quality assurance provisions of MIL-C-3600, MIL-STD-129, and the requirements of section 5 herein.

5. PACKAGING.

5.1 First article pack. Unless otherwise specified (see 6.2), the contractor shall furnish a first article pack for examination and test, within the time frame specified (see 6.2), in accordance with the preproduction pack requirements of MIL-C-3600 except that the test car for the guided-impact test shall

travel at speeds of 4, 6, and 8 miles per hour (mph) for a total of three impacts in one direction and one impact at 8 mph in the opposite direction.

5.2 Preservatives. Special care shall be exercised so that the life support areas of the system is not coated with a preservative material that is detrimental to the human respiratory system. The use of a petroleum base preservative on the life support areas is prohibited.

5.3 Preservation, packing, and marking.

5.3.1 Domestic (CONUS) shipments. When specified (see 6.2), the compressor and all components of the unit shall be preserved (see 5.1), packed and marked in accordance with the level A requirements of MIL-C-3600.

6. Notes.

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory).

6.1 Intended use. The systems are intended to provide clean, dry, breathable compressed low pressure air to surface supplied diving equipment and to recompression chambers used to treat diving related injuries.

6.2 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number, and date of this purchase description.
b. Issue of DODISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2.1.1 and 2.2).
c. Time frame required for submission of first article and number of first article systems to be furnished (see 3.3).
d. When the Government shall conduct any or all of the first article examination and tests. When the Government shall conduct some but not all of the first article examination and tests, the contracting officer shall specify which examination and tests shall be conducted by the Government and which examinations and tests shall be conducted by the contractor (see 3.3).
e. When volume capacity of receiver other than as specified is required (see 3.9.2.3).
f. Composition required (see 3.17).
g. Color when other than as specified (see 3.23).
h. When compressor shall be overcoated with Government furnished camouflage patterns (see 3.23).
i. Time frame for camouflage pattern data, when required (see 3.23.1).
j. When a first article pack is not required (see 5.1).

k. Time frame for submission of first article pack, when required (see 5.1).
l. When compressor is to be preserved, packed and marked for other than domestic (CONUS) shipment (see 5.3.1 and 5.3.2).
m. When transportability report is required (see 6.9).

6.2.1 Consideration of data requirements. The following data requirements must be listed, as applicable, on the Contract Data Requirements List (DD Form 1423) when this specification is applied on a contract, in order to obtain the data, except where DOD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1423.

Reference paragraph	DID Number	DID Title
3.23.1	DI-MISC-80192	Color photograph prints
3.23.1	DI-MISC-80176	Camouflage line art data

The above DID's were those cleared as of the date of this specification. The current issue of DOD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be researched to ensure that only current, cleared DID's are cited on the DD Form 1423.

6.3 First article. When a first article inspection is required, the item(s) should be a preproduction model. The first article should consist of one or more units. The contracting officer should include specific instructions in acquisition documents regarding arrangements for examinations, approval of the first article test results and disposition of the first articles. Invitation for bids should provide that the Government reserves the right to waive the requirement for samples for first article inspection to those bidders offering a product which has been previously acquired or tested by the Government, and that bidders offering such products, who wish to rely on such production or test, must furnish evidence with the bid that prior Government approval is presently appropriate for the pending contract. Bidders should not submit alternate bids unless specifically requested to do so in the solicitation.

6.4 Lubricants. MIL-STD-838 prescribes the policy for using specification-type products wherever possible and provides specific requirements for potential use of non-standard proprietary products. MIL-STD-838 is implemented by MIL-HDBK-113. MIL-L-17331 lubricants are the only type of lubricants approved for use in the life support side of diving and diving support equipment. The contracting officer should note that unless otherwise authorized by the US Army Belvoir Research, Development, and Engineering Center (ATTN STRBE-FMT), Fort Belvoir, VA 22060-56-6, lubricants, fluids, and greases for ground equipment and diving equipment systems must be restricted to those listed under MIL-HDBK-113, chapter 2 and MIL-LL-17331.

6.5 Definitions. For the purpose of this specification, the following definitions apply:

6.5.1 Pressure. All pressures referred to herein, unless otherwise specified as absolute shall be interpreted as psi gage (psig) (kPa).

6.5.2 Ambient temperature. Ambient temperature is defined as the temperature at atmospheric conditions surrounding the system but not in the immediate vicinity where temperature may be affected by the heat of the system or engine cooling system.

6.5.3 Free air. Free air is defined as air at atmospheric condition surrounding the system, at the point where the compressor is installed, but not in the immediate vicinity where it may be affected by the heat of the system or engine cooling system.

6.6 Technical manuals. The requirement for technical manuals should be considered when this specification is applied on a contract. If technical manuals are required, military specifications and standards that have been cleared and listed in DOD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL) must be listed on a separate Contract Data Requirements List (DD Form 1423), which is included as an exhibit to the contract. The technical manuals must be acquired under separate contract line item in the contract.

6.7 Provisioning. The contracting officer shall include provisioning requirements for repair parts and maintenance/special tools as necessary, and instructions on shipment of the system. A suggested paragraph is as follows:

> "Shipment of the system shall include repair parts, maintenance/special tools, operational instructions, and accessories, unless exceptions are provided elsewhere in the contract."

6.8 First article pack. Approval of the first article pack will not relieve the contractor of his obligation to preserve, pack and mark the compressors in accordance with this purchase description. Any changes or deviation in production packs from the approved first article pack will be subject to the approval of the contracting officer.

6.9 Transportability report. When specified (see 6.2), the contracting officer should arrange for the contractor to furnish a transportability report in accordance with AR 70-47 and S.O.P. 70-38 for the compressors 95 days prior to delivery of the first article compressor.

6.10 Government-furnished property. The contracting officer should arrange to furnish property listed in 3.23.2.

Preparing activity:
Army - ME

DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
WASHINGTON DC 20362-5101

IN REPLY REFER TO
NAVSEAINST 10560.2A
OPR 00C32
21 FEB 1989

NAVSEA INSTRUCTION 10560.2A

From: Commander, Naval Sea Systems Command

Subj: DIVING EQUIPMENT AUTHORIZED FOR NAVY USE

Ref: (a) NAVSEA 0994-LP-001-9010, U. S. Navy Diving Manual (Volume 1, "Air Diving")
(b) NAVSEA 0994-LP-001-9020, U. S. Navy Diving Manual (Volume 2, "Mixed Gas Diving")

Encl: (1) Diving Equipment Authorized for Navy Use

1. Purpose. To issue a list of diving equipment Authorized for Navy Use (ANU).

2. Cancellation. NAVSEAINST 10560.2 of 10 June 1987.

3. Background. OPNAVINST 3150.27 (series) requires Commander, Naval Sea Systems Command (SEA 00C) to prepare and publish a list of diving equipment.

4. Definition. ANU denotes selected commercially available diving equipment, tools, accessories, and hyperbaric systems components which have undergone design safety reviews, test and evaluation, or both to ensure diver safety. The ANU process addresses two basic categories of equipment:

Category I. Life support diving equipment (e.g., helmets, regulators, compressors, etc.).

Category II. Non-life support equipment which are potentially hazardous to the diver (e.g., explosively actuated tools, surface powered electrical tools, hydraulic chain saws, etc.).

5. Discussion. Life support diving equipment must undergo physical and physiological test and evaluation through the entire range of operation under the auspices of the Navy Experimental Diving Unit or other designated testing activity. Potentially hazardous non-life support equipment, as a minimum, will undergo a design safety review, test and evaluation, or both as appropriate. SEA 00C will conduct a review of all test results, design studies, and documentation to determine acceptability of the equipment for use by Navy divers. Reliability and maintainability are also important considerations. Additionally, diver preference items that have been proven safe and operationally adequate by years of satisfactory use are listed as recommended items for procurement (e.g., diver tools that do not pose a hazard, hydraulic and pneumatic power sources for tools, cameras, wet suits etc.). This listing does not prohibit procurement of similar, commercially available items which pose no safety hazard to divers and which are not classified as category I or II items. Where appropriate, Navy standard stock and military specifica-

U. S. NAVY DIVING EQUIPMENTS AUTHORIZED FOR NAVY USE

ITEM	STOCK NUMBER/CATEGORY	MANUFACTURER'S NAME	DESIGNATION	NOTES
Watch, wrist submersible	Commercially Available	Diver Preference		23
Other Diving Equipment				
Bell, open diving	NSN 7H-4220-01-230-7375	NAVSEA Control		
Bibs, Mask O_2,	Commercially Available/ I NSN 4220-00-240-7150	Scott Aviation	800931	24
Bibs, Mask O_2 for Overboard Dump System	Commercially Available/ I NSN 4220-01-173-5384 NSN 4220-01-173-5385 NSN 1H-4240-01-233-6639 NSN 1H-1940-01-219-6370	Scott Aviation	803139 803139-01-02 803139-01-03 803238-00 801238-01	
Booster, pump, gas/O_2	Commercially Available/ I	Haskel	26968/55016/55312	25
		Haskel	54420(Steel Frame)	
		Haskel	54420-1(Aluminum Frame)	
CO_2, Analyzer, hand held pump	NSN 1H-6665-00-710-7815/ I	Draeger	N/A	26
tube, 0.1 to 6%	NSN 1H-6665-00-769-0945/ I	Draeger	N/A	
Communications				
Amplifier (Recompression chamber only)	Commercially Available/ I NSN 7H-4220-01-256-8452	Amron Intl.	AMCOM II 2820/24 AMCOM II 2820-4003	
		EFCOM	DAR 1000 Mod 2	
Amplifiers	Commercially Available/ I NSN 7H-4220-01-223-0051	Helle Engineering Hydro Products	3315, 3315S Hydrocom	
Microphone	Commercially Available/ I	OTS	1PMC	27
			SDV16	28
	NSN 1H-5965-01-119-8682	HELLE	10780,10782	
Compressor, H.P.	Category I			29,30
3000 PSIG 2 SCFM	Commercially Available	Bauer	Varius	
3000 PSIG 4 SCFM	Commercially Available	Bauer	KA-51-DF/C-G	
	NSN 4310-00-165-4865	Bauer	UTILUS-G	
3000 PSIG 5 SCFM	NSN 1H-4220-LL-H-077797	N/A	N/A	
3000 PSIG 5 SCFM	NSN 1H-4220-01-248-0412	RIX	1S3B-6G(SA-6G)	
3000 PSIG 7 SCFM	Commercially Available	Bauer	Mariner	
3000 PSIG 8 SCFM	Commercially Available	Hardie-Tynes	3M-133	
3000 PSIG 9.2 SCFM	Commercially Available	Bauer	KA-14/K14	
		Mako Compair	K14	9
3000 PSIG 14 SCFM	Commercially Available	Mako Compair	K15	9
3000 PSIG 15 SCFM	Commercially Available	Ingersoll Rand	10T2	
	Commercially Available	Bauer	K15	

U. S. NAVY DIVING EQUIPMENTS AUTHORIZED FOR NAVY USE

ITEM	STOCK NUMBER/CATEGORY	MANUFACTURER'S NAME	DESIGNATION	NOTES
3000 PSIG 20 SCFM	Commercially Available	RIX	3K3B-44,K8G-44	
		Ingersoll Rand	4R15,15T4	
		BAUER	K20	
3000 PSIG 24 SCFM	MIL-C-18419 ✓	N/A	N/A	
	MIL-C-52973 ✓	N/A	N/A	
3000 PSIG 34 SCFM	Commercially Available	Bauer	FS 34	
3000 PSIG 60 SCFM	MIL-C-18419	N/A	N/A	
3000 PSIG 90 SCFM	Commercially Available	RIX	2JS48-150	
400 PSIG 150 SCFM	Commercially Available	RIX	2JS2B-300	
200 PSIG 18 SCFM	Commercially Available	Aqua Air	AAI 325	31
250 PSIG 97 SCFM	Commercially Available	Quincy	5120	
Filters, Divers' Air	Category I			
Up to 150 PSIG	Commercially Available	Pall	Housing: MCC1001G160	32
			MCD1001G160	32
			Element: MDC1001SUM	
			MDS1001SUM	
			POC1001SUM	
			POS1001SUM	
		Filterite	Housing: 913794-001	
			Element: REV-DUO-FIN-10	
		Deltech	Housing:DELGUARD 45C	9
			Element:450E	
		King	Housing:2260-1	32
			Element:(6 required)	
			9326A-241 (1)	
			2430-5-6 (5)	
		Dollinger	Housing: GP-11-105	32
			Element: 2-34	
		Consler	Housing: CCP-3	32
			Element: 11714	
Up to 180 PSIG	Commercially Available	Facet	Housing: 056800	32
			Element:(18 required)	33
			041315-12 (12)	
			045800-06 (6)	
Up to 250 PSIG	Commercially Available	Arrow	Housing: F518-12	32
			Element: EKF518	
		Monnier	Housing: 204-6209-8	32
			Element: 26540	
Up to 300 PSIG	Commercially Available	Filterite	Model: 915140-000	34
			Type:LMOVS10S-3/4 HPNMS-8	
			Model: 926045-000	
			Type:LMOVS10S-3/4 HPNMS-8	
		Pall	Housing: VCS3001G160	34
			VCS3002G160	
			MEC3003G320	
			MOC3003G320	
	NSN 4330-00-436-8159		Element:PFS-1001-ZMM	
		Filterite	Element:REV-DUO-FIN-10	

APPENDIX (B)

Vendor Lists, Commercial Diving Companies contacted

Vendors that responded:

Manufacturer	Address	POC
Hamworthy USA, Inc.	Allied Marine Services 659 S. Washington St. Alexandria, VA 22314 (703) 836-0300	Tim Gale
Atlas Copco	161 Lower Westfield Rd. P.O. Box 431 Holyoke, MA 01041 (413) 536-0600	Matthew Hanna
Bauer Compressor	1328 Azalia Garden Rd. Norfolk, VA 23502 (804) 855-6006	Allen Hunts
Ingersoll-Rand	5110 - 27 Center Dr. Charlotte, NC 28224 (919) 658-5275	Mike Sexton
Rix Industries	P.O. Box 8605 Oakland, CA 94662 (415) 658-5275	Michael Parker

Vendors who did not have applicable products or who did not respond:

Manufacturer	Address	POC
American Bristol Industry	1600 West 240th St. Harbor City, CA 90710	Charles Lamoreaux
Amer-Tech	P.O. Box 201868 San Antonio, TX 78220	William Hudgens
Astro Pak	1624 Steele St. P.O. Box 6240 Chesapeake, VA 23323	Charles Wetzel
Blackwater Engineers	7420 82 St. Lubbock, TX 79424	Calvin Worley
Buck Industries, Inc.	6930 Sykesville Rd. Sykesville, MD 21784	John Buck
Caci, Inc.	831 Industrial Ave. Chesapeake, VA 23324	Ron Snyder
Carey Machinery and Supply	P.O. Box 206 Baltimore, MD 21203	Hall Worthington
Comp-Air Equipment, Inc.	1445 South Mint St. Charlotte, NC 28203	Lillian Pouliot
Dee Sea Underwater Video Service	P.O. Box 304 Wynnewood, PA 19096	Bill James
Eagle Air Systems	P.O. Box 458 6122 Hunt Road Pleasant Garden, NC 27313	Ray Sexton
Henderson Limited, Inc.	P.O. Box 830876 Richardson, TX 75083	Shakeel Ahmed
Hoffman Industries	P.O. Box 1666 2113 Smith Ave. Chesapeake, VA 23320	Lee Barrett

Manufacturer	Address	POC
International Construct. Services Inc.	1049 30th St., NW Washington, DC 20007	Ivette Abud
Leroi Division, Dresser Industries, Inc.	6135 Barfield Road Suite 119 Atlanta, GA 30328 (704) 846-2745	Brad Kroll
Mako Compressors Inc.	1634 SW 17th St. P.O. Drawer 1630 Ocale, FL 32678	A. M. Gonzalez
Ocean Technology, Inc.	2810 Via Orange Way Suites A-E Spring Valley, CA 92078	J. J. Fenwick
Omni Southeast, Inc.	P.O. Box 5484 Charlotte, NC 28225	Micheal Fogle
PK Lindsey Co.	63 Nottingham Rd. Deerfield, NH 03037	Rich Buswell
Knox Western (Quincy)	1111 Bacon Street Erie, PA 16511 (814) 459-2754	John Craduck
Sull Air Corp.	3700 E. Michigan Blvd. Michigan City, IN 46360	Tom Sherman
Universal Technologies, Inc.	P.O. Drawer G.Alsonia St. Estill Springs, TN 37330	
Brodie, Frank	P.O. Box 6576 Long Beach, CA 90806	
O'Hanlon, Mike	161 Lower Westfield Rd. Holyoke, MA 01040	

Commercial Diving Companies that were contacted

1. Stroud Diving & Hydrography
   2045 Gilmore St.
   Jacksonville, FL 32204
   (800) 525-6326
   POC - Will Hux

2. Cal Dive International
   2707 North Loop West, STE. 200
   Houston, TX 77008
   (713) 880-1944
   POC - Ernie Webber

3. Oceaneering International, Inc.
   P.O. Box 1118
   Aransas Pass, TX 78336-1118
   (505) 395-5247
   POC - Bruce Pickering

4. Global Divers & Contractors
   Houston, TX
   (318) 261-9716
   POC - Chuck Mowry

APPENDIX (C)

Copies of Vendor Literature and Response Material

1. Atlas Copco
2. Bauer
3. Hamworthy Engineering Ltd.
4. Ingersoll-Rand
5. Rix Industries
6. Quincy

Atlas Copco

October 31, 1989

Commander
Belvoir RD and E Center
Fort Belvoir, VA 22060-5606

Attention: STRBE-FMT (J. Leary)

RE: MARKET SURVEY: DIVING AIR COMPRESSOR

Dear Sir:

We are pleased to respond to your request for information for a Diving Air Compressor package. In keeping with your request to use off-the-shelf components, we have focused our attention on our mid-pressure LT12-435 Reciprocating Air Compressor Block as our corner stone of our potential offerings.

We would also like to point out at this time that the LT12-435 is the higher pressure, big-brother to the LT8 air compressor package which has gone through an exhaustive testing procedure at the Department of the Navy, Naval Coastal Systems Center, Panama City, FL 32407-5000. Our air compressor package has been assigned a Navy part number 5371-592-6314343 and the project personnel was Scott Steedly and Chris Bottomy. We would direct you to these gentlemen, as they are most familiar with the style package we can supply.

Please reference drawing number 1310-9003-36 (enclosed) as a similar configuration to what we can develop for your specific requirements.

Basis your existing equipment, we have made several assumptions concerning compressed air storage. One is that receiver tanks are passive and not mechanical. Therefore, they are extremely low maintenance when compared to any mechanical machinery. Moreover, if you use compressed air storage tanks, you can utilize a smaller, lighter and more portable compressed air system; therefore, our system will require the 330 gallons (or 44 cubic foot) of compressed air storage as currently being used in the existing packages. We suggest more storage capacity would only help in all aspects of this application. We have also calculated that our system will require between 60 and 65 minutes to pressurize the 330 gallons (44 cubic feet) of storage as a basic start-up function.

Address
161 Lower Westfield Rd.
Box 451
Holyoke, MA 01041-0451

Telephone
(413) 536-0600

Telex
955325
951719

Telefax
(413) 536-0091

Our LT12-435 will produce 42 cfm (FAD) at 435 psig. We have calculated that with proper storage of no less than 330 gallons (44 cubic foot), we will be able to maintain the required 70-72 psig (165 FSW). To maintain this pressure for 40 hours will be a function of system leaks. As long as the leaks are less than the capacity of the air compressor, then 40 hours can be maintained.

We have included several pieces of information for you to review. You will find a component description, outline drawing of the block and basic literature of various packages in the L-Series. But, most interesting to you will be the drawing of the current unit that has been designed to produce compressed air to be used in a breathing air package for NAVSEA in Panama-City, Florida.

Lastly, the information contained on the market survey section should be used as a guide only and only applies to the air compressor and its driver. We request further discussions that can address the controls and filtration systems, as we prefer to engineer to your specific needs using standard components where possible.

As always, if you have questions or comments, please feel free to contact Mr. Ted Beasley at (803) 532-2575. Mr. Beasley is our Regional Manager for your area.

Very truly yours,

Matthew B. Hanna

Matthew B. Hanna
Sr. Product Specialist
Lubricated Products

am
enclosures

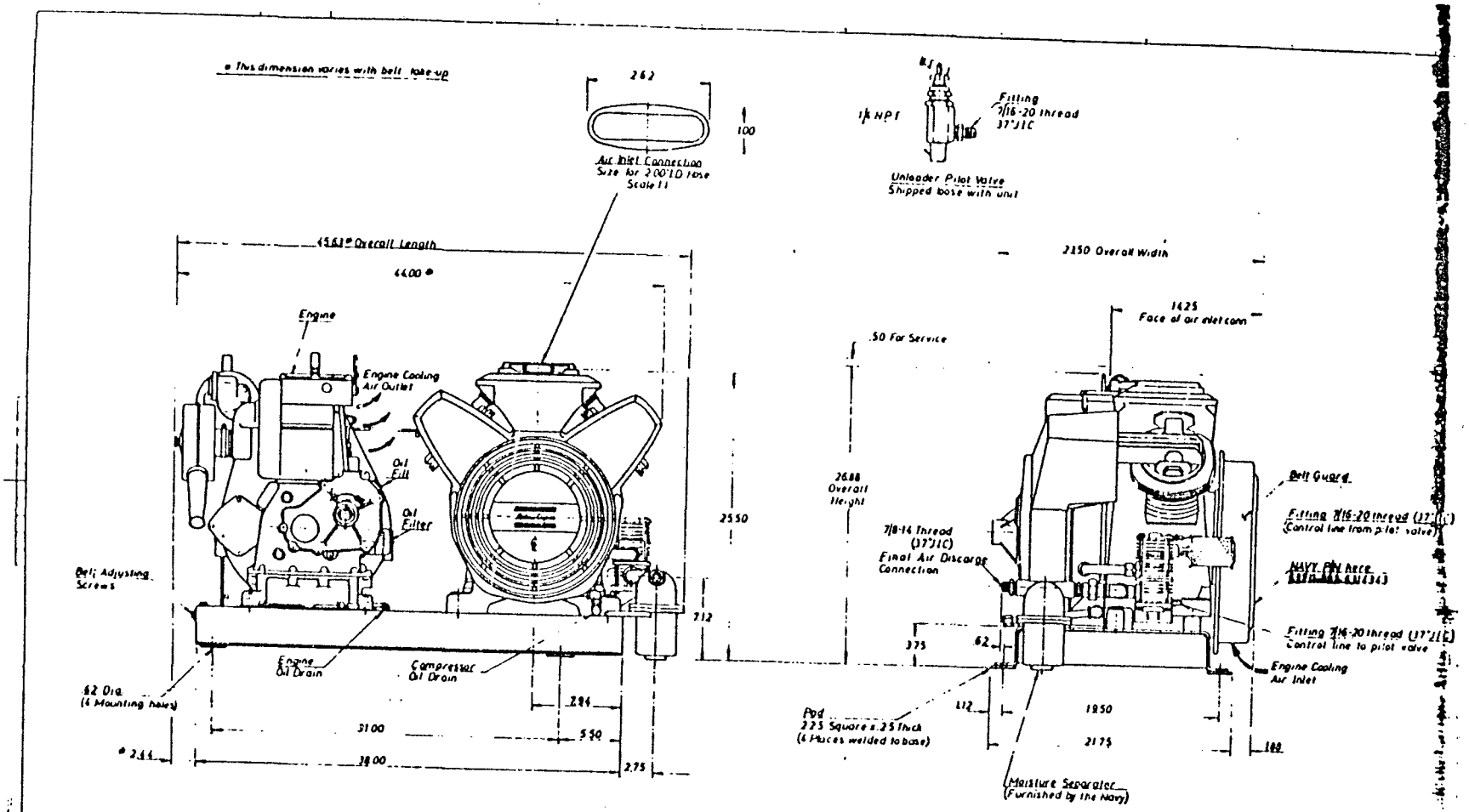
cc: Michael O'Hanlon
Ted Beasley

Atlas Copco

MARKET SURVEY

A.	MODEL	LT12-435 Block used in a package designed for the Army application. Similar to Navy P/N 537115926314343 (see drawing enclosed).
B.	TYPE	LT12-435 Mid Pressure Block - Reciprocating Style, Aircooled We will only address the air compressor package as the filtration, controls and receiver storage are to be engineered to your specific needs. Please refer to the above Navy P/N for an air compressor package we have supplied in the past.
C.	CAPABILITY	42 CFM (FAD) at 435 PSIG
D.	PRESSURE	435 PSIG
E.	COMPRESSOR PRIME MOVER:	DIESEL ENGINE V BELT DRIVE
F.	FUEL	Diesel
G.	COOLING SYSTEM	Aircooled
H.	STORAGE FLASKS	Yet to be determined. Suggest minimum of 330 gallon
I.	FILTRATION SYSTEM	Down-stream filtration is yet to be determined as our expertise is the air compressor package.
J.	SYSTEM PIPING	Yet to be decided
K.	CONTROL PANEL	Yet to be decided
L.	DIMENSIONS AND WEIGHTS	APPROXIMATE ONLY L = 76" W = 45" H = 39" Weight Compressor Package only approx. 1225 lbs.
M.	ENVIRONMENTAL LIMITATIONS	Yet to be decided, as our compressor packages typically are for 32 Deg F through 110 Deg F ambients

N.	AIR QUALITY	Air Compressor Package only. We refer you to the Navy tests done in Panama City for a typical air quality.
O.	NOISE LEVEL	88 dB(A) for Block only. Diesel drive may or may not effect this level - information to follow if required.
P.	PACKAGING DESCRIPTION AND ACCESSORIES	This packet of information concerns the air compressor section only, which consists of the air compressor block, drive motor, V-belt drive system and sub-base. Controls, filtration and receiver storage are not a part of this request for information and must be addressed at a later date.
Q.	INSTRUCTION AND PARTS MANUALS	The depth of these will depend on the final scope of supply
R.	AVAILABILITY	Yet to be determined, as final scope of supply will effect this. Our block configuration is typically a stock to 2 week lead time item. If alterations to the standard block are required, then that will impact the delivery.
S.	ESTIMATED PRICE AND DELIVERY	Estimated price for the compressor portion only will fall into the $15,000 - $22,000 +/- range. Receiver storage, controls and filtration will be additional.
T.	MAINTENANCE	Estimated maintenance per year can range from 2% to 7% of the initial cost.
U.	REFERENCES	We have recently completed a lengthy design, build and test process with the Naval Coastal Systems located in Panama City, Florida. The air compressor package we supplied is shown on the attached drawing numbered 1310-9003-26. This was a lower pressure and smaller horsepowered unit than what we envision designing for this application.


* This dimension varies with belt take-up
2.62
1.00
Air Inlet Connection
Size for 2.00 I.D. hose
Scale 1:1
1/4 NPT
Fitting
7/16-20 thread
37° JIC
Unloader Pilot Valve
Shipped loose with unit
45.63* Overall Length
44.00*
2350 Overall Width
14.25
Face of air inlet conn
.50 For Service
Engine
Engine Cooling
Air Outlet
Oil
Fill
Oil
Filter
25.50
26.88
Overall
Height
7/8-14 Thread
(37° JIC)
Final Air Discharge
Connection
Belt Guard
Fitting 7/16-20 thread (37° JIC)
(Control line from pilot valve)
NAVY P/N here
Fitting 7/16-20 thread (37° JIC)
Control line to pilot valve
Engine Cooling
Air Inlet
Belt Adjusting
Screws
7.12
.62
3.75
Engine
Oil Drain
Compressor
Oil Drain
.62 Dia.
(4 Mounting holes)
2.94
31.00
5.50
* 2.44
38.00
2.75
Pad
2.25 Square x .25 Thick
(4 Places welded to base)
1.12
19.50
21.75
1.69
Moisture Separator
(Furnished by the Navy)
PLEASE NOTE
This print is merely for preliminary use unless the following are filled correct for customers order
Number
Customer
Branch office order
Our shop order
Approved by
Date
CONDITIONS OF SERVICE
Compressor speed 1800 RPM
Capacity 20 CFM
Working pressure 200 PSIG
Approx Unit Weight 590 lbs
Dimensions in inches
GENERAL PURPOSE MARINE
1310 9002

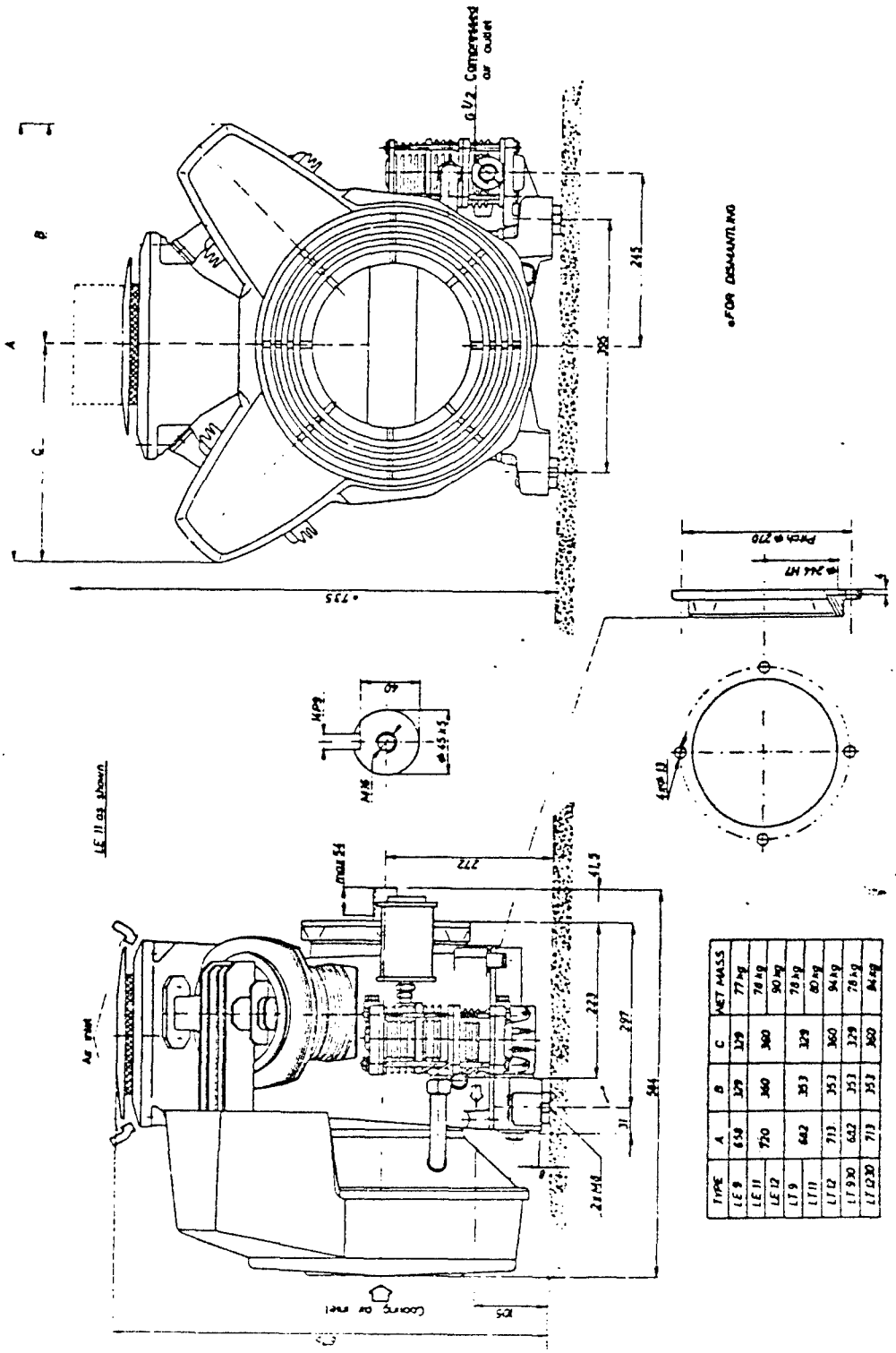
Stationary piston compressors
AIRLET LE/LT9, -11, -12, LT930, -1230

Dimension drawings

Atlas Copco

Reg. code
AHB LE/LT-592
1988-06

To be filled in the AHB collection - binder 21, part 2 - under tab. 17. Replaces Printed Matter No. 2933 4931 00 (1984-04).



Bare compressor

TYPE	A	B	C	NET MASS
LE 9	650	329	329	77 kg
LE 11	750	360	360	78 kg
LE 12				90 kg
LT 9	642	353	329	78 kg
LT 11				80 kg
LT 12	713	353	360	94 kg
LT 930	642	353	329	78 kg
LT 1230	713	353	360	94 kg

No. 9821 0467 00
ed 87 10 20

Atlas Copco

L-SERIES

Component Description

BLOCK CONSTRUCTION

LE Single Stage, 2 Cylinder, Lubricated

LT Two Stage, 2 Cylinder, Lubricated

LE-N Single Stage, 2 Cylinder, Non-lubricated

CRANKCASE—Two-piece, die cast aluminum. The crankcase acts as the oil reservoir with a capacity of .5 gallon to 1.5 gallon, depending on model. Located on the top of the crankcase is a ventilator, which prevents the crankcase from becoming pressurized. An oil sight glass is located next to the unloader valve and an oil drain plug is provided on the base. In addition a nameplate containing specific product data is mounted on one side.

NOTE: On LE-N single stage oil-free compressors there is no oil in the crankcase.

CRANKSHAFT—Made of forged steel with a single throw. The crankshaft is supported by heavy duty ball bearings on either end. The crankshaft has extensions on both ends to accommodate connection to the drive motor and dedicated cooling air fan. The crankshaft also has precision-drilled oil passages.

LUBRICATION SYSTEM—Consists of a single steel slinger ring, rotating on the crankshaft. The slinger ring forces lubricating oil up into oil collectors on the crankshaft. Oil is then force fed into the precision-drilled oil passages inside the crankshaft. This provides positive lubrication to the journal bearings. To insure total lubrication, oil is also splashed on the cylinder walls, main bearings and needle bearings.

CONNECTING RODS—Two piece forged aluminum. Rugged needle bearings are provided on the small (piston) end. Replaceable shell type journal bearings are provided on the large (crankshaft) end.

NOTE: On LE-N single stage oil-free compressors connecting rods are made of forged steel and split needle bearings are used on the large (crankshaft) end. All bearings are permanently greased and sealed, which allows the unit to run efficiently with no oil in the crankcase, cylinders or compressed air.

PISTONS—Full skirt design. The pistons are made of chrome plated aluminum, coated with graphite to aid lubrication.

NOTE: On LE-N single stage oil free compressors, pistons are anodized aluminum with a PTFE teflon-based coating.

PISTON RINGS—Comprised of two types, compression rings (carbon steel) and oil scraper rings (stainless steel), both of which are graphite coated for extended life. LE single stage compressors have 2 compression rings and one oil scraper ring. LT two stage compressors have 3 compression rings and 1 oil scraper ring on the high pressure side and 2 compression rings and 1 oil scraper ring on the low pressure side.

NOTE: On LE-N single stage oil free compressors, there is only 1 extended surface ring which is

L-SERIES
Component Description

CYLINDERS—Die cast aluminum with deep 360° cooling fins. The inside surface is obtained through an extensive Alusil process used in many high technology applications throughout the world. After etching, the silicon impregnated surface has a hardness of 95 HB (Brunnel Scale), which is harder than cast iron.

NOTE: On LE-N single stage oil free compressors the cylinders have a brass inner surface which is coated with PTFE (Teflon).

CYLINDER HEADS—Both LE cylinders and LT low pressure cylinder, the heads are two-piece construction and made of die cast aluminum. Cylinders are deep-finned for efficient cooling. On LT two-stage compressors, the high pressure stage has an extended four-piece construction, which provides for greater surface area and increased cooling.

INTERCOOLER—(For LT two-stage units only) Deep-finned die cast aluminum, set behind fan shroud prior to second stage. The intercooler provides an extended cooling surface and includes a pulsation dampener. This feature helps to increase valve life. A safety relief valve is also provided and is mounted on the pulsation dampener.

FAN—A dedicated cooling fan specifically engineered for increased cooling flow across the unit. The cooling fan can generate up to 1750 cfm. On LE/LT 5-8 the fan is a radial style. On LE/LT 9-12 the fan is a curved axial style.

NOTE: Reverse direction fans are available. Contact Lubricated Products Marketing.

FAN SHROUD—A high volume, high impact, polypropylene fan shroud. To reduce discharge air temperature as well as uniquely provide cooling air across the hottest areas of the machine. The fan shroud is both non-corrosive and shock-proof. The fan shroud design brings in the ambient cooling air through its main body. This cool air is then directed through 2 cooling channels. The channels are ported so that the cooling air must directly pass over the cylinders and cylinder heads. This design insures the most efficient heat transfer and contributes to overall cool operation.

AFTERCOOLER/TEMP. REDUCER—On the LE/LT 7-12 a multispiral, aluminum temperature reducer is located in the cooling air fan shroud. This is the final step in the cooling system. The overall effect is reduced discharge air temperatures and high quality discharge air.

NOTE: LE/LT 5 and 6 pumps do not require a temperature reducer for cool operation.

CHECK/UNLOADING VALVE—On LE/LT 5 and 6. A built-in check valve with blow-off/unloading directed to the pressure switch is provided. On LE/LT 7 through 12 unloading is through the check/unloading valve and muffler. The check/unloading valve is of 3 piece construction and is anodized for extended service life. The checking area is in the bottom segment and the unloading area is in the top segment. A small aluminum piston with a teflon ring rides through middle segment to insure maximum valve efficiency.

L-SERIES
Component Description

MUFFLER—The muffler consists of heavy duty phenol-fiber surrounded by a protective metal mesh. The entire assembly is then supported by end caps. The muffler works in conjunction with the check/unloading valve.

VENTURI INLET SILENCER—Constructed of high impact plastic, the pulsation damper supports the replaceable dry type inlet filter. The inlet filter is a high quality pleated paper filter with metal shell secured in place by a plastic cover. Through the center of the Venturi, an isolated oil fill tube will be found. The oil fill tube is sealed with a threaded nut. The central oil fill design bathes the critical running gear area to insure lubricated start-up after oil changes.

VALVES—Are of two-piece stainless steel construction (one disc for the inlet and one disc for the discharge). Valves are concentric discs which form a system for 360° dispersion of air. This simple two-piece system produces large flow area and minimal valve movement, resulting in increased efficiency.

SHEAVE KIT AND PUMP FOOT (Required for V-belt drive configuration only)—The sheave kit is composed of fly-wheel/pulley and V-belts. The foot levels the compressor for V-belt drive configurations.

PACKAGE CONSTRUCTION

LE/LT V-belt drive units

D/DT Direct drive units

ADDITIONAL COMPONENTS

MOTOR—G.E. TEFC motor (or equal), NEMA frame size, NEMA Design B, 1800 rpm, with 1.25 maximum service factor.

BLOCK AND MOTOR MOUNT—(Direct drive units only) A steel L-shaped "sugar scoop" design for mounting the motor through a coupling to the compressor block. Included is a Woods sure-flex 3-piece coupling. The two outer metal parts of the coupling are the flanges and the inner elastomeric piece is the sleeve.

STANDARD REGULATION—(Automatic start and stop) Standard regulation for the L-Series machine is automatic stop/start. When the pre-set pressure switch reaches the upper set point the compressor unloads and the motor stops. As system pressure decreases and the cut-in pressure is attained, the motor will re-start and the unit will compress air until the upper set point is again reached; then the cycle is repeated.

L-SERIES
Component Description

DUAL CONTROL REGULATION—(Optional) Incorporates automatic stop/start as well as constant speed control through the use of a pneumatic unloader pilot valve assembly with an adjustable knob. When functioning (knob open), excess air is relieved through the unloader and the machine will continue to run unloaded (constant speed control) until cut in pressure is reached and the machine will reload. When in stop/start mode (knob closed), the pilot valve is by-passed. The compressor will then operate in the automatic start and stop mode only.

PRESSURE SWITCH—Pressure switches are pre-set at the factory and are both CSA and UL approved.

SOLENOID VALVE—A NEMA 1, normally open, 3-way solenoid valve is supplied. The solenoid has a brass body and is both UL and CSA approved. The solenoid valve is used to actuate the check valve unloader and is wired into the pressure switch.

STARTER—(Optional) A magnetic CSA and UL approved starter in a NEMA 1 enclosure (single or three phase) correctly sized for proper voltage. It is provided with heater elements for thermal overload protection. A panel mounted re-set button is also supplied.

TANK—(Optional) Steel tank complies with ASME unfired pressure vessel code UG-22B (1979) and State of California OSHSB ACT 462M (1979). Tanks also include feet and saddle. As standard, tanks have discharge service valve, ASME approved safety valve, manual pet cock drain valve, and encaps for required inspections. Tanks are mounted both horizontally and vertically for 60 and 80 gallon configurations. Tanks 120 gallons and larger are mounted horizontal only.

NOTE: On 2 and 3 horsepower, vertical or horizontal 60 gal. tanks are supplied. On 5 and 7.5 horsepower, vertical or horizontal 80 gal. tanks are supplied. On 10, 15 and 20 horsepower, horizontal 120 gallon tanks are supplied.

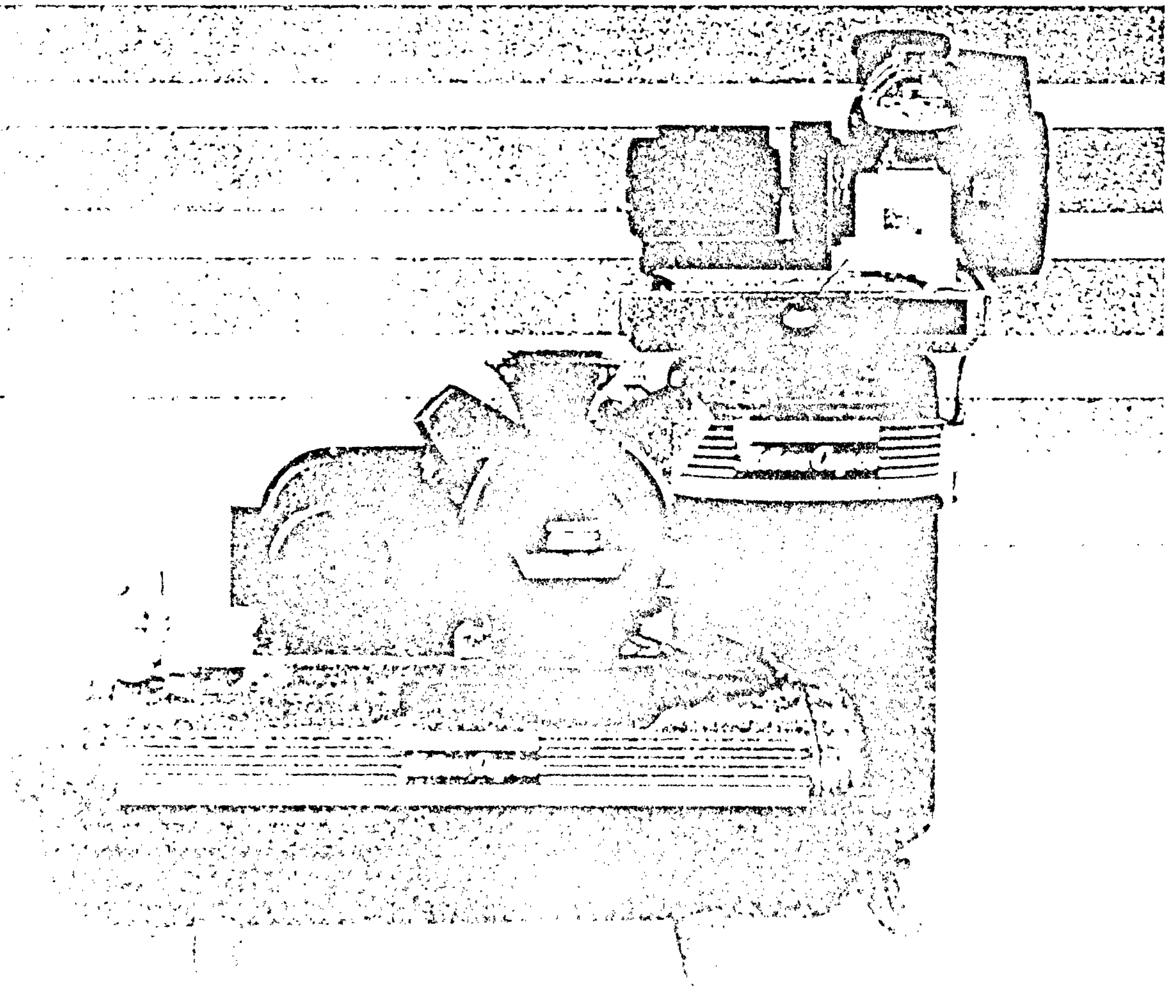
AUTO TANK DRAIN—(Optional) An automatic tank drain can be supplied. The drain is pneumatically operated and will open for approximately 5 seconds at every 10 psi decrease in tank pressure.

LOW OIL LEVEL SHUTDOWN (Optional-starter required)—A NEMA 1 low oil level switch is installed in place of the oil sight glass. If the oil level in the crankcase drops below a safe operating level the float will drop, stopping the compressor until the oil level is replenished.

SEPARATE CONTROL VOLTAGE-120 VOLT—(Optional) A voltage reduction start control (when starter is required) which is now required by law in many areas. Through the use of a transformer and change of coil in the contactor, a standard voltage magnetic starter can be derated to conform with local standards.

L-Series
Reciprocating Compressor

Atlas Copco



ATLAS COPCO Unmatched Experience

Atlas Copco has been manufacturing air compressors since 1904. Today, we are the world's largest company specializing in compressed air equipment. These many years of experience have yielded advanced designs, strict quality control, and a professional, knowledgeable, workforce.

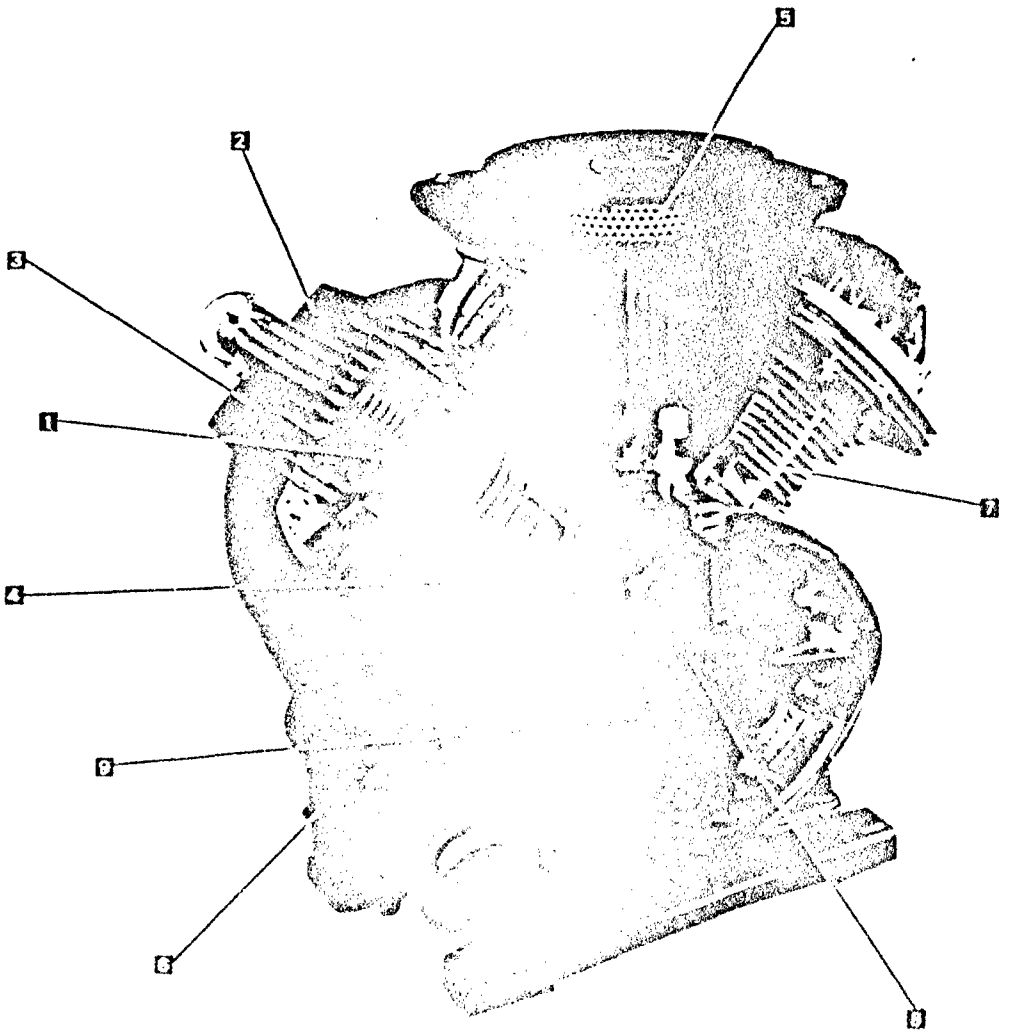
The L-Series reciprocating air compressor is a mainstay in the Atlas Copco line-up. Utilizing state-of-the-art materials, the L-Series reciprocating air compressor delivers the coolest operating temperatures in the industry. This results in longer equipment life, higher quality air for customer's applications, and lower maintenance costs.

Warranty L-Series

To demonstrate our confidence in the integrity of the L-Series design, Atlas Copco warrants that the Products manufactured by Atlas Copco and affiliates shall be free of defects in design, material and workmanship for a period of:

One (1) year from date of start-up on the complete package.

Two (2) years from date of start-up on the compressor block.

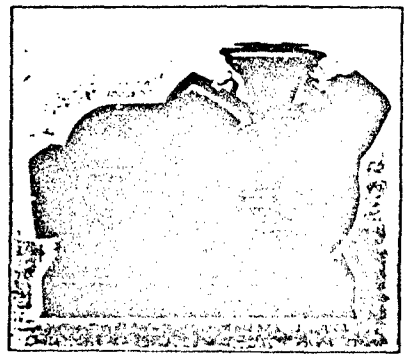


V-Belt Drive Packages

V-belt driven units can be mounted on vertical or horizontal receiver tanks. As with the direct drive models, all units are provided with a TEFC (Totally Enclosed Fan Cooled) motor; thereby providing protection from environmental containments which can cause premature motor failures.

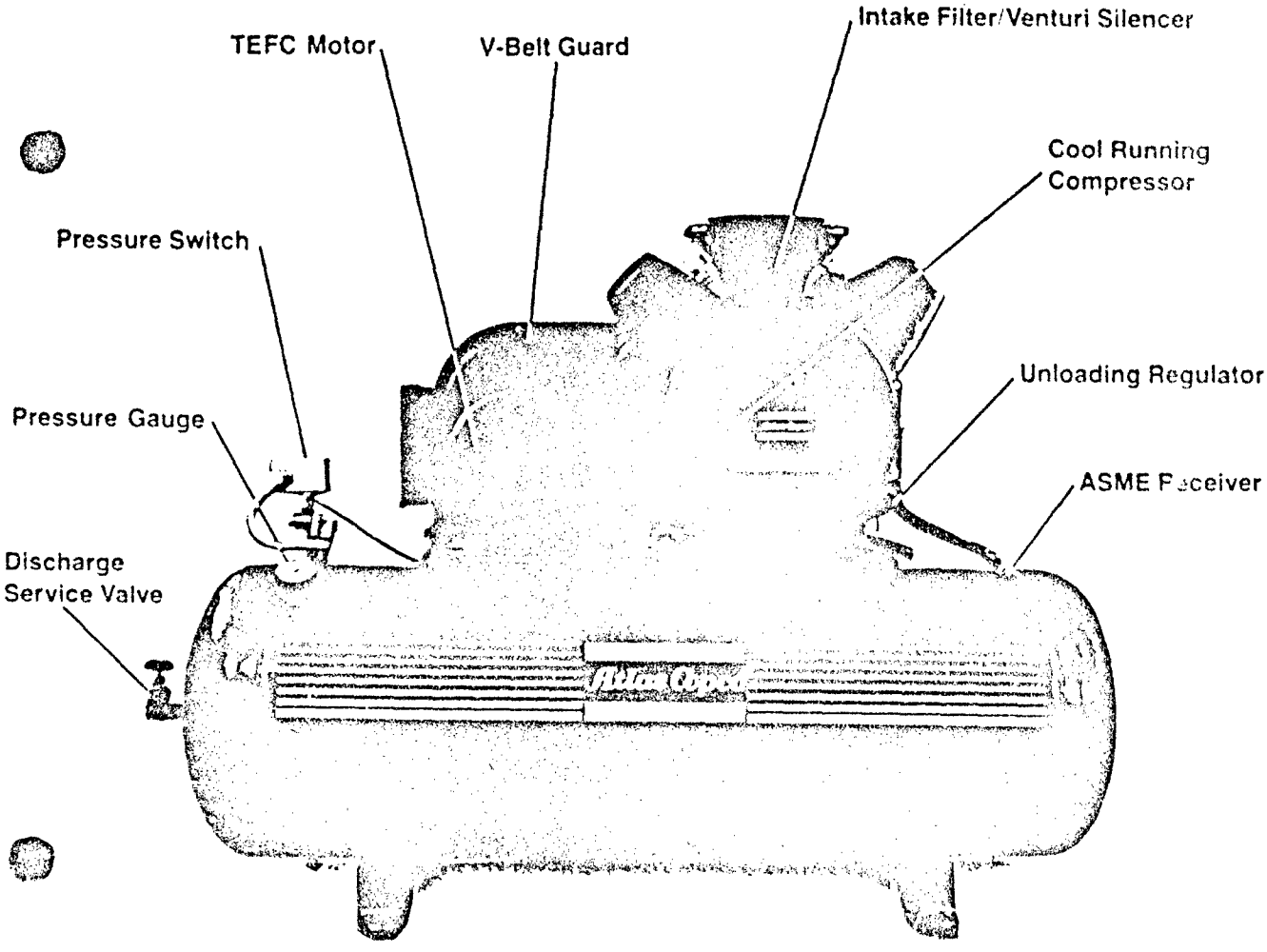
The complete package includes receivers that meet the same high standards as those used on direct drive models.

Most V-belt drive compressors use the compressor sheave as the cooling fan, thereby only flowing cooling air across the compressor frame. The L-Series compressor incorporates a dedicated fan and shroud in order to direct the cooling air to where it is needed the most—the cylinders.



V-Belt Drive Packages

In application where there is already a receiver, V Belt Drive Power Packs provide a reliable and compact installation



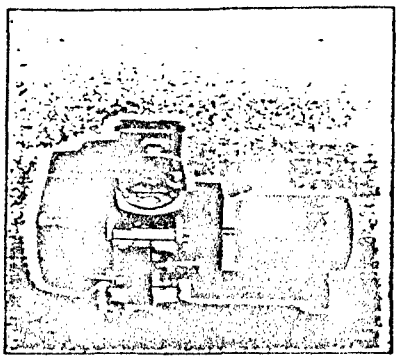
Direct Drive Packages

L-Series air compressors offer great flexibility for a wide range of applications. An effective, compact package design incorporates a reliable direct drive system.

Starting with a TEFC (Totally Enclosed Fan Cooled) motor, power to the air compressor is provided directly through a high quality industrial coupling. The direct drive system provides a more efficient use of horsepower than V-belt drive systems, because there are no V-belts to slip and slide, no pulleys to constantly align, and no belt guards to shake and rattle. Isolation mounts in both the compressor and motor provide smooth operation.

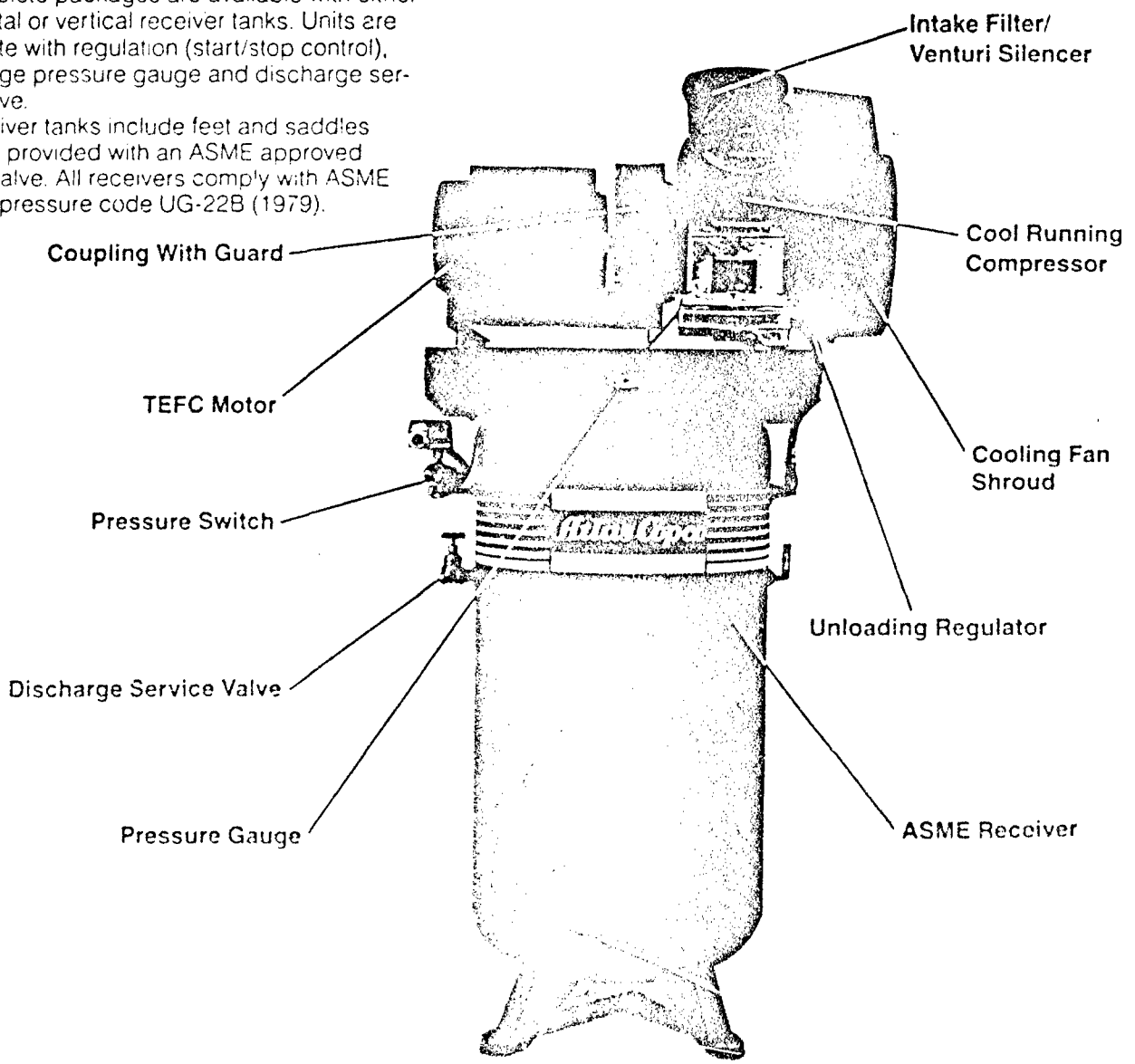
Complete packages are available with either horizontal or vertical receiver tanks. Units are complete with regulation (start/stop control), discharge pressure gauge and discharge service valve.

Receiver tanks include feet and saddles and are provided with an ASME approved safety valve. All receivers comply with ASME unfired pressure code UG-22B (1979).



Direct Drive Packages

In application where there is already a receiver, Direct Drive Power Packs provide a reliable and compact installation.

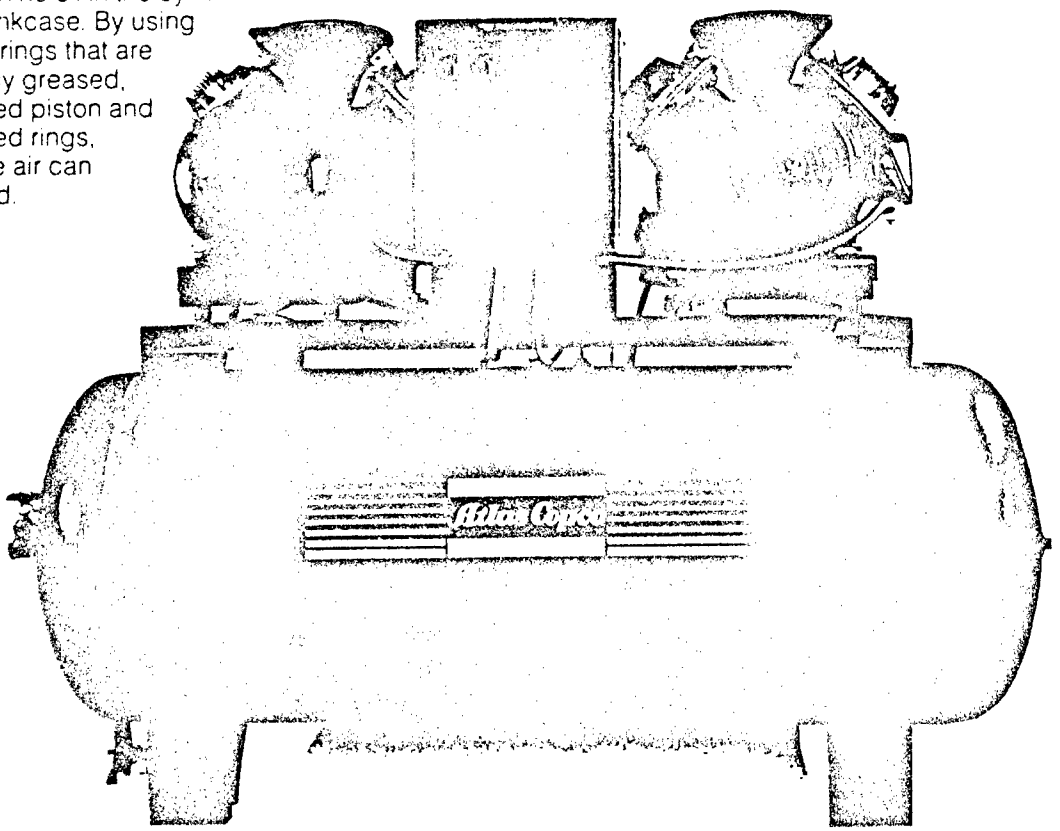


High Pressure Blocks

For high pressure applications the LT 435 blocks are engineered to work between 290 psig and 435 psig; flow ranges between 3.26 and 44.3 CFM.

Oil Free Non-Lubricated Blocks

For special applications where oil cannot be tolerated in the compressed air, Atlas Copco can supply LEN blocks. These units operate with no oil in the cylinders or crankcase. By using sealed bearings that are permanently greased, teflon-coated piston and teflon-coated rings, truly oil-free air can be provided.



Duplex Packages

L-Series duplex packages offer great flexibility for many applications with its two separate compressor blocks driven by two separate TEFC (Totally Enclosed Fan Cooled) motors, all mounted on a rigid steel frame. The frame straddles an ASME approved receiver tank so that no weight from the air compressors rests on the receiver.

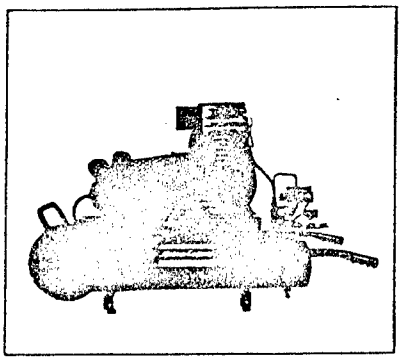
With the duplex arrangement, you can alternate operation of the air compressors. This method of operation will allow you 100% back up at all times. It will also allow you to schedule regular service on one air compressor and not have to shut your air system down.

The duplex system can also be set up to allow both air compressors to run simultaneously. This will double the effective compressed air output and satisfy your air needs twice as fast.

Portable Compressors

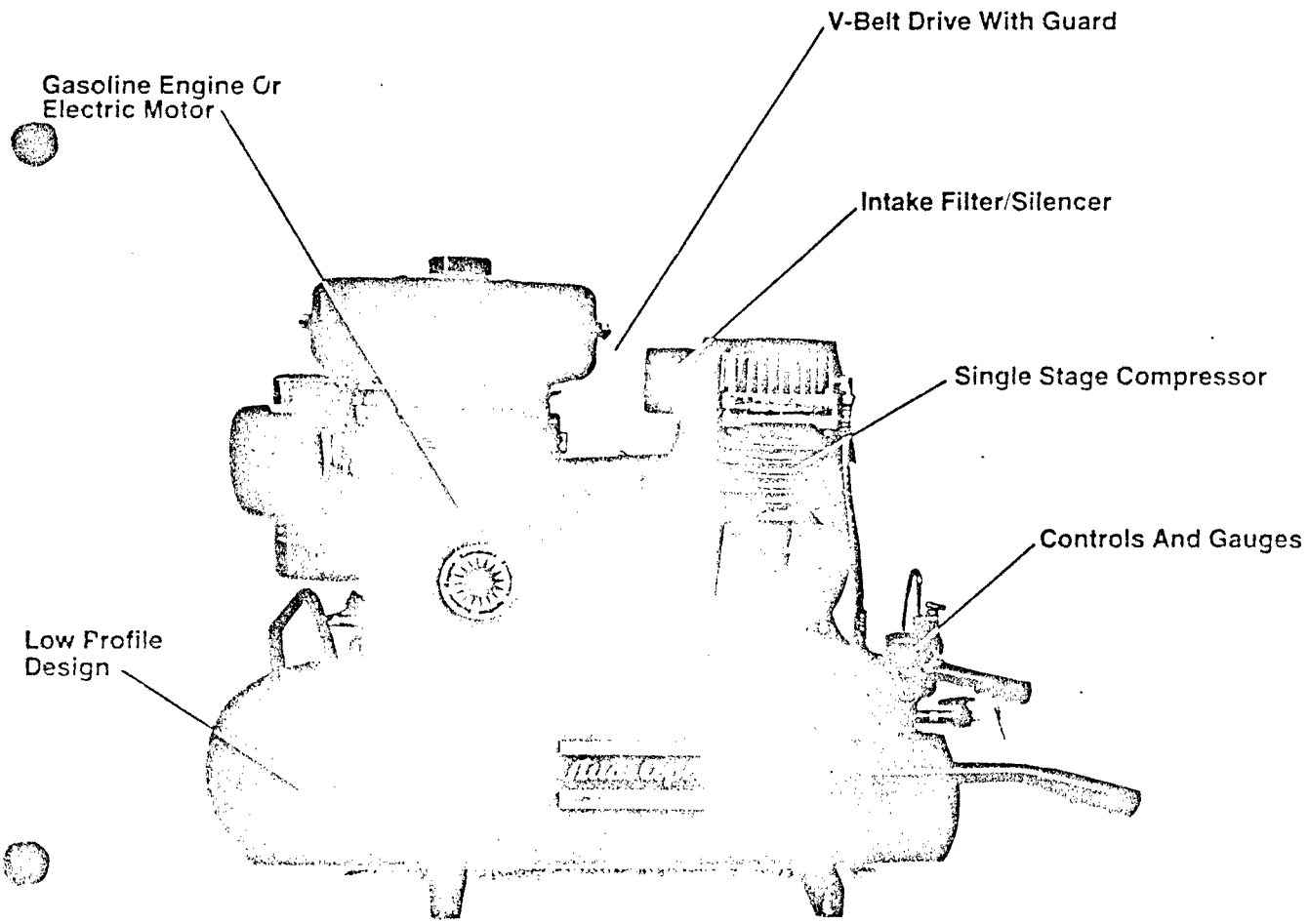
Atlas Copco L-Series portable air compressors are designed to be extremely rugged and built to last. Maximum job site portability is obtained, and tip-over damage is reduced to a minimum with our low center of gravity design. This, combined with weighing an average of 30% less than competitive units, ensures job site air on demand.

All models come equipped with a totally enclosed metal belt guard, pressure relief valve, tank gauge tank drain, handles, and wheel. Electric models include a heavy-duty cord set and built-in motor overload protection. For conditions where air requirements are varied, all gas engine models include a slow down control device which reduces rpm to an idle speed, saving fuel.



Electric Drive Portable

Portable models are available with electric motor for 1–3 Hp sizes.



1 Longer Life/Low Maintenance Valves
Exclusive Flexidisc Valving System has just one moving part per valve. Atlas Copco's valves are stainless steel annular discs with low air velocities for reduced power consumption.

2 Large Cooling Fan
Cool air flows over the V designed pump for better heat transfer and cool operation.

3 Fan Shroud
The fan shroud directs the cooling air flow evenly across the deep cooling fins on the aluminum cylinders and heads, reducing temperature build up at the hottest points of any compressor. This extends oil, valve and service life of the pump.

4 Wear Resistant Cylinders
The cylinders are all cast in a special patented alloy, enabling the piston rings to run directly against the silicon treated cylinder walls. This system eliminates the need of a cylinder liner and gives excellent heat transfer from the cylinder wall to the cooling fins. Furthermore, this allows the possibility of keeping the clearance between the piston and cylinder within hundredths of millimeters, reducing oil carry-over.

5 Air Intake System
Air enters through a venturi-type suction silencer which includes an easily replaceable automotive type filter. This unique design also incorporates a central tube for easy oil filling of the crankcase, allowing [illegible]

6 Loadless Starts
A pneumatic unloading system [illegible] loadless starts and longer motor [illegible]

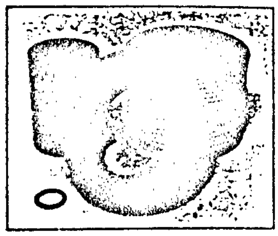
7 All Cast Alloy Construction Components
[illegible]

8 Forged Steel Crankshaft
The crankshaft is dynamically balanced on three planes and is supported by heavy-duty ball bearings on each side of the crankcase for smooth operation.

9 Service Free Lubrication
Atlas Copco uses a single steel ring which rotates off the crankshaft to assure positive lubrication. No splash-pin to fall out and no oil pump to fail. Oil is forced to bearings through a rifle-drilled crankshaft.

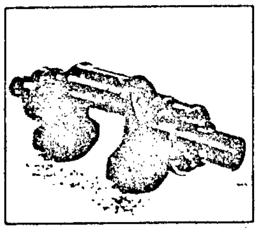
Air Intake Filter/Venturi Inlet Silencer

A high quality, automotive style replaceable filter element is supplied on all models. The large surface area filter is reinforced by a protected metal mesh and is held in place by a non-corrosive filter cover. This high quality filter insures that the cleanest air is used for compression. The venturi style inlet chamber also helps to reduce noise during operation.



Crankshaft

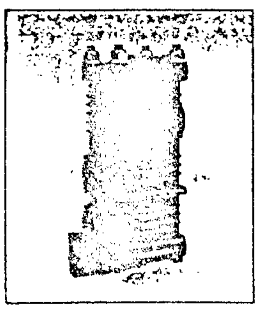
Made of forged steel with a single throw and balanced on 3 planes. High quality, heavy duty ball bearings on both ends insure trouble free operation. The crankshaft also has precision drilled oil passages to feed oil to the connecting rods. This conservative design will last years longer than competitive offerings.



Valves

Simple stainless steel construction (one disc for the inlet and one disc for the discharge). Valves are concentric discs which form a system for 360 degree dispersion of air. This simple system produces large flow area and minimal valve maintenance.

Check Valve/Unloader



A simple pneumatic unloading system insures loadless starts and longer motor life. A high quality phenol-fiber muffler is designed into the package to further reduce noise levels.

Atlas Copco

March 19, 1990

Phillips Cartner & Co.
Management and Services Divisions
700 N. Fairfax Street
Suite 400
Alexandria, VA 22313-5457

Attention: Mr. Gregory Nau
Project Engineer

RE: U.S. ARMY DIVING AIR COMPRESSOR
MARKET INVESTIGATION

Dear Mr. Nau:

I am pleased to provide the attached documents pertaining to the unit we have designed for the U.S. Navy.

The LT12-435 compressor is the same design as the compressor used on the Navy job, though it is somewhat larger.

Please feel free to contact me if you have any questions.

Sincerely,

Michael P. O'Hanlon

Michael P. O'Hanlon
Marketing Manager
Lubricated Products

am
attachment

Address
161 Lower Westfield Rd
P.O. Box 431
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955325
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(413) 536-0091

Contents

1.0 Introduction

1.1 Background

There is a continuing requirement for the Navy to conduct noncombatant, shallow-depth, surface-supported diving for the performance of underwater ship husbandry; underwater inspection of mooring equipment, anchors, and ground tackle; underwater repair of piers and docks; mobile salvage operation; and security swims. The need for underwater shallow-depth, life support systems, tools, and ancillary equipments was identified in Specific Operational Requirements (SOR) 46-54 and a program initiated in the early 1970's to acquire equipments that would satisfy the shallow depth diving requirements. In 1979, Navy Decision Coordinating Paper (NDCP) S-0394-SL, Shallow Depth Diving Equipment, was approved by the Chief of Naval Operations. The NDCP redefined the program established in response to SOR 46-54.

Since initiation of the shallow depth diving equipment program, two surface supported, shallow depth diving equipments have been developed and approved for service use: Mk1 Mod 0 (band mask) and the Mk 12 Surface Support Dive System (SSDS). The shortcomings of existing systems and the need for a lightweight, cost-effective, surface supplied dive system were established in the Operational Requirement for Lightweight Dive System (OR No. 108-02-87). The Lightweight Dive System (LWDS) is a specific replacement for the Jack Browne mask, which has been in continuous service since the early 1950's.

1.2 Description

The Lightweight Diving System (LWDS) is made up of several components which when integrated are capable of supporting shallow depth diving operations. Each component is designed so that it may be readily transported by a typical dive team. Present configurations have both primary and secondary (emergency) air sources. While secondary air is always in the form of HP composite flasks, primary air may be supplied by HP composite flasks or LP diesel compressor. The following components make up the LWDS:

a. Air Compressor. Low pressure with diesel prime mover used as the primary air source in configuration 1.

b. Air Flasks. One rack of three each composite high pressure flasks (564 scf of air available) used as the secondary air supply when using the compressor as primary air source.

* In configuration 2, primary air will be provided by three racks of three each composite high pressure flasks (1692 scf of air available).

c. Surface Control Console. Air and pneumo fathometer control console, 4 scf volume tank, and interconnecting hoses and whips.

d. Diver Umbilical. .375-inch air hose, .250-inch pneumo hose and combination strength/communication cable.

e. Diver Worn Equipment. Interspiro full face mask (FFM) with communications, diver harness, and manifold.

1.3 Modes of Operation

a. **Configuration** 1-Configuration 1 utilizes the diesel powered compressor as primary low-pressure air supply (LP). Secondary air supply is provided by one rack of three each high pressure composite flasks (HP-564 scf of air available @ 3000 PSIG).

b. **Configuration** 2-Configuration 2 utilizes three racks of three each high-pressure composite flasks as primary supply.(HP-1692 scf of air available @ 3000 PSIG). Secondary supply is provided by one rack of three each high-pressure composite flasks. (HP-564 scf of air available @ 3000 PSIG).

1.4 Evaluation

The technical evaluation of the lightweight dive system is outlined in the Lightweight Dive System Techeval Test Plan.

2.0 Manned Testing

2.1 General

The manned testing portion of the LWDS TECHEVAL placed 86 divers in the water from mid July to late September, 1988. Dive missions were carried out in three distinct phases at different locations:

a. Phase one was conducted by NAVXDIVU-Panama City.
b. Phase two by EODMU4-NAS, Key West.
c. Phase three by NDSTC, NAVCOASTSYSCEN-Panama City.

The individual dives were performed so that each dive fell into one of the following four categories:

Category 1. Pierside-utilizes two divers, and one standby: each on 150 ft. umbilical. Tasks performed include FFM ditch-don: small object recovery: and general system performance evaluation. Primary air is supplied by the diesel-compressor with HP flasks utilized as secondary supply. (LWDS Configuration 1).

Category 2. Pierside-utilizes one diver on a 300 ft. umbilical with the standby diver on an alternate air supply. Primary air is supplied by the diesel-compressor with HP flasks utilized as secondary supply. (LWDS Configuration 1). Tasks performed include FFM ditch/don: small object recovery: and general system performance evaluation.

Category 3. L.C.U. shipboard-utilizes two divers, and one standby: each on 150 ft. umbilical. Primary air is supplied by the diesel-compressor with HP flasks utilized as secondary supply. (LWDS Configuration 1). Tasks performed include support of MK 98 tests-with high work rates.

Category 4. Pierside- utilizing two divers , with one diver as standby: each on 150 ft. umbilical.. Primary as well as secondary air is supplied by HP flasks. (LWDS Configuration 2). Tasks performed include general system evaluation as well as small object recovery.

2.2 NEDU-Phase 1

2.2.1 NEDU Category 2 Dives

This series of dives took place on the east pier behind NAVXDU, Panama City, FL on July 21 and 22, 1988. Thirteen category 2 dives took place, each of approximately thirty minutes duration to a maximum depth of 22 F.S.W.. NEDU test plan 88-17 served as a guideline to evaluate emergency procedures as well as the overall effectiveness of the LWDS. In general, the LWDS performed very well in overall effectiveness. In fourteen hours of operation, no Compressor failures

occurred, and air delivery was termed satisfactory in all regards. Emergency endurance trials were also performed, and revealed the following :

a. Air trapped in an isolated 300 foot umbilical will support a resting diver at 20 FSW for 90 seconds.

b. The air reserve of the volume tank was depleted from 138 PSIG to 100 PSIG by a resting diver at 20 FSW in 10 minutes.

These endurance times provide excellent cushion for a switch to secondary air, even with extenuating circumstances and 3 divers on line. Also evaluated were communications, set-up/breakdown procedures, transportability, diver-worn equipment, human-factors, and emergency operations. All were found to be satisfactory with minor recommended changes incorporated. (See NEDU report No. 7-88 for further results.)

2.3 EODMU4-Phase 2

2.3.1 EODMU4 Category 1 Dives

These dives were performed on August 16 thru 19, 1988 on the Southwest pier of NAS in Key West, FL. All 25 missions were category 1 dives which reached a maximum depth of 40 FSW and averaged 30 minutes in duration. Diver tasks were primarily ditch/don FFM training with some intermingled small object recovery. The primary purpose of these dives was to evaluate the effectiveness of the LWDS. Total run time of the compressor unit during these dives was 10.5 hours with no compressor related failures. Diesel consumption was 6 gallons over the entire course of these dives. Compressor duty cycles for two diver ditch/don at 40 FSW are as follows:

Table 1. Compressor Duty Parameters

LOADED RPM	UNLOADED RPM	LOADED TIME	UNLOADED TIME	LOAD PRESSURE	UNLOAD PRESSURE
1827	1872	15 SEC	45 SEC	148 PSIG	164 PSIG

Communications problems were experienced with two failed microphones and one failed earphone. The microphone failures were due to bad connector insulation; replacement took 10 minutes per failure. The earphone failure was attributed to bad potting and subsequent corrosion; its replacement took 5 minutes. Additional problems were noted with the HP secondary supply. After leaving the flasks pressurized to the control console overnight, a significant leak was encountered (50 PSIG per hour). The leak was found to be in the CGA fittings on the flask interconnecting whips. Nylon-tipped fittings cured the leak and will become a permanent part of the system. All other evaluations proved highly satisfactory and EODMU4 was impressed with the simplicity, quick set-up, and overall effectiveness of

the system.

2.3.2 EODMU4 Category 2 Dives

This mission was performed on August 22,23 and 25, 1988 on the southwest pier of NAS, in Key West, FL. Twenty category 2 dives were performed. Each dive reached a maximum depth of 40 FSW and averaged approximately 30 minutes in duration. Diver tasks were small object recovery and effectiveness evaluation of the LWDS. In particular, these dives were to verify the compressor duty cycles and general performance of the LWDS using a 300 foot umbilical. Total run time of the compressor was 13 hours and diesel consumption was 6 gals.. Between dives 5 and 6, the Pilot Valve was adjusted to determine what effect operating pressures had on the AGA mask, and to ensure adequate pressure for the deep dives later in the week. The pressure differential changes had no effect on mask performance. A comparison between compressor duty cycles is as shown below:

Table 2. Compressor Duty Parameters Comparison

LOADED RPM	UNLOADED RPM	LOADED TIME	UNLOADED TIME	LOAD PRESSURE	UNLOAD PRESSURE
1827	1972	10 SEC	80 SEC	148 PSIG	164 PSIG
1764	1849	14 SEC	90 SEC	150 PSIG	170 PSIG

During pilot valve adjustment it was discovered that the compressor-mounted gauge is susceptible to slight pulsation. It is recommended that all pressure readings for pilot valve adjustment be taken from the volume-tank pressure gauge. In addition, it is suggested that the compressor moisture separator be 'blown-down' once every thirty minutes of operation. Several minor problems were documented during this series of dives. The function of the 'air supply this rack' valve caused some confusion with the divers. This valve's use needs to be clarified in the operation procedures. The fuel gauge float pivots caused inaccurate fuel readings. Once the pivots were reamed, the gauge operated normally. The problem was corrected at the conclusion of the first day, and took 10 minutes to repair. Finally, a 41 hour leak check was performed at the conclusion of the second day. The control console leaked at a rate of 1/2 PSIG per hour, while the Volume Tank leaked 1 PSIG per hour.

2.3.3 EODMU4 Category 3 Dives

These category 3 dives took place on August 26 and 29, 1988 at NAS, Key West, FL., and were actual shipboard working dives in support of MH 98. Tasks included mine neutralization charge tests in 56 FSW with each of the 13 dives approaching 45 minutes in duration. Total compressor run-time was 14.5 hours with a diesel consumption of 7 gallons. After almost 40 prior dive hours, 1/4 quart of oil was required by the diesel,

and none by the compressor. Air delivered to the divers was satisfactory with regards to pressure, taste, humidity, and mixture. HP leaks were still a problem with the hard-tipped CGA fittings. One mask's positive pressure release was sticking slightly, and the entire mask was subsequently changed out- requiring 10 minutes of down time. The green diver pneumo leaked and its repair required 15 min. The leakage occured in a screw-on type fitting which was replaced with a barb fitting. During the first dives, the communications became severely garbled. The INAC circuit had been inadvertently activated, and was squelching the divers voice. Troubleshooting required 5 minutes. In this actual working dive, comments were very positive towards the LWDS. Shipboard, Divers found it easy to transport, set-up, and use. Several suggestions were made for LWDS improvements. First, the bulkhead connector on the compressor must be moved up for adequate wrench clearance between the fitting and the ground. More wrench clearance is also required on the control console back panel, between the umbilical and pneumo-fathometer connections. The air-in and air-out fittings on the volume tank also need easier access. Requests for control console external gauge calibration fittings were also made. Even without the suggested improvements, EODMU4 found the shipboard LWDS very effective in configuration 1.

2.3.4 EODMU4 Category 4 Dives

These dives differed from the preceding dives in that they utilized the LWDS in configuration 2: that is, HP flask primary and secondary. These 12 pierside dives totaled 10.5 hours in duration, and reached a maximum depth of 47 FSW. Dive times were approximately 45 minutes in duration and divers again found air quality to be adequate in all regards. It was discovered that labeling on volume tank's HP regulator is necessary for clear operation. A slight leak on the HP primary manifold required tightening of the handwheel. This repair required 5 minutes. A second HP leak was isolated, this time in the secondary circuit. The leak occured in the HP deck hose fittings and is correctable by the addition of teflon sealing washers to the fitting's flared sealing surface. It was also recommended that four handles be added to the HP flask racks to aid man portability. Overall, EODMU4 found the LWDS very effective in configuration 2, particularly ue to its quiet. operation and ease of transportation.

2.4 NDSTC-Phase 3

This mission was conducted on the east pier of NDSTC, Panama City, FL on 27 September, 1988. This was a category 1 dive lasting for approximately 2 hours. Its purpose was to familiarize the NDSTC personnel with set-up procedures, and the general function of the system for the upcoming technical manual evaluation. (See 3.0, Unmanned Testing). In performing the set-up procedures it was discovered that the check-valve in the volume tank was inoperative. Thus, an addition to the set-

up procedures is required to check back-flow at the compressor moisture separator. To diagnose the problem and correct the jammed spring took 5 minutes. NDSTC personnel found the LWDS very easy to set-up and use and were impressed by its portability and rugged simplicity.

3.0 Unmanned Testing

3.1 General

Unmanned tests were performed during phase 3, immediately following the NDSTC familiarization dives. Testing was performed during the week of SEPT 26-30, 1988. The primary goal of the testing was evaluation of the LWDS technical publications. Test procedure involved the performance of routine and diagnostic maintenance using only the technical manuals for input. After each test, questionaires were completed outlining any discrepencies/difficulties found in the manuals. This input was then transfered to the technical manuals themselves.

3.2 Specific Testing

The following maintenance items, and the associated times to perform are listed below:

Maintenance Item	Time to perform
Repair Check Valve	5 MIN
Change Diesel Oil and Filter	20 MIN
Change Diesel Air Filter	5 MIN
Change Compressor Air Filter	5 MIN
Change Compresor Oil	20 MIN
Clean and Adjust Pilot Valve	30 MIN
Replace Diesel Fuel Filter	20 MIN
Adjust Focler Clearance	45 MIN
Diagnose and Correct Air in Fuel	10 MIN
Diagnose and Correct Pilot Valve	25 MIN

3.3 Unmanned Test Results

Review of the questionaires (Appendix B) answered during unmanned testing revealed several discrepencies in the LWDS technical documentation:

a. The dive set-up procedures need to address:

1. checking operation of the volume tank anti-return valve.

2. Eliminating HP blowdown because ofpotential danger.

3. Set-up procedures for opening flasks and details of flask rack valve operation.

b. An MRC card is needed for diesel speed checking/adjustment.

c. An MRC card is necessary for air filter replacement on the snorkel stand as well as on the compressor.

d. The technical manual illustration is not adequate for replacement of the compressor air filter or snorkel stand air filter.

e. The MRC card for pilot valve maintenance needs corrected pressure values for operation: ...145 PSIG-LOAD...160 PSIG-UNLOAD. A reference should also refer to illustrations and detailed procedures in the operation and maintenance manual.

f. Emergency procedures need to mention what to do in case of secondary HP failure.

g. The Technical manual needs illustrations and accurate instructions on pilot valve adjustment.

f. Diesel speed adjustment needs to be addressed in the technical manual with illustrations and instructions.

g. The instruction on rocker clearance adjustment needs to mention removal of the stop-switch bracket.

h. Maintenance times should be given in days-weeks-months, instead of run hours so that an hour log does not have to be maintained for every run hour. Elimination of the run-hour log will enhance the simplicity and usefulness of the LWDS.

i. Several NDSTC personnel reviewed the Operation and Maintenance manual and made deletions and additions to maintenance instructions and technical documentation. These various items need to be incorporated into the manuals.

4.0 TECHEVAL Test Results

4.1 Results of Test M-1, Reliability

Total operating time of the LWDS reliability test is 628.5 hours. Since no failures were experienced during TECHEVAL or the 564 hours of operational testing, the Mean Time Between Failures (MTBF) is calculated as follows:

MTBF=(TECHEVAL run time + Operational run time) x (1/w)

w= 2.30 (Table 15.3, Reliability Handbook by Ireson)

MTBF=(564 + 64.5) x (.435) = 273.4 hours

Since no failures occured during testing, an MTBF of 273.4 hours is a minimum value at the 90 % lower confidence level. In practice, the actual MTBF value should be significantly higher. Acceptance level, as defined in the TECHEVAL test plan, P. 13, pp. 5.4, is 60 hours.

Reliability, R, is defined as follows using the previously calculated value of MTBF:

$R = e^{-t/MTBF}$ (Taken from Appendix A, Reliability and Maintainability Management Handbook, P. A-1, pp. A-2.)- NAVAIR 01-1A-31

t = 6 Hours (Defined in TECHEVAL test plan, P.13, pp 5.4)

MTBF = 273.4 Hours (Calculated from previous step)

This Yields a reliability value, R, of .978 which surpasses the acceptance level of .9 established by the TECHEVAL test plan, P. 13, pp 5.4

4.2 Results of Test M-2, Maintainability

Since no failures occured during TECHEVAL testing, a mean time to repair (MTTR) was computed from the time required for general maintenance, incidental repair, and induced failures during technical documentation evaluation. These repairs were performed at an organizational level as described in the Integrated Logistics Support Plan.

Problem Description	Repair Time
Replace Shorted Microphone	10 MIN
Replace Shorted Earphone	5 MIN
Replace Shorted Microphone	10 MIN
Ream Fuel Tank Pivots	10 MIN
Change Mask	10 MIN
Correct Comm. INAC	5 MIN
Tighten Handwheel fitting	5 MIN
Repair Check Valve	5 MIN
Change Diesel Oil and Filter	20 MIN
Change Diesel Air Filter	5 MIN
Change Compressor Air Filter	5 MIN
Change Compresor Oil	20 MIN
Clean and Adjust Pilot Valve	30 MIN
Replace Diesel Fuel Filter	20 MIN
Adjust Rocker Clearance	45 MIN
Diagnose and Correct Air in Fuel	10 MIN
Diagnose and Correct Pilot Valve	25 MIN
Total times of Repair =	240 MIN

Repair times include troubleshooting time and time for any incidental adjustments, but do not reflect time required to obtain spare parts. MTTR is calculated using the following formula as taken from Appendix A, Reliability and Maintainability Management Handbook, P. A-6, pp. A-23.- NAVAIR 01-1A-31:

$$MTTR = \frac{\text{(Total times of repair)}}{\text{(Number of Repairs)}} = \frac{240 \text{ MIN}}{17} = 14.1 \text{ MIN}$$

This MTTR value easily surpasses the acceptance level of 30 MIN as required by the TECHEVAL test plan, P.13, pp. 5.4.

4.3 Results of Test M-3, Operational Availability

Operational Availability, A_O, will be calculated assuming a mission time of 6 hours, with system downtimes consisting of 45 minutes per day for setup procedures (op's), combined with one multiple of the MTTR value. Operational Availability is calculated using the following formulas taken from Appendix A, Reliability and Maintainability Management Handbook, P. A-11, pp. A-29-(b).- NAVAIR 01-1A-31:

Availability will be calculated using $A_O = \frac{\text{uptime}}{\text{uptime + downtime}}$

Uptime = MTBF @ 90% confidence = 273.4 Hours

Downtime = MTTR (Hours) + System Setup Time (Hours)

$$MTTR = 14.1 \text{ MIN} \times \frac{1 \text{ HOUR}}{60 \text{ MIN}} = .235 \text{ Hours}$$

System Setup Time= (Total Missions) x (Hours Setup/Mission)

$$\text{System Setup Time} = \frac{273.4 \text{ Hours}}{6 \text{ Hours/Mission}} \times \frac{.75 \text{ Hours}}{\text{Mission}} = 34.2 \text{ hours}$$

Downtime = (.235 Hours) + (34.2 Hours) = 34.4 Hours

$$\text{Thus, } A_O = \frac{273.4}{273.4 + 34.4} = .89$$

The LWDS meets the acceptance level for Operational Availability of A_O= .8, as taken from the TECHEVAL test plan, P. 13, pp 5.4. Another measure of operational availability as defined in the test plan is availability, A_O:

where,

$$A_O = \frac{\text{\# Predive checks passed}}{\text{\# Total checks attempted}} = \frac{19}{20} = .95$$

Which also meets the minumum acceptance level of $A_O = .8$

4.4 Results of Test M-5, Logistics Supportability

Since there were no failures of the LWDS during the test, the Mean Logistic Delay Time (MLDT), or LSI was computed for the maintenance items performed during TECHEVAL. The calculation is based upon estimated delivery times of spare parts, assuming that these parts must be ordered from their respective manufacturers. This is an extreme case, and is analagous to a critical failure with no spare parts on hand.

ITEM	Logistic Delay Estimate (Hours)
Diesel Air Filter	48
Air Compressor Air Filter	36
Diesel Fuel Filter Kit	48
Diesel Oil Filter	48
Spare Unloader Valve	36
Spare Belt Guard	24
Spare Compressor Air Box	24
Spare First Stage Head	24
Replacement Gauges	24
Communication Spares	24
MLDT	33.6 Hours

This value is considerably less than the 133-hour value given for Navy-wide hull-mechanical-electrical type systems.

4.5Results of Test M-4, COMPATABILITY

The following TECHEVAL testing items were extracted from test data as compatability related items:

a. The LWDS was found to work very well with the Interspiro mask and modified harness. Divers found air delivery through the mask excellent with regards to flow and pressure.

b. HYDRO-COM communications were also found to interface well with the LWDS. Several communications problems were noted throughout the duration of the test, but these problems were attributed to age and condition of the communication system.

c. LWDS umbilicals were assembled with NORECO strength/communication cables. These cables performed flawlessly throughout the many hours of testing. Although subjected to abrasion, abuse and strenous loads, they provided an excellent link between diver and surface support.

4.6 Results of test M-6, Technical Documentation

Documentation available during the TECHEVAL included the commercial manuals for the diesel and compressor and preliminary drafts of the following:

a. Operation and Maintenance Technical Manual

b. Operating and Emergency Procedures (Op's and Ep's)

c. Maintenance Requirement Cards

These drafts were evaluated in the unmanned portion of the testing (See Section 3.0) and several important changes were requested:

a. Dive set-up procedures were useable and thorough. Corrections should address volume tank check valve operation checks, and HP 'air-supply-this-rack' valve usage instructions.

b. Maintenance times should be given in days-weeks-months, instead of run hours so that an hour log does not have to be maintained for every run hour. Elimination of the run-hour log will enhance the simplicity and usefulness of the LWDS.

c. Several NDSTC personnel reviewed the Operation and Maintenance manual and made deletions and additions to maintenance instructions and technical documentation. (See 3.3 above).

4.7 Human Factors and Results of Test H-1, Operating Equipment

The engineering aspect of human factors testing was carried out per instruction of the LWDS TECHEVAL Test Plan. Questionaires were answered throughout the testing and are included in Appendix A. The system was found to be very easy to set-up, use, and maintain. All personnel responded positively to questions pertaining to the overall effectiveness of the LWDS. General consensus comments are listed below as they pertain to desirable improvements on the LWDS:

a. Many divers wanted to have 'click-stops' on the supply selector valve on the diver's control console.

b. Operation Instructions should be included on the volume tank's HP regulator so that pressure may be cognizantly increased and decreased.

c. More space is required on the back of the control console to remove and replace umbilicals and pneumo hoses.

d. Handles on the HP flask rack would greatly increase man-

portability.

e. Guards for the Pilot Valve on the compressor should be be fabricated.

f. Another location for the diesel oil drain should be found in addition to larger drain piping.

g. Compressor bulkhead connector should be moved so that wrench clearance is adequate.

h. A positive means for fastening the control console to the volume tank is required.

i. Changes to technical publications should be made as recommended by 'red-lined' preliminary draft.

j. In place calibration fittings should be included to ease Calibration on all system gauges-particularly, the control console.

K. Bulkhead fittings on the volume tank need more wrench clearance.

TABLE 1. THRESHOLD LIMIT VALUES FOR SELECT COMPOUNDS

COMPOUND	TVL IN PPM	V
ACETONE	1000	
ACRYLONITRILE	20	
ANILINE	5	
BENZENE	10	
BUTADIENE	1000	
CARBON TETRACHLORIDE	10	
CHLOROFORM	25	
CHLOROPRENE	25	
CRESOLS	5	
CYCLOHEXANE	300	
DECAHYDRONAPHTHALENE	190	
ETHYLENE DICHLORIDE	50	
HYDROGEN CYANIDE	10	
HYDROGEN SULFIDE	10	
METHYLCHLOROFORM	350	
METHYLMERCAPTAN	10	
METHYLCYCLOHEXANE	500	
n-HEPTANE	500	
n-HEXANE	500	
n-OCTANE	500	
N-PENTANE	1000	
NAPTHA	100	
NAPTHA (PETROLEUM)	100	
STYRENE	100	
SULFUR DIOXIDE	5	
SULFUR MONOCHLORIDE	1	
TETRACHLOROETHANE (1122)	5	
TOLUENE	200	
TOLUENE DIISOCYANATE	0.02	
TRICHLOROETHYLENE	100	
TRICHLOROTRIFLUOROETHANE	1000	
TURPENTINE (OIL)	100	
VINYL CHLORIDE	1	
XYLENE	100	

NAVAL SEA SYST WASH. D.C. 20362	SIZE	FSCM NO.		ORG. NO.	
DRAWN	A	53711			
ISSUED	SCALE UNLESS NOTED			REV.	SHEET OF

Memorandum 15 Jan 1988

From: Glen Deason: Code 3430
To: F. Hamilton: Code 3410

Subject: Analysis of Atlas Copco Air Samples: Results of

1. In accordance with your request of 14 Jan 1988. the air samples delivered to the gas analysis lab were analyzed and found to contain:

Component	Atlas Copco #1 Taken 12-29-87	Atlas Copco #2 Taken 01-13-88
Oxygen	21.0%	21.0%
Nitrogen	78.1%	78.1%
Argon	0.9%	0.9%
Carbon Dioxide	413 PPM	337 PPM
Carbon Monoxide	2.4 PPM	1.0 PPM
Total Hydrocarbons*	5.1 PPM	3.6 PPM
Total Halogens	<0.5 PPM	<0.5 PPM
Methane	1.6 PPM	2.1 PPM
Acetylene	<0.1 PPM	<0.1 PPM
Freon 113	<0.1 PPM	<0.1 PPM
Methyl Ethyl Ketone	<0.1 PPM	<0.1 PPM
Benzene	<0.1 PPM	<0.1 PPM
Toluene	<0.1 PPM	<0.1 PPM
C4+	<0.4 PPM	<0.5 PPM

*Expressed as methane equivalents

2. The above sample showed no appreciable contamination: all components were within acceptable range.

Glen Deason
Chemist

Memorandum 15 Jan 1988

From: Glen Deason: Code 3430
To: F. Hamilton: Code 3410

Subject: Analysis of Webster Air Samples: Results of

1. In accordance with your request of 14 Jan 1988, the air samples delivered to the gas analysis lab were analyzed and found to contain:

Component	Webster #1 Taken 12-29-87	Webster #2 Taken 01-13-88
Oxygen	21.0%	21.0%
Nitrogen	78.1%	78.1%
Argon	0.9%	0.9%
Carbon Dioxide	476 PPM	403 PPM
Carbon Monoxide	4.0 PPM	1.6 PPM
Total Hydrocarbons*	3.6 PPM	4.8 PPM
Total Halogens	<0.5 PPM	<0.5 PPM
Methane	1.8 PPM	1.9 PPM
Acetylene	<0.1 PPM	<0.1 PPM
Freon 113	<0.1 PPM	0.1 PPM
Methyl Ethyl Ketone	<0.1 PPM	<0.1 PPM
Benzene	<0.1 PPM	<0.1 PPM
Toluene	<0.1 PPM	<0.1 PPM
Acetaldehyde	0.2 PPM	0.4 PPM
2,2-Dimethylpropane	0.2 PPM	0.2 PPM
Unknown #1	<0.1 PPM	0.4 PPM
Unknown #2	<0.1 PPM	0.4 PPM
C4+	<0.4 PPM	0.5 PPM

*Expressed as methane equivalents

2. The above sample showed no appreciable contamination: all components were within acceptable range.

Glen Deason
Chemist

Memorandum 15 Jan 1968

From: Glen Deason: Code 3430
To: F. Hamilton: Code 3410

Subject: Analysis of Lerci Air Samples: Results of

1. In accordance with your request of 14 Jan 1968, the air samples delivered to the gas analysis lab were analyzed and found to contain:

Component	Lerci #1 Taken 12-29-67	Lerci #2 Taken 1-12-68
Oxygen	21.4%	21.1%
Nitrogen	78.1%	78.1%
Argon	0.5%	0.8%
Carbon Dioxide	315 PPM	331 PPM
Carbon Monoxide	3.0 PPM	1.0 PPM
Total Hydrocarbons*	4.5 PPM	4.6 PPM
Total Halogens	0.5 PPM	0.5 PPM
Methane	2.7 PPM	2.7 PPM
Acetylene	0.1 PPM	0.1 PPM
Freon 113	0.1 PPM	0.1 PPM
Methyl Ethyl Ketone	0.1 PPM	1.1 PPM
Benzene	0.1 PPM	0.1 PPM
Toluene	0.1 PPM	0.1 PPM
Cyclopentane	0.1 PPM	1.5 PPM
C4+	0.1 PPM	0.5 PPM

*Expressed as methane equivalents

2. The above sample showed no appreciable contamination: all components were within acceptable range.

Glen Deason
Chemist

Memorandum 24 Nov 1987

From: Al Purer, Code 3230
To: F. Hamilton, Code 3410

Subj: Offgasing Analysis of Rotork Umbilical Liner; Results of

1. The above sample was placed in a 1000 cubic centimetre outgasing chamber which had been precleaned to ensure a zero hydrocarbon background. The chamber was then charged to 100 psia, 6800 cubic centimetre ambient conditions, with high purity (Zero) air. The hydrocarbon content of the contained sample was then allowed to equilibrate with the zero air for 4 hours at 130F(54.4C) before an analysis for specific and total hydrocarbons. The analysis yielded the following results:

COMPONENT	LEVEL DETECTED		LIMITS	
Total Hydrocarbons+	1.5	ppm	25	ppm
Carbon Monoxide	1.0	ppm	10	ppm
Halogens***	<0.5	ppm	5	ppm
Methane	<0.1	ppm	1000	ppm
Acetone	<0.1	ppm	300	ppm
Freon 113	0.1	ppm	10	ppm
Methyl Ethyl Ketone**	<0.1	ppm	200	ppm
Benzene	<0.1	ppm	1	ppm
Toluene **	<0.1	ppm	200	ppm
C4+	<0.1	ppm		
Sample Weight	26.0	grams		
Dilution Volume	6800	cc		

+ Expressed as methane equivalents
** OSHA Limit
*** Expressed as methyl chloride equivalents

2. The above sample did not show excessive offgasing and would be safe in a non-rated, closed environment at temperatures up to 130F(54.4C).

Al Purer
Research Chemist

Memorandum 2 August 1988

To: E. Hamilton: Code 5110
From: G. Deason: Code 5130

Subject: Analysis of Cold Test Compressor Gauge and Cold Test Manifold at IHR; Results of Air-Gel

1. In accordance with your request the air samples delivered to the gas analysis lab were and found to contain.

Component	Compressor	Manifold
Oxygen	21.0%	21.0%
Nitrogen	78.1%	78.1%
Argon	0.9 %	0.9%
Carbon Dioxide	749 PPM	956 PPM
Carbon Monoxide	2.9 PPM	3.3 PPM
Total Hydrocarbons*	2.5 PPM	4.6 PPM
Total Halogens	<0.5 PPM	<0.5 PPM
Methane	1.4 PPM	1.2 PPM
Acetylene	0.1 PPM	<0.1 PPM
Freon 113	0.1 PPM	<0.1 PPM
Methyl Ethyl Ketone	<0.1 PPM	<0.1 PPM
Benzene	<0.1 PPM	<0.1 PPM
Toluene	<0.1 PPM	<0.1 PPM
Cl2	0.2 PPM	<0.2 PPM

*Expressed as methane equivalents

2. The above sample showed no appreciable contamination. All components were within the acceptable range.

Glen Deason
Chemist

Memorandum 9 August 1988

To: F. Hamilton: Code 5110
From: G. Deason: Code 5130 Atlas Copco A001

Subject: Analysis of LWDS Compressor Air Sample (China Lake); Results of

Description: 1 HR into run, 25 July 88, LWDS 120F Compressor Air Sample A001 (China Lake).

1. In accordance with your request of 8 August 1988, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Component	Air Sample
Oxygen	21.0 %
Nitrogen	78.1 %
Argon	0.9 %
Carbon Dioxide	442 PPM
Carbon Monoxide	1.8 PPM
Total Hydrocarbons*	4.8 PPM
Total Halogens**	<0.5 PPM
Methane	1.5 PPM
Acetylene	<0.1 PPM
Acetone	0.1 PPM
Freon 113	<0.1 PPM
Methyl Ethyl Ketone	<0.1 PPM
Ethylene	<0.1 PPM
Toluene	<0.1 PPM
Benzene	<0.1 PPM
C4+	<0.9 PPM

*Expressed as methane equivalents.
**Expressed as methyl chloride equivalents.

2. The above sample showed no appreciable contamination; all components were within the acceptable range.

Glen Deason
Chemist

TEXAS RESEARCH INSTITUTE, INC.
NATIONAL LIFE SUPPORT AIR QUALITY ASSURANCE PROGRAM
9063 BEE CAVES ROAD
AUSTIN, TEXAS 78733-6201
PHONE: (512) 263-2101

REPORT NUMBER: REPORT DATE: SAMPLE DATE:
AIR SOURCE: CUSTOMER NO.:
AIR SAMPLED—FROM: KIT NO.:

AB
AB61

ANALYSIS RESULTS

ANALYTE	SOURCE AIR	AMBIENT AIR	AIR STANDARD
OXYGEN (%)			
CARBON MONOXIDE (ppm)			
METHANE (ppm)			
TOTAL GASEOUS HYDROCARBONS (ppm) - METHANE			
CARBON DIOXIDE (ppm)			
OIL MIST & PARTICULATE (mg/cu m)		N/A	
ADDITIONAL ANALYSIS			
WATER (dewpoint, °F)		N/A	
ASBESTOS FIBERS (cc)		N/A	
SULFUR DIOXIDE (ppm)		N/A	
NITROGEN DIOXIDE (ppm)		N/A	
HALOGENATED SOLVENT (ppm)		N/A	

ANALYZED USING _____ STANDARD
ANALYZED BY: _____
COMMENTS:

From compressor head gift

TRI/AUSTIN, INC.
A Texas Research International Company

NATIONAL LIFE SUPPORT AIR QUALITY ASSURANCE PROGRAM
9063 BEE CAVES ROAD
AUSTIN, TEXAS 78733-6201
PHONE: (512) 263-2101

REPORT NUMBER: 89-6760 REPORT DATE: 10/05/89 SAMPLE DATE: 09/29/89

AIR SOURCE: LWDS PROTOTYPE #2 Atlas Copco A002

AIR SAMPLED—FROM: Compressor

CUSTOMER NO.: 04563

KIT NO.: 846

CO/NAVAL COASTAL SYS. CEN.
ATTN: F. HAMILTON, CODE 5110
PANAMA CITY, FL 32407-5000

ANALYSIS RESULTS

ANALYTE	SOURCE AIR	AMBIENT AIR	AIR STANDARD
OXYGEN (%)	20.9	20.9	20-22
CARBON MONOXIDE (ppm)	< 1.0	< 1.0	20
METHANE (ppm)	2.0	1.7	N/A
TOTAL GASEOUS HYDROCARBONS (ppm) - METHANE	3.9	2.1	25
CARBON DIOXIDE (ppm)	350.2	358.3	1000
OIL MIST & PARTICULATE (mg/cu m)	0.2	N/A	5
ADDITIONAL ANALYSIS			
WATER (dewpoint, °F)	N/A	N/A	N/A
ASBESTOS FIBERS (cc)	N/A	N/A	N/A
SULFUR DIOXIDE (ppm)	N/A	N/A	N/A
NITROGEN DIOXIDE (ppm)	N/A	N/A	N/A
HALOGENATED SOLVENT (ppm)	N/A	N/A	N/A

ANALYZED USING U.S. Navy STANDARD

ANALYZED BY: ANNE RHYNE

COMMENTS: YOUR SAMPLE IS WITHIN SPECIFICATIONS

CC: COMMANDING OFFICER NAVAL COASTAL SYSTEMS CENTER ATTN: THERESA BARTH/CODE 5130 PANAMA CITY, FL 32407

SP: 3219 AP: 10671 FT: 40 50: 0

Memorandum 20 July 1988

To: F. Hamilton: Code 5110
From: G. Deason: Code 5130

Atlas Copco AO02 Unit FH

Subject: Analysis of Complete System Sample From End Of Diver's Umbilical; Results of

1. In accordance with your request of 20 July 1988, the Complete System Air Sample delivered to the gas analysis lab was analyzed and found to contain:

Component	Air Sample
Oxygen	21.0 %
Nitrogen	78.1 %
Argon	0.9 %
Carbon Dioxide	333 PPM
Carbon Monoxide	0.7 PPM
Total Hydrocarbons*	17.9 PPM
Total Halogens**	2.2 PPM
Methane	1.4 PPM
Acetylene	<0.1 PPM
Acetone	<0.1 PPM
Freon 113	<0.1 PPM
Methyl Ethyl Ketone	<0.1 PPM
Ethylene	<0.1 PPM
Toluene	<0.1 PPM
Benzene	<0.1 PPM
1-Hexene	1.1 PPM
Unknown #1	0.5 PPM
Unknown #2	0.6 PPM
C4+	<4.1 PPM

*Expressed as methane equivalents.
**Expressed as methyl chloride equivalents.

2. The above sample showed no appreciable contamination; all components were within the acceptable range.

Glen Deason
Chemist

Memorandum 9 August 1988

To: F. Hamilton: Code 5110
From: G. Deason: Code 5130

Atlas copies A+01

Subject: Analysis of LWDS Manifold Air Sample (China Lake); Results of

Description: 1300 HRS, 21 July 88, LWDS 124F Manifold Air Sample (China Lake).

1. In accordance with your request of 8 August 1988, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Component	Air Sample
Oxygen	21.0 %
Nitrogen	78.1 %
Argon	0.9 %
Carbon Dioxide	504 PPM
Carbon Monoxide	1.4 PPM
Total Hydrocarbons*	15.5 PPM
Total Halogens**	<0.5 PPM
Methane	1.1 PPM
Acetylene	<0.1 PPM
Acetone	1.0 PPM
Freon 113	<0.1 PPM
Methyl Ethyl Ketone	2.7 PPM
Ethylene	<0.1 PPM
Toluene	<0.1 PPM
Benzene	<0.1 PPM
Unknown #1	0.3 PPM
C4+	<3.7 PPM

*Expressed as methane equivalents.
**Expressed as methyl chloride equivalents.

2. The above sample showed no appreciable contamination; all components were within the acceptable range.

Glen Deason
Chemist

NATIONAL LIFE SUPPORT AIR QUALITY ASSURANCE PROGRAM
9063 BEE CAVES ROAD
AUSTIN, TEXAS 78733-6201
PHONE: (512) 263-2101

REPORT NUMBER: 88-2347 REPORT DATE: 04/08/88 SAMPLE DATE: 04/05/88
AIR SOURCE: ATLAS COPCO LT8 COMPRESSOR CUSTOMER NO.: 0456
AIR SAMPLED—FROM: Compressor KIT NO.: 349

COMMANDING OFFICER
NAVAL COASTAL SYSTEMS CENTER
ATTN: CODE 3410, F. HAMILTON
PANAMA CITY, FL 32407-5000

ANALYSIS RESULTS

ANALYTE	SOURCE AIR	AMBIENT AIR	AIR STANDARD
OXYGEN (%)	20.9	20.9	20.93
CARBON MONOXIDE (ppm)	1.0	1.0	9
METHANE (ppm)	1.9	1.9	N/A
TOTAL GASEOUS HYDROCARBONS (ppm) - METHANE	2.9	1.4	10
CARBON DIOXIDE (ppm)	370.6	469.3	1000
OIL MIST & PARTICULATE (mg/cu m)	< 0.2	N/A	5
ADDITIONAL ANALYSIS			
WATER (dewpoint, °F)	N/A	N/A	N/A
ASBESTOS FIBERS (cc)	N/A	N/A	N/A
SULFUR DIOXIDE (ppm)	N/A	N/A	N/A
NITROGEN DIOXIDE (ppm)	N/A	N/A	N/A
HALOGENATED SOLVENT (ppm)	N/A	N/A	N/A

ANALYZED USING U.S. Navy STANDARD
ANALYZED BY: Chuck Combs
COMMENTS:

YOUR SAMPLE IS WITHIN SPECIFICATIONS

CC: COMMANDING OFFICER NAVAL COASTAL SYSTEMS CENTER ATTN: TERESA BARTH, CODE 5130 PANAMA CITY, FL 32407-5000

SB: 4302 AB: 13075 FT: 1259 MO: 0

NATIONAL LIFE SUPPORT AIR QUALITY ASSURANCE PROGRAM
9063 BEE CAVES ROAD
AUSTIN, TEXAS 78733-6201
PHONE: (512) 263-2101

REPORT NUMBER: 88-2347 REPORT DATE: 04/08/88 SAMPLE DATE: 04/05/88
AIR SOURCE: ATLAS COPCO LT8 COMPRESSOR CUSTOMER NO.: 0458
AIR SAMPLED—FROM: Compressor KIT NO.: 247

COMMANDING OFFICER
NAVAL COASTAL SYSTEMS CENTER
ATTN: CODE 3410, F. HAMILTON
PANAMA CITY, FL 32407-5000

ANALYSIS RESULTS

ANALYTE	SOURCE AIR	AMBIENT AIR	AIR STANDARD
OXYGEN (%)	20.9	20.9	20.93
CARBON MONOXIDE (ppm)	< 1.0	1.0	5
METHANE (ppm)	1.9	1.5	N/A
TOTAL GASEOUS HYDROCARBONS (ppm) - METHANE	2.9	1.4	25
CARBON DIOXIDE (ppm)	370.6	469.3	1000
OIL MIST & PARTICULATE (mg/cu m)	< 0.2	N/A	5
ADDITIONAL ANALYSIS			
WATER (dewpoint, °F)	N/A	N/A	N/A
ASBESTOS FIBERS (cc)	N/A	N/A	N/A
SULFUR DIOXIDE (ppm)	N/A	N/A	N/A
NITROGEN DIOXIDE (ppm)	N/A	N/A	N/A
HALOGENATED SOLVENT (ppm)	N/A	N/A	N/A

ANALYZED USING U.S. Navy STANDARD
ANALYZED BY: CHUCK CONTOS

COMMENTS:
YOUR SAMPLE IS WITHIN SPECIFICATIONS
CC: COMMANDING OFFICER NAVAL COASTAL SYSTEMS CENTER ATTN: TERESA BARTH, CODE 5130 PANAMA CITY, FL 32407-5000

SB: 4302 AB: 13075 FT: 1259 MO: 0

BAUER HIGH PRESSURE LINE

1. DIVING COMPRESSORS
   - A. PORTABLE LINE
   - B. STATIONARY LINE
2. FIREFIGHTING UNITS
   - A. STATIONARY LINE
   - B. MOBILE LINE
3. ACCESSORIES
4. PRICE LIST

CHARGING SYSTEM

STANDARD SCOPE OF SUPPLY

A single stage, air cooled air booster compressor with 8 HP gasoline drive with electric starter and centrifugal clutch. Also available with hydraulic motor drive.

An activated carbon purifier cartridge is provided for oil removal.

An air receiver air cascade system consisting of a minimum of six high pressure air storage cylinders. Air receivers are code stamped to section V111 of the ASME code for unfired pressure vessels.

An air distribution panel complete with receiver gauges, receiver valves, air distribution and bypass valves. The panel includes a fill valve for each of the three SCBA cylinders which can be filled simultaneously.

Fill station with provision for three SCBA bottles. The bottle holders are designed to accomodate 2216, 3000 or 4500 psi breathing air bottles.

Air booster compressor controls are installed on the main control panel. The panel includes:

- Air booster compressor inlet pressure gauge.
- Main system air inlet valve.
- Inlet minimum pressure switch.
- Inlet pressure safety valve.
- Bleeder valve control for fill hoses.
- On/off switch for engine.

All of the above are supplied on a welded steel skid enclosed in a heavy duty steel frame.

A highway rated, tandem axle four wheel trailer is optional.

TECHNICAL DATA

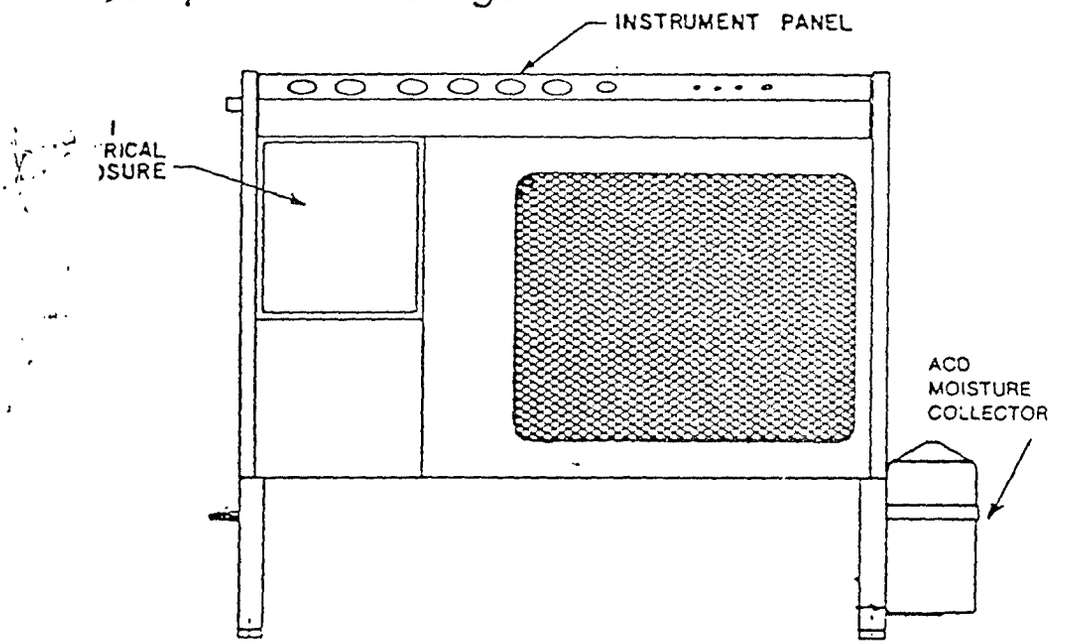
MODEL NO	WEIGHT lbs with trailer	WEIGHT lbs without trailer	DIMENSIONS L x W x H			
SMART I	4500	3200	with trailer	192	62	80
			without trailer	84	43	60

Service Pressure
5000 psig

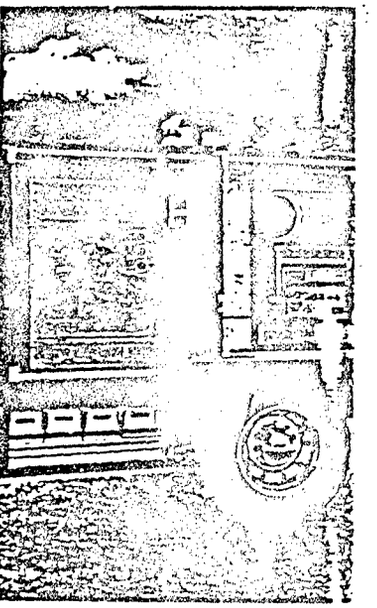
pressing ——— Processing ———

ODULE NO. 1
Compressor Package

Range: •6 - 100 cfm
•Pressures to 6000 psig

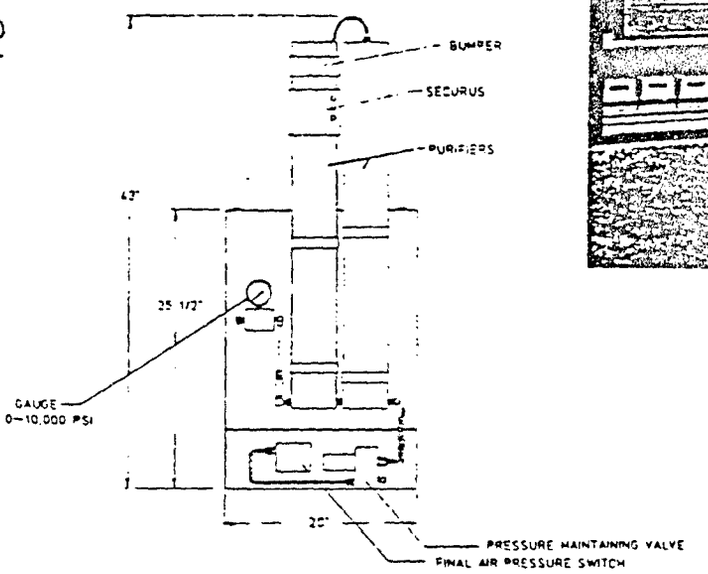


Compressors available in horizontal or vertical configuration.



MODULE NO. 2
Purification Panel

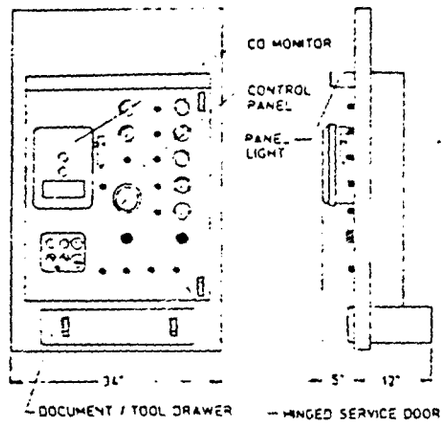
Range: •5,700 cu. ft to 424,000 cu. ft
•All units available with Securus

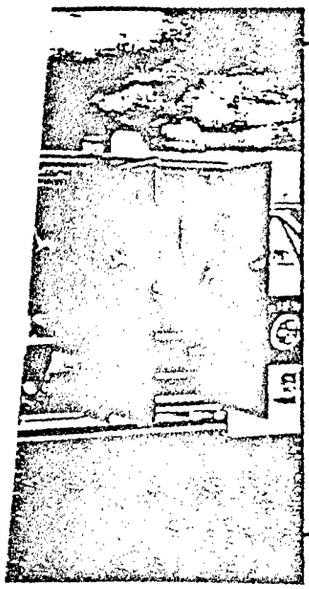


OUR MODULAR CONCEPT was designed to completely satisfy the requirements of the fire and rescue vehicle manufacturers of mobile SCBA recharging systems. Module No. 1 - the high pressure air compressor is available in compressors with air recharging capabilities over a range of 6 scfm to

DULE NO. 3
strument/Control Panel

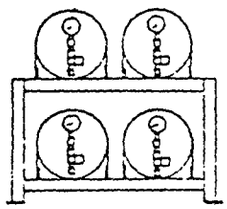
Range: • To accomodate 1 to 4 storage banks.





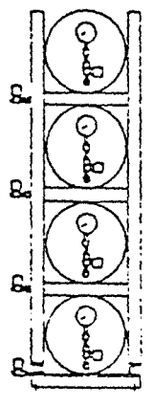
MODULE NO. 4
Air Storage System

Cascade system consisting of either high pressure 5000 PSI receivers, ASME stamped, or DOT 4500 PSI or 6000 PSI air receivers.



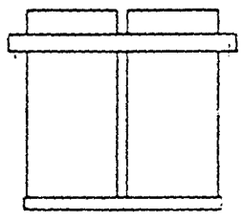
2 x 2 Method

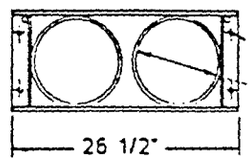
1 x 4 Method



MODULE NO. 5
Bottle Holder (2 Reqd.)

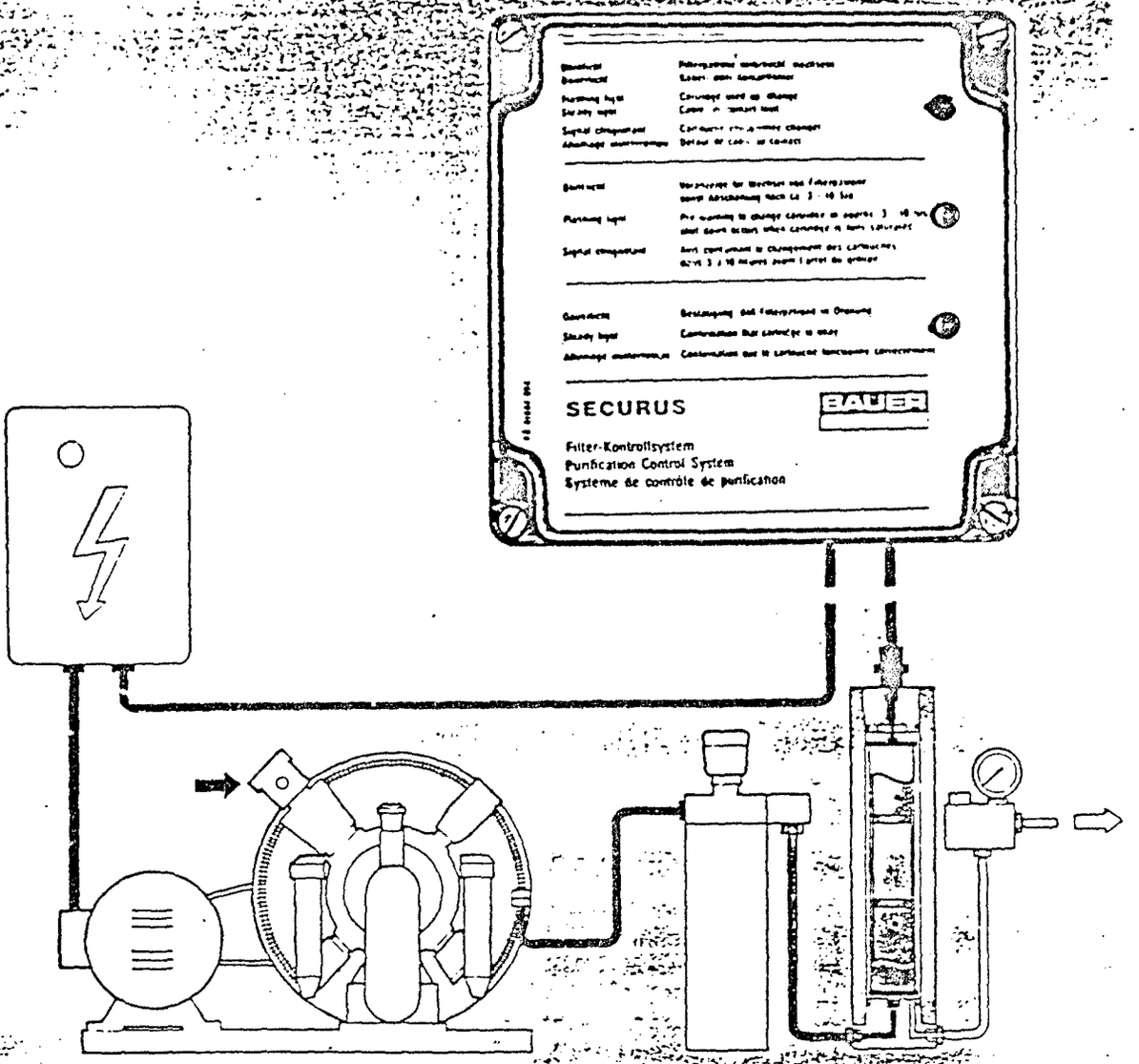
Designed to accommodate High and Low Pressure SCBA and Scuba bottles.





00 scfm with a choice of prime movers in electric, engine, hydraulic and P.T.O. drive, as well as combination drive units such as hydraulic/electric, engine/electric.

standard modules. bles to meet our ot requirements



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- The SECURUS electronic air purification monitor warns the operator in advance of the impending expiration of the purifier cartridges.
- SECURUS monitors continuously and guarantees that the compressed air is always of the highest quality.
- SECURUS measures air quality directly in the purification cartridge.
- SECURUS is designed in such a way that if the operator fails to change the cartridge when indicated the compressor is automatically shut down. It cannot be restarted until the used cartridge is replaced with a fresh one. For absolute safety no manual override is provided.

Practice shows that, on an average, the working life of the cartridge doubles, and the extra cost may be compensated after a short period of use.

For detailed information please ask for brochure SECURUS AT 069.

ALLIED MARINE SERVICES, INC.
659 SOUTH WASHINGTON STREET, ALEXANDRIA, VIRGINIA 22314, U.S.A.
TELEPHONE: (703) 836-0300 FACSIMILE (703) 836-5430 TELEX: 709335

Commander
Belvoir RD&E Center,
Attn: STRBE-FMT (J. Leary)
Fort Belvoir, VA. 22060-5606

9 November 1989

Ref: FB1109hm

Dear Sir,

MARKET SURVEY: DIVING AIR COMPRESSOR

Further to your request for manufacturer's literature/information on diving air packages, Allied Marine Services, Inc., (AMS) is pleased to submit the enclosed literature for your interest. By way of general information, AMS is the exclusive representative of Hamworthy USA, Inc., Forest Park, Georgia, with specific responsibility for meeting the requirements of the U.S. Departments of Defense and Transportation. As you will note from the enclosed literature, Hamworthy's primary production facilities are located in Poole, England, though it should be pointed out that a U.S. manufacturing capability is being developed. Hamworthy are among the leading suppliers of compressors to the British Ministry of Defense with over 70 years experience, and can supply a complete range of advanced reciprocating compressors to suit most situations and applications.

With regard to the Department of the Army's specific requirement for a diving air compressor, we are confident that Hamworthy can supply a suitable package at most competitive prices. We have carefully examined the characteristics contained in your request for market survey, and have determined that either our 70mm or 100mm horizontal reciprocating would best satisfy the stated requirement, depending on whether a medium or high pressure compressor is preferred. Preliminary details of these two compressors are as follows:

Option 1: 177 CFM FAD @ 1000 PSIG

Model 3TH 190W70, 3 stage, horizontal, water cooled compressor, belt driven from diesel engine (manufacturer to be agreed upon).

Capacity:	177 CFM FAD
Pressure:	1000 PSIG
Speed:	1530 RPM nominal
Shaft Power:	113 H.P.
Minimum Engine Power:	130 H.P.
Mean Piston Speed:	11.7 feet/sec.
Required Cooling Water Flow:	55 USG/min.
General Arrangement Drawing:	E 11614-42
Publication:	2111

ENCLOSURE 3P PAGES 1-4

Option 2: 177 CFM FAD @ 5000 PSIG

Model 4TH 275W100, 4 stage, horizontal, water cooled compressor, belt driven from diesel engine (manufacturer to be agreed upon).

Capacity:	177 CFM FAD
Pressure:	5000 PSIG
Speed:	1085 RPM nominal
Shaft Power:	138 H.P.
Minimum Engine Power:	160 H.P.
Mean Piston Speed:	11.86 feet/sec.
Required Cooling Water Flow:	86 USG/min.
General Arrangement Drawing:	D 6040
Publication:	2145

Typical preliminary general arrangement drawings and applicable publications for each of the two options, as referenced above, are enclosed.

In addition to the brief information set out above, we would offer the following comments in response to your stated requirements contained in Paragraphs (a) thru (u) of Section 3.0 of your market survey. Our comments are as follows:

a. Model: As above.

b. Type: Horizontal, reciprocating.

c. Capability: 177 CFM (NB. alternative capability can be supplied to meet final requirement).

d. Pressure: 1000 PSI (Model 3TH 190W70): 5000 PSI (Model 4TH 275W100) (NB. alternative delivery pressures can be supplied to meet final requirement).

e. Prime Mover: To be determined. Hamworthy are happy to consider the use of a qualified U.S. manufactured diesel, should this be preferable.

f. Fuel: Diesel.

g. Cooling System: Both identified compressor models are water cooled. Please see above for required cooling water flow.

Alternatively, we can offer a closed fresh water cooling system and utilize either an air blast radiator, F.W./S.W. heat exchanger, or an evaporative cooling tower.

h. Storage Flasks: Storage vessels would be mounted on a common base and supplied to U.S. standards. Selection will depend on required

capacity and final specification.

i. Filtration: Full details of the filtration system will be provided under separate cover. However, we have routinely supplied compressors for breathing air duty throughout the world and are confident that we can meet any referenced standard.

j. System Piping: The basic compressor unit is constructed at our Poole, England, facility to British standards with metric dimensions and fittings. However, the modulization of units supplied for this requirement would be carried out in the United States, and therefore all piping/materials used outside the compressor confines will be supplied to the appropriate U.S. standards.

k. Control Panel: A suitable U.S. manufactured control panel will be selected for mounting on the module.

l. Dimensions/Weights: Basic compressor details are as shown in the enclosed literature and drawings. We are unable to supply firm dimensional details until after an appropriate prime mover has been selected. However, we are confident that we can easily comply with all requirements, and believe we should be able to supply a suitable diving air package at the desired weight of 7,500 lbs.

m. Environmental Limitations: Hamworthy standard design parameters are as follows:

Ambient temperature: 0 - 113 degrees F
Cooling water temperature: 0 - 104 degrees F

However, we are confident that we can meet the stated environmental requirements.

n. Air Quality: To be advised under separate cover (see i. above).

o. Noise: All compressors are fitted with a standard air filter/silencer. Additional measures can be taken as required.

p. Packaging/Accessories: It is intended that our offered package would include the compressor, drive belts, diesel engine, control panel, filtration, mounted as a module on a common bedplate suitable for lifting by a forklift truck.

q. Instruction, Parts Manual and Drawing Costs: General instruction manuals, complete with appropriate parts lists and final certified drawings are supplied with each compressor as standard. Special manuals required to meet additional standards (Levelised MIL-SPEC) together with any required PTD and drawings can be provided with costs to be agreed.

r. Availability: Standard lead time is approximately 120 days after receipt of order. Actual lead time will depend on various factors, including which diesel engine is selected.

s. Estimated Price: As this is a market survey we have not investigated prices at this time.

t. Maintainability: A full complement of spares are held in the United States with qualified service engineers in attendance.

u. References: Many units are in service throughout the world. Current U.S. D.O.D. applications include a four stage (5000 PSIG) horizontal 70 mm compressor providing breathing air for submarines at Norfolk Naval Base, five each three stage horizontal 70 mm compressors at Cherry Point Naval Air Force Base and one similar unit at Pensacola Naval Air Base.

Obviously, the above information is general in nature and is intended to demonstrate Hamworthy's capabilities and our ability to meet most customer requirements. We look forward to receiving additional details and would welcome the opportunity to meet with your personnel to discuss how we can best assist the U.S. Department of Defense in obtaining a modern diving air system at most competitive prices. Please do not hesitate to contact the undersigned should you have any specific questions. Assuring you of our best attention, we remain,

Yours sincerely,

T.J. Gale
V.P. Marketing

Encl: Publication 2111
Publication 2145A
Publication 2171
Drawing E11614-42
Drawing D6040

HAMWORTHY USA, INC.
Air and Gas Compressor Systems

COMPRESSOR

One (1) Model 3TH 190W70, 3 stage, Horizontal, water cooled compressor (reciprocating type) belt driven from a diesel engine (see below).

Capacity:	177 CFM FAD
Pressure:	1000 PSIG
Speed:	1500 RPM nominal
Shaft Power:	113 H.P.
Minimum Engine Power:	130 H.P.
Mean Piston Speed:	11.7 feet/sec.
Required Cooling Water Flow:	55 USG/min.
Publication:	2111
L X W X H	112.5"X 70.5"X 55"
Weight (with Engine)	6200 lbs.
PRICE	$59,360.00

ENGINE

Type	Diesel
Model Number	CAT 3208 NA
Power Rated	131 H.P.
Speed	1800 RPM
Radiator and Fan	Incl.
Pedestal Engine mounts	Incl.
PRICE	$20,125.00

RECEIVERS

One (1) Manchester Tank	30 G, 250 psi
One (1) Manchester Tank	60 G, 250 psi
One (1) Manchester Tank	240 G, 250 psi
Ancillary equipment, as specified	Provided
PRICE	$ 4075.00

FILTRATION

Manufacturer	Dominick Hunter
Model Number	HP-A0-40-HE30
Connection(s)	1"NPT (f)
Coalescor	Yes
Standard(s)	PNEUROPA NATO AQAP 1
PRICE	$2025.00
Availability Delivery	14-16 Weeks FOB Atlanta, Ga.

HAMWORTHY

70 mm series

MEDIUM AND HIGH PRESSURE AIR COMPRESSORS

Capacities 55 — 735 m³/h
Pressures 17 — 450 bar

Hamworthy 70 mm series medium and high pressure water cooled compressors are three or four stage, two crank, dry sump pressure lubricated machines. Designed for industrial and marine applications involving the supply of air or gas at high pressures.

Standard Features

Air pressure gauge and relief valve for each stage, oil pressure gauge and relief valve, suction filter and silencer, cooler drain valves, integral inter-stage and after coolers, water jacket safety valve, high efficiency low lift concentric valve at each stage, and fusible plugs for high temperature protection.

Optional Features

Water circulating pump, evaporative water cooling tower, indirect heat exchanger, or radiator cooling system, air and water thermometers, air delivery non-return valve, separator column, lubrication oil heater, visual water flow indicator, relief valve vent pipes, skid type baseplate.

Optional Features (Automatic Control)

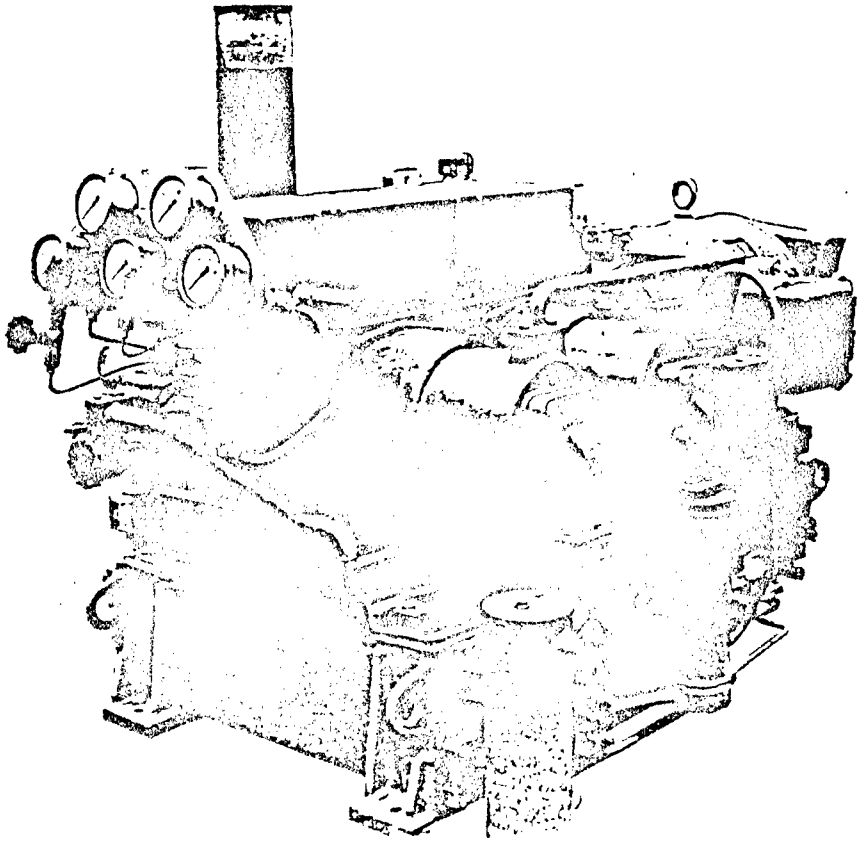
Automatic unloaders, automatic cooler drains, high air temperature switch, high water temperature switch, low lubricating oil pressure switch, cooling water flow switch, solenoid unloading valve, air pressure switch, automatic control panel.

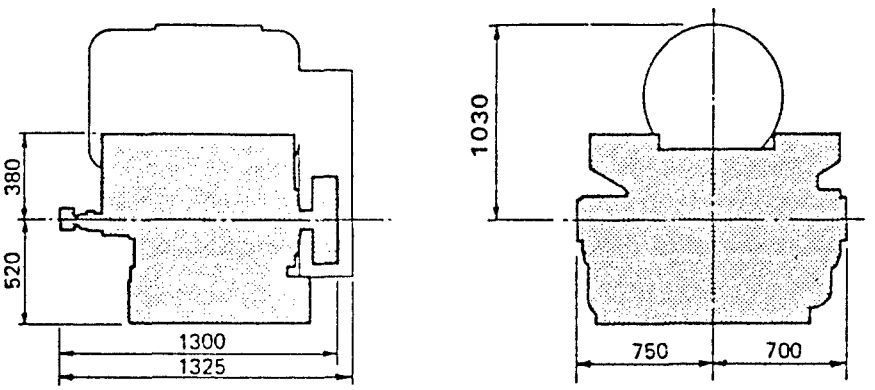
Drives and Mountings

Bare machines supplied with flexible half coupling or vee grooved flywheel. Electric motor or engine driven machines are direct or vee belt driven and mounted on a combined baseplate with safety guards.

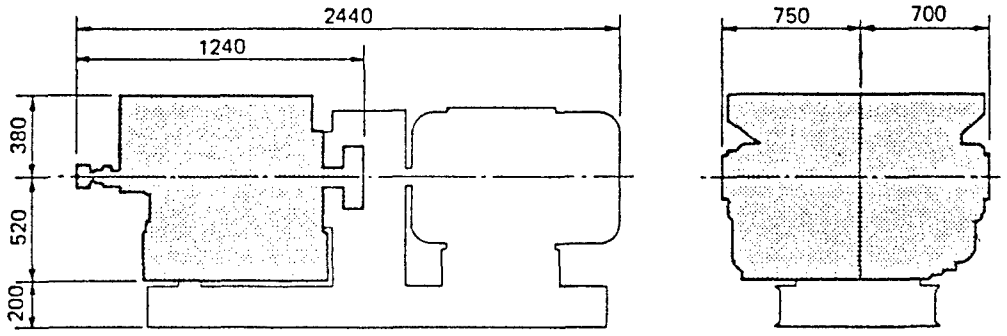
Classification and Spares

Compressors meet the requirements of major industrial users and the marine classification societies. Standard sets of spares are available for commissioning and to comply with these societies' rules.





Belt driven compressor



Direct coupled compressor

Weight Specification Net Weight (Compressor only) 1000 kg.

MACHINE PERFORMANCE DATA

Compressor Type	Capacity		Pressure		Power
	m^3/h	cfm	bar	psig	kW
4TH 190	115 — 345	65 — 200	100 — 350	1400 — 5000	31 — 115
4TH 140	80 — 245	47 — 145	100 — 450	1400 — 6500	23 — 95
4TH 100	55 — 170	32 — 100	100 — 450	1400 — 6500	16 — 65
3TH 190	110 — 340	65 — 200	40 — 100	600 — 1400	26 — 120
3TH 140	80 — 245	47 — 145	40 — 100	600 — 1400	20 — 90
3TH 100	55 — 170	32 — 100	40 — 100	600 — 1400	14 — 60
3TM 380	245 — 735	145 — 430	17 — 40	250 — 600	40 — 155
3TM 280	180 — 540	105 — 315	17 — 40	250 — 600	29 — 115
3TM 190	120 — 365	70 — 215	17 — 40	250 — 600	20 — 80

Capacities shown are free air delivered at constant pressure

SPEED RANGE 600 — 1800 rev/min

HAMWORTHY

HAMWORTHY ENGINEERING LIMITED
PUMP & COMPRESSOR DIVISION
POOLE DORSET BH17 7LA ENGLAND

PCS 2111/3 1184

HAMWORTHY

100 mm series

MEDIUM AND HIGH PRESSURE AIR COMPRESSORS

Capacities: 100 — 670 cfm (170 - 1100 m³/h)
Pressures: 450 - 6600 psig (30 - 450 bar)

Hamworthy 100 mm series medium and high pressure compressors are three or four stage, two crank, water cooled, dry sump pressure lubricated machines. Designed for continuously rated industrial, process and marine applications involving the supply of compressed air or gas at high pressures.

Standard Features

Air pressure gauge and relief valve for each stage, oil pressure gauge and relief valve, suction filter and silencer, cooler drain valves, integral inter-stage and after coolers, water jacket safety valve, high efficiency low lift concentric valve at each stage, and fusible plugs for high temperature protection.

Optional Features

Water circulating pump, evaporative water cooling tower, indirect heat exchanger or radiator cooling system, air and water thermometers, air delivery non-return valve, separator column, lubrication oil heater, visual water flow indicator, relief valve vent pipes, skid type baseplate.

Optional Features (Automatic Control)

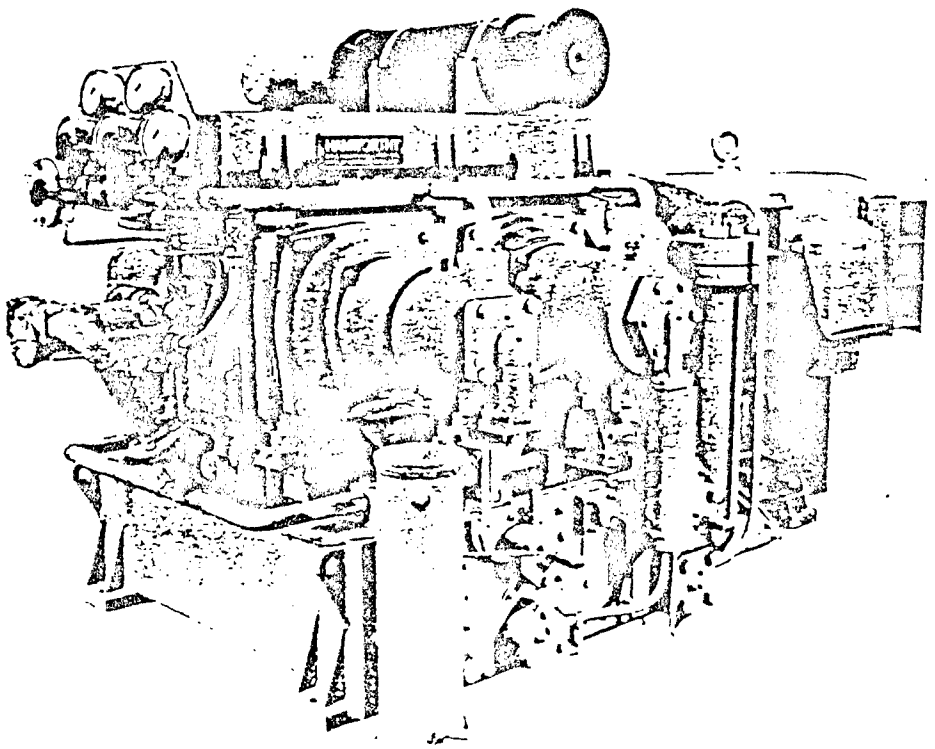
Automatic unloaders, automatic cooler drains, high air temperature switch, high water temperature switch, low lubricating oil pressure switch, cooling water flow switch, solenoid unloading valve, air pressure switch, automatic control panel.

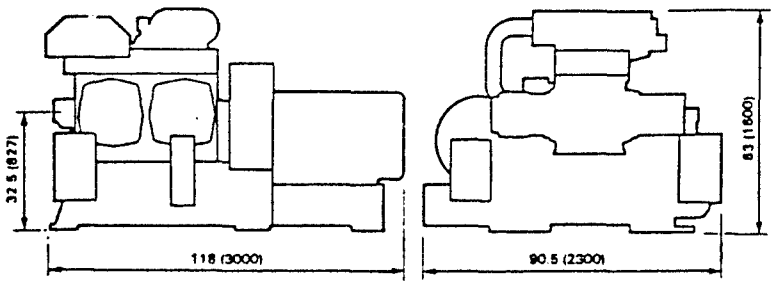
Drives and Mountings

Bare machines supplied with flexible half coupling or vee grooved flywheel. Electric motor or engine driven machines are direct or vee belt driven and mounted on a combined baseplate with safety guards.

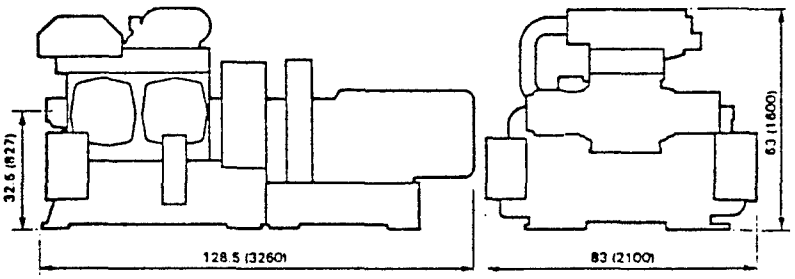
Classification and Spares

Compressors meet the requirements of major industrial users and the marine classification societies. Standard sets of spares are available for commissioning and where applicable to comply with classification societies' rules.





Belt driven compressor



Direct coupled compressor

Dry weight excluding motor 4800kg.

MACHINE PERFORMANCE DATA

Pressure		Compressor Type	Compressor				Drive	Motor		
			Capacity		Speed	Power		Power		Speed
psig	bar		cfm	m³/h	rpm	hp		hp	Kw	rpm
450	30.7	3TM860W	670	1139	1175	320	D	352	263	1175
		3TM860W	600	1020	1050	286	B	329	246	1175
		3TM860W	502	853	880	217	D	239	179	880
		3TM860W	402	683	705	142	D	157	117	705
		3TM565W	327	556	880	138	D	153	114	880
600	40.9	3TM565W	448	761	1175	229	D	252	188	1175
		3TM565W	400	680	1050	205	B	235	175	1175
		3TM565W	336	571	880	161	D	178	133	880
		3TM565W	269	457	705	103	D	114	85	705
		3TM430W	206	350	705	78	D	85	64	705
2000	136	4TH565W	454	772	1175	304	D	335	250	1175
		4TH565W	400	680	1040	269	B	310	231	1175
		4TH565W	339	576	880	201	D	222	116	880
		4TH565W	272	462	705	133	D	147	110	705
		4TH430W	208	353	705	104	D	115	86	705
3000	204	4TH565W	454	772	1175	304	D	335	250	1175
		4TH565W	400	680	1040	269	B	310	231	1175
		4TH565W	339	576	880	201	D	222	166	880
		4TH565W	272	462	705	133	D	147	110	705
		4TH430W	208	353	705	104	D	115	86	705
5000	340	4TH565W	406	690	1175	338	D	372	278	1175
		4TH565W	305	518	880	223	D	246	184	880
		4TH565W	244	414	705	147	D	162	121	705
		4TH430W	187	317	705	116	D	128	96	705
		4TH275W	119	202	705	73	D	81	61	705

Capacities shown are free air delivered at constant pressure D = direct drive, B = belt drive

The manufacturers reserve the right to alter the specification and data to incorporate improvements in design. Certified drawings will be issued on request.

PCS 2145A 0486

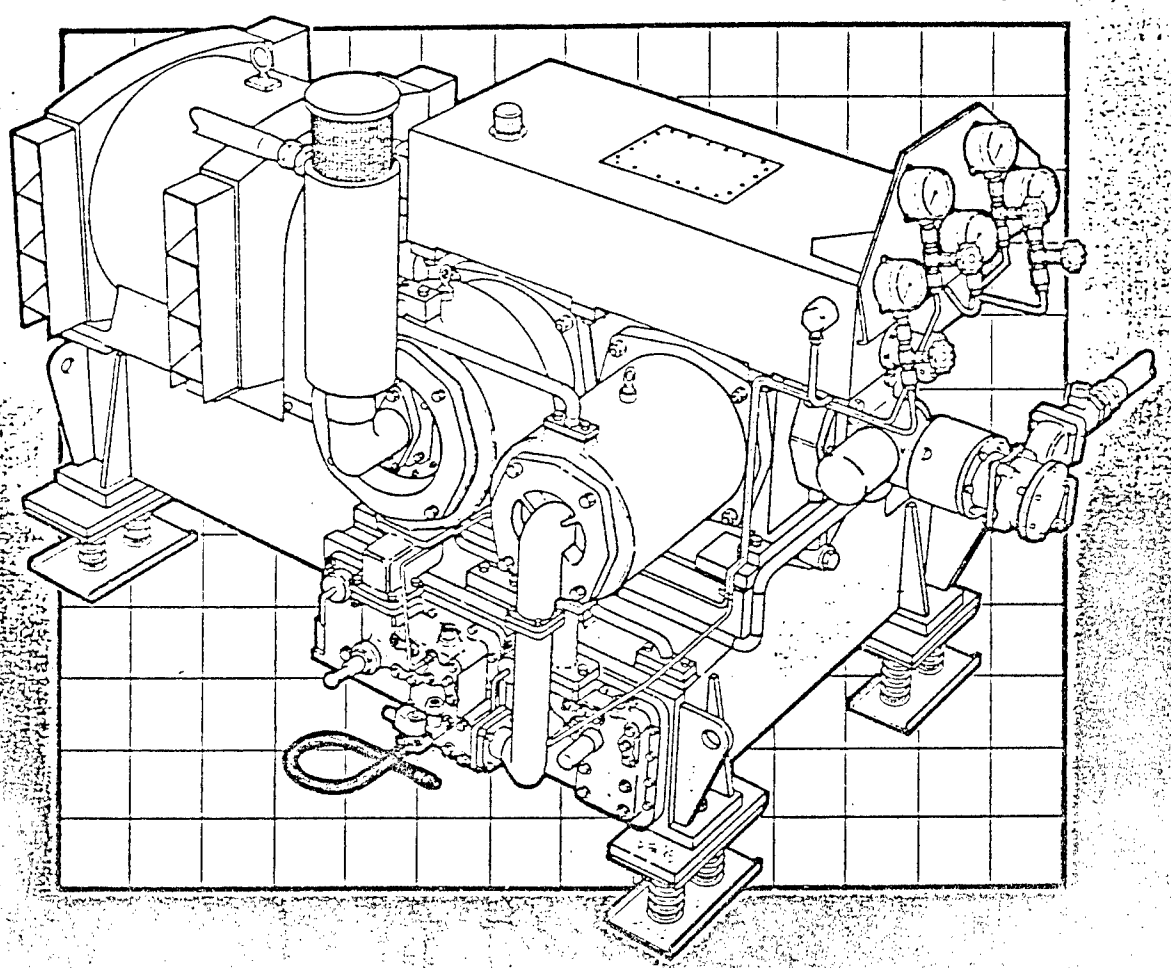
HAMWORTHY ENGINEERING LIMITED
10555 Lake Forest Boulevard Suite 5F New Orleans
Louisana 70127 USA
Telephone [illegible] 953691

HAMWORTHY CANADA LIMITED
113-115 Cushman Road St Catharines Ontario
[illegible]

HAMWORTHY ENGINEERING LIMITED
Pump & Compressor Division
Fleets Corner Poole Dorset BH17 7LA England
Telephone 0202 675123 Telex 41348

Hamworthy [illegible] about the world

HAMWORTHY COMPRESSORS



2 to 450 bar

Our design and engineers using their considerable experience and with the advantages of modern C.A.D. techniques have now produced a range of advanced machines with a large number of design options to cover low, medium and high pressures for air, gas and booster applications.

Depuis plus de soixante ans, Hamworthy produit des compresseurs d'air et de gaz pour les marchés industriels et maritimes.

Nos concepteurs et ingénieurs ont utilisé leur expérience considérable et profité des avantages des techniques C.A.O. (conception assistée par ordinateur) modernes pour produire toute une gamme de machines perfectionnées, avec un grand nombre d'options de conception pour couvrir les pressions basses, moyennes et élevées dans les applications de compression d'air, de gaz et de surcompression.

Hamworthy stellt seit über sechzig Jahren Luft- und Gaskompressoren für die Industrie und den Schiffbau her.

Unsere Konstrukteure und Ingenieure konnten aufgrund langjähriger Erfahrung und durch Nutzung der Vorteile moderner, computergestützter Konstruktionsverfahren jetzt ein Programm hochentwickelter Verdichter in zahlreichen Sonderausführungen für niedrige, mittlere und hohe Luft- und Gasdrücke sowie für Boosterbetrieb auf den Markt bringen.

competitive machines [illegible]

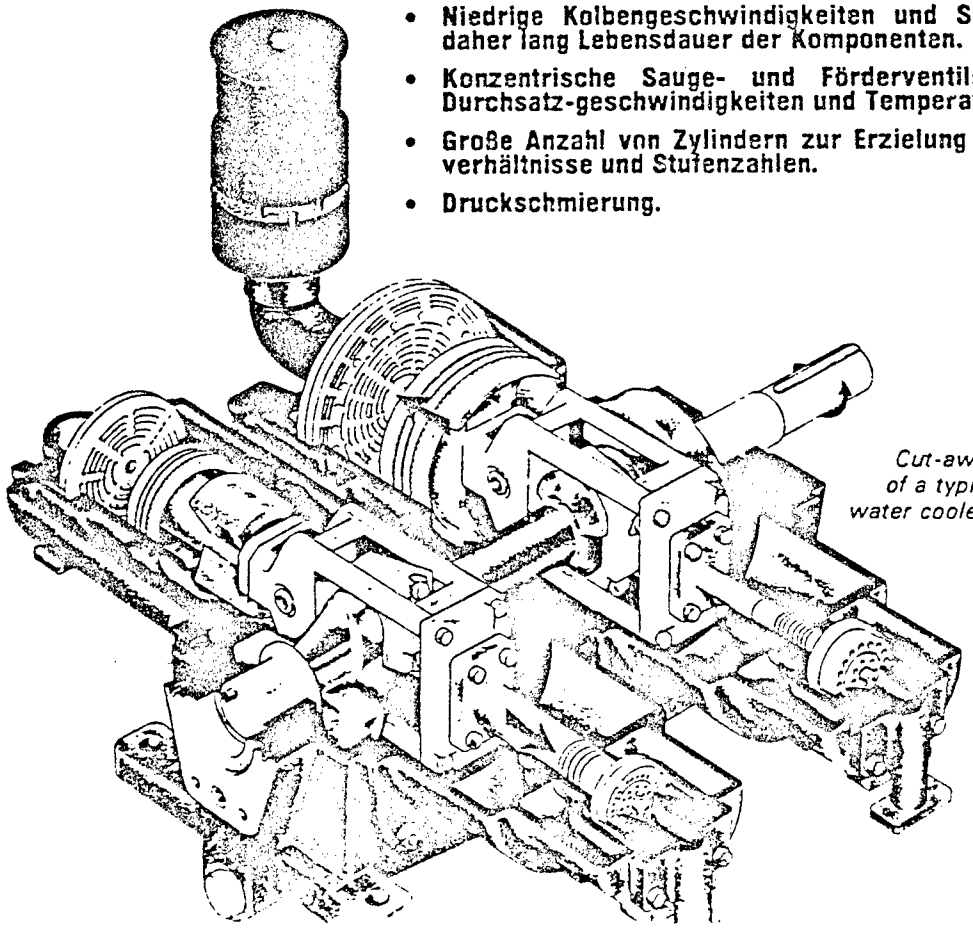
- Horizontally disposed [illegible] opposite pistons.
- Low piston speeds and side loads resulting in extended component life and lower maintenance costs.
- Concentric suction and delivery valves with low flow velocities and temperature.
- Wide range of cylinders available to obtain optimum compression ratios and number of stages.
- Force fed lubrication system.

Les principaux advantages des machines sont les suviants:

- Elles sont compactes et légères.
- Les cylindres sont disposés horizontalement avec des pièces d'accouplement reliant les pistons opposés.
- Les vitesses des pistons et les charges latérales sont basses, ce qui donne une grande longévité des composants.
- Les soupapes d'aspiration et de refoulement sont concentriques, et la vitesse d'écoulement et la température sont basses.
- Une grand gamme de cylindres est disponible pour optimaliser les taux de compression et le nombre d'étages.
- Le système de lubrification est sous pression.

Diese Verdichter bieten folgende wesentliche Vorteile:

- Kompakte Bauweise, leichtes Gewicht.
- Horizontal angeordnete Zylinder mit steifem Joch zur Verbindung der gegenüberliegenden Kolben.
- Niedrige Kolbengeschwindigkeiten und Seitenbelastungen, daher lang Lebensdauer der Komponenten.
- Konzentrische Sauge- und Förderventile mit niedrigen Durchsatz-geschwindigkeiten und Temperaturen.
- Große Anzahl von Zylindern zur Erzielung optimaler Druckverhältnisse und Stufenzahlen.
- Druckschmierung.



Cut-away illustration of a typical four stage water cooled compressor

[illegible] 35 mm, 50 mm, 70 mm and 100 mm. Machines can be [illegible] with single or double throw crankshafts, and [illegible] one, two, three or four stages. With the ability to select alternative cylinder sizes for each stage, the flexibility of machine build allows the optimum choice of machine to suit customer service conditions.

Alternative cooling arrangements are available, air or water cylinder and interstage cooling being offered dependant upon machine size. Hand or automatic interstage draining and off loading can be specified and standard or special control systems can be included.

Direct or belt driven compressors can be provided with prime movers to suit operational requirements.

Le compresseur est construit à partir de quatre grandeurs de châssis identifiées par la course du piston — 35 mm, 50 mm, 70 mm et 100 mm. Les machines peuvent être construites avec vilebrequins à course simple ou double et avec un, deux, trois ou quatre étages. Etant donné la possibilité de sélectionner des alternatives de taille et de cylindre pour chaque étage, la souplesse de construction permet d'optimaliser le choix de la machine pour convenir aux conditions de service demandées par le client.

Diverses dispositions sont disponsibles pour le refroidissement, et en fonction de la taille de la machine nous proposons le refroidissement des cylindres et inter-étages par l'air ou par l'eau. Le client peut spécifier la vidange et le délestage inter-étages manuels ou automatiques et des systèmes de commande standards ou spéciaux peuvent être inclus.

Nous pouvons fournir des compresseurs entrainés directement ou par courroies, avec des générateurs de force motrice convenant à des exigences opérationnelles spécifiques.

Der Kompressor besteht aus vier Grundrahmengrößen, die durch den Kolbenhub 35, 50, 70 und 100 mm gekennziechnet sind. Die Kompressoren können mit Einzel- und Doppelkurbelwelle mit einer, zwei, drei oder vier Stufen ausgeführt werden. Durch die Wahl anderer Zylinder und Größen je Stufe sind die Maschinen flexibel und gewährleisten eine optimale Selektion unter Berücksichigung der Einsatzbedingungen des Kunden.

Alternative Kühlsysterne werden offeriert, wobei Luft- oder Wasser-kühlung der Zylinder und der Zwischenkühler angeboten werden in Abhängigkeit der Verdichtergröße. Hand - oder automatische Zwischenstufen - Entwässerung und Entlastung können spezifiziert werden. Ebenfalls können Standard- oder Sonder- überwachungs- und Alarmsysteme vorgesehen werden

Der Antrieb [illegible] mit direkt gekuppelten Motoren oder über [illegible] Riemenantriebe entsprechend

Steel, aluminium and copper production
Rolling mills
Aerospace production and servicing
Plastic moulding
Mining
Gas [illegible]
[illegible] separation
Gas boosting
[illegible]
[illegible]

Power generation [illegible]

Diesel [illegible]
Air [illegible]
Hydroelectric

Oil exploration and [illegible]

Seismic survey
Anchor tensioning
Breathing [illegible]

General Marine

General service
[illegible]
Breathing [illegible]
Control instruments [illegible]
[illegible] services

Les applications comprennent:-

Application industrielle générale:

Production de l'acier, de l'aluminium et du cuivre
Laminoirs, Production aérospatiale et entretien
Formage des plastiques et caoutchoucs
Moulage des bouteilles
Démarrage des turbines à gaz
Séparation de l'air, Surcompression du gaz
Installations de recherche et d'essai
Air de respiration, lutte contre l'incendie et plongée

Production et distribution de l'énergie électrique:

Démarrage des moteurs diesel
Appareillages de commutation de soufflerie
Hydroélectricité

Exploration et exploitation du pétrole:

Etudes sismiques, Tension des ancres de marine
Air de respiration

Applications maritimes générales:

[illegible] général, Démarrage des moteurs
Air de respiration
Alimentation des instruments de commande
Services de [illegible]

Mögliche Anwendungen

Allgemeine [illegible]

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
Forschungs- und Prüfungsanlagen
Atemluft bei der Brandbekämpfung und [illegible]
Tauchen

Stromerzeugung und -verteilung:

Starten von Dieselmotoren
Luftdruck-Leistungsschalter, Wasserkraft

Ölsuche und -förderung vor der Küste

Seismische Untersuchungen
Ankerspannung, Atemluft

Allgemeiner Schiffbau

Arbeitsluft auf Schiffe[illegible]
Anlaßluft für Diesel[illegible]
Steuer- und [illegible]

[illegible] shown for maximum speeds

35 mm series	2500 rpm
50 mm series	2000 rpm
70 mm series	1800 rpm
100 mm series	1500 rpm

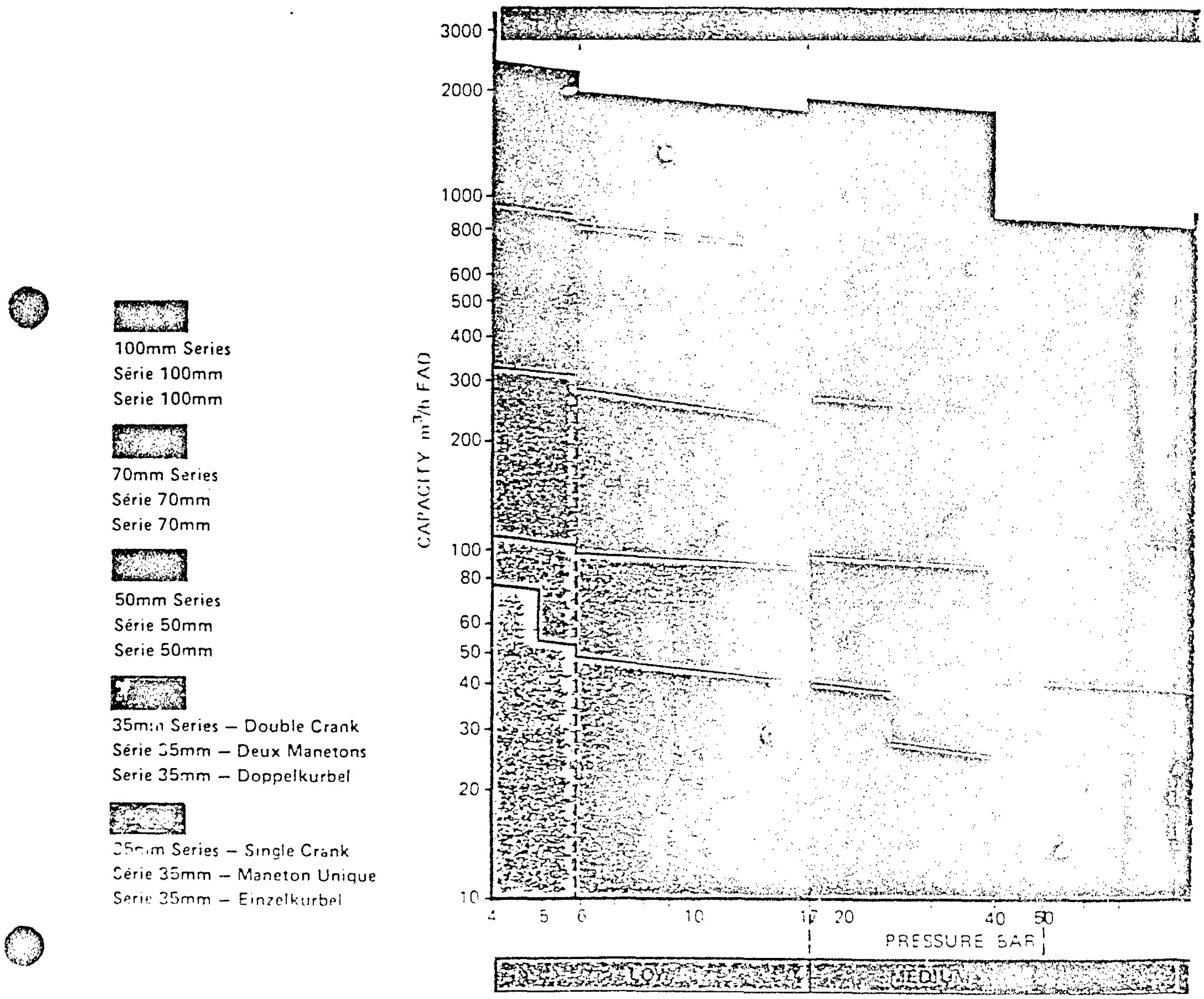
Alternative maximum speeds may be applicable dependent upon the application and this chart should be used as a [illegible] alternative [illegible] selection [illegible] meet particular requirements [illegible] our Sales Office.

TABLEAU DE SÉLECTION

Ce tableau de sélection correspond a des vitesses maximales de:

série 35 mm	2500 t/mn
série 50 mm	2000 t/mn
série 70 mm	1800 t/mn
série 100 mm	1500 t/mn

D'autres vitesses maximales peuvent être obtenues en fonction de l'application et le tableau ci-dessus ne doit être utilisé qu'à titre d'information. Nous mettons à la disposition du client d'autres possibilités de sélection de la construction de la machine pour répondre à des impératifs particuliers. Pour tous conseils veuillez contacter notre Service Commercial.

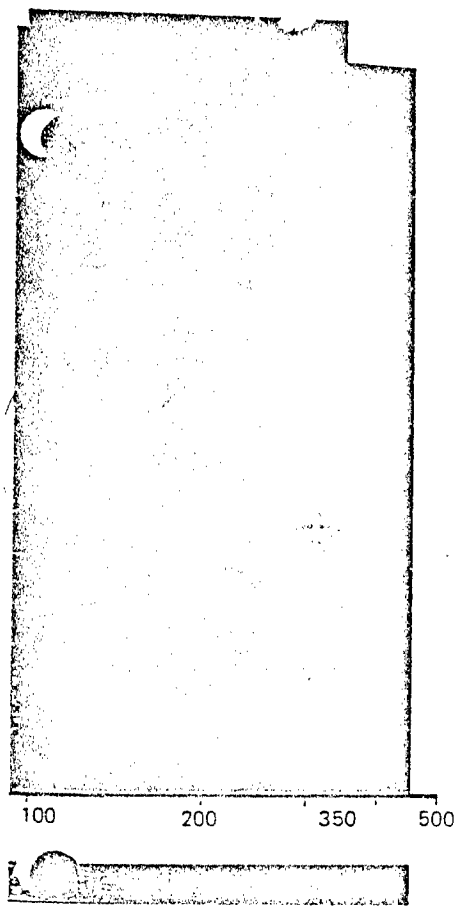


Die Auswahltabelle gilt für Höchstgeschwindigkeiten von:

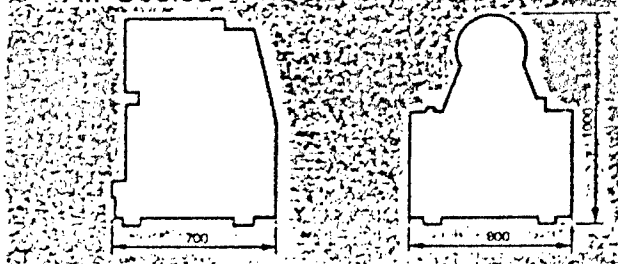
Serie 35 mm	2500 U/min.
Serie 50 mm	2000 U/min.
Serie 70 mm	1800 U/min.
Serie 100 mm	1500 U/min.

Alternative Höchstgeschwindigkeiten können bei bestimmten Einsätzen Anwendung finden. Daher dient diese Tabelle nur der Übersicht.

Weitere Maschinenausführungen sind für bestimmte Einsatzbedingungen lieferbar. Unsere Verkaufsabteilung berät Sie bei der Auswahl sehr gerne.

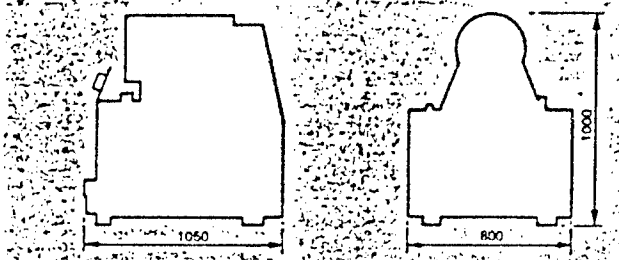


35 mm Single Crank — Belt Driven — Air Cooled



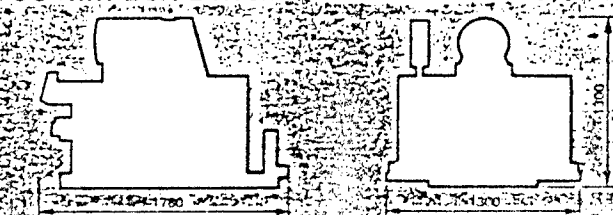
Typical Weight 220 kg

35 mm Double Crank — Belt Driven — Air Cooled



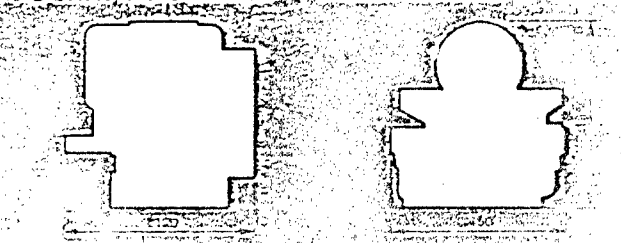
Typical Weight 350 kg

50 mm Belt Driven — Air Cooled



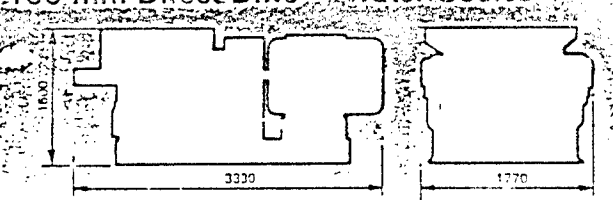
Typical Weight 900 kg

70 mm Belt Driven — Water Cooled



Typical Weight 2700 kg

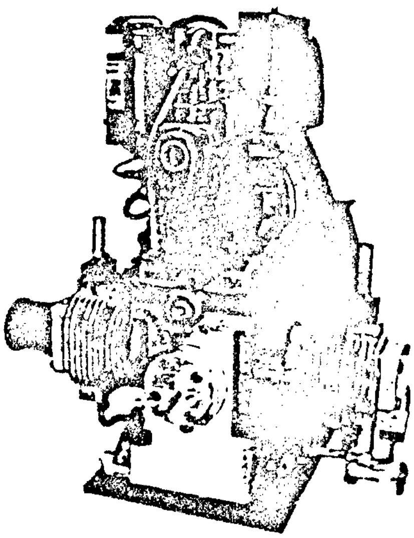
100 mm Direct Drive — Water Cooled



Typical Weight 4900 kg

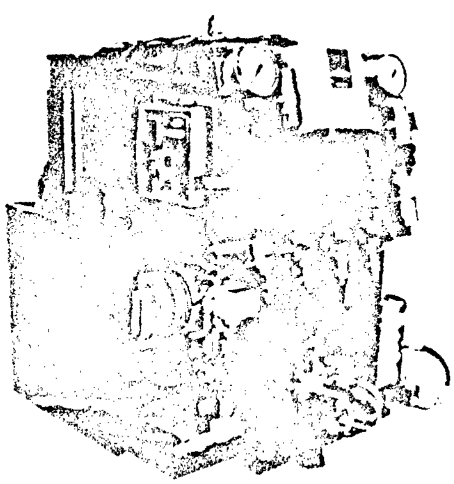
DIMENSIONS IN MILLIMETRES

THE HAMWORTHY RANGE



SERIE 3E (m) ... MANETON UNIQUE

SERIE 3E (m) ... EINZELKURBE



SERIE 3 ... DEUX MANETONS

SERIE 3E (m) ... ZWEIKURBE

Trockensumpf-Druckschmierung, luftgekühlten Zylindern

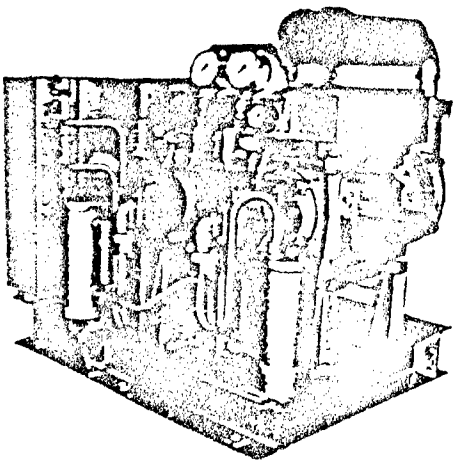
50 mm SERIES

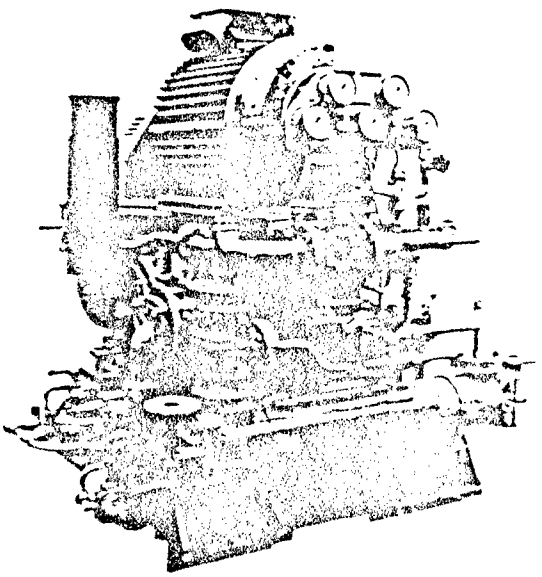
SERIE 50 mm

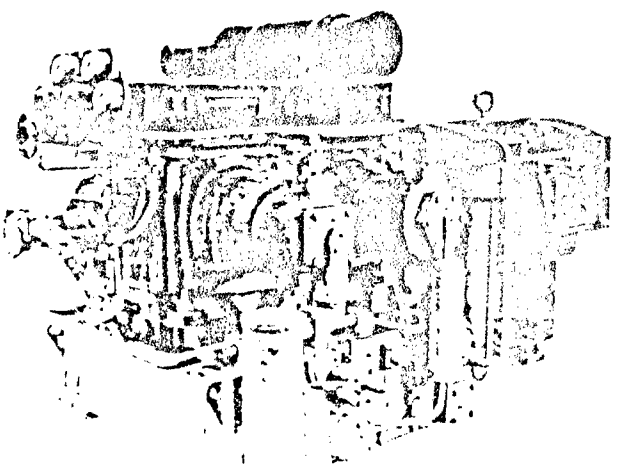
SERIE 50 mm

SERIE 70 mm

SERIE 100 mm







Hamworthy, is a modern industrial complex with one of the most up-to-date factories in the U.K. From the design stage using C.A.D. to computer controlled machining and extensive quality control facilities, a very high standard of product is maintained.

The Pump and Compressor division was the first company in the world to be awarded Lloyds Certification for self-administered quality procedures.

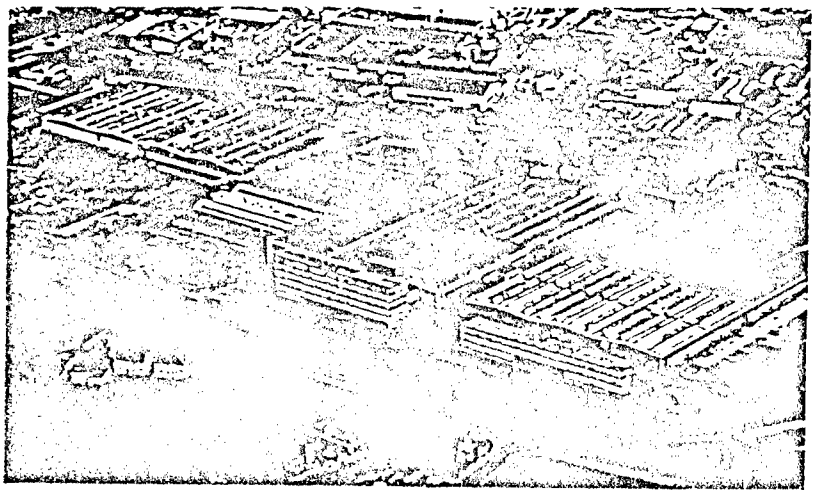
DES INSTALLATIONS MODERNES

Hamworthy est un complexe industriel moderne avec l'une des usines les plus perfectionnées de Grande-Bretagne. Les très hautes normes de qualité des produits sont maintenues depuis le stade de la conception avec l'utilisation des techniques C.A.O. jusqu'à l'usinage contrôlé par ordinateur et les moyens extensifs de contrôle de la qualité.

La Divison Pompes et Compresseurs a été la première société au monde à recevoir l'Homologation Lloyds pour l'auto-administration de ses méthodes de contrôle de la qualité.

MODERNE ANLAGEN

Hamworthy ist ein moderner Industrie-komplex mit einem der fortschrittlich-[illegible]



WORLD WIDE SALES AND SERVICE

A network of company offices and agents is available world wide for on the spot sales and service.

With our close connection with the marine industry where immediate availability of spare parts is vital our organisation is second to none.

Parts can be supplied to almost anywhere in the world within 24 hours.

UN RÉSEAU MONDIAL POUR LES VENTES ET L'ENTRETIEN

Un réseau de sociétes, bureaux et agents est disponible dans le monde entier pour la vente et l'entretien sur place.

Grâce à notre collaboration étroite avec l'industrie maritime depuis de nombreuses années, notre organisation des pièces de rechange peut satisfaire des demandes urgentes en quelques heures.

La puissance de Hamworthy se trouve aussi reflétée par sa société parente Powell Duffryn plc qui est une société holding industrielle avec des filiales travaillant dans les domaines de l'ingenierie, de la distribution et des transports, en particulier en relation avec les industries de l'energie, navales, chimiques et de la construction.

WELTWEITE VERTRETUNGEN UND KUNDENDIENST

Fur Varkauf und Kundendienst steht ein weltweites Vertriebs- und Kundendienstnetz zur Verfugung.

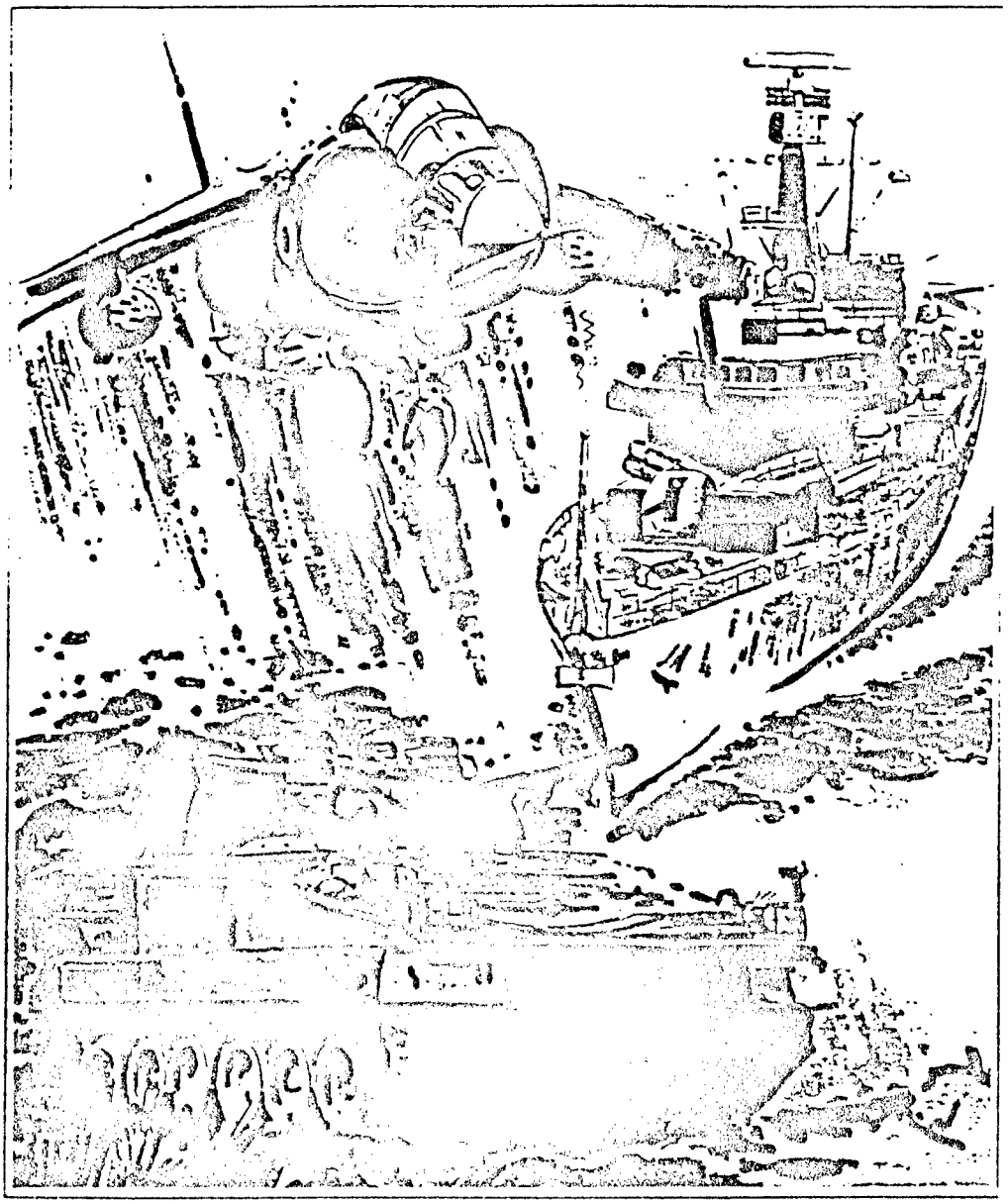
Durch unsere langjahrigen, engen Verbindungen zum Schiffbau kann die Ersatzteil-Abteilung dringend benotigte Ersatzteile innerhalb von Stunden ausliefern.

Hamworthy arbeitet mit Unterstutzung der Muttergesellschaft, der Firma Powell Duffryn plc, einer Dachorganisation mit Tochtergesellschaften im Maschinenbau, Vertrieb und Transportwesen, besonders jedoch in Verbindung mit der Energieerzeugung, Schiffahrt, der chemischen Industrie und dem Baugewerbe.

HAMWORTHY ENGINEERING

HAMWORTHY ENGINEERING LIMITED
PUMP & COMPRESSOR DIVISION
POOLE [illegible] ENGLAND

HAMWORTHY DEFENCE EQUIPMENT



HAMWORTHY ENGINEERING

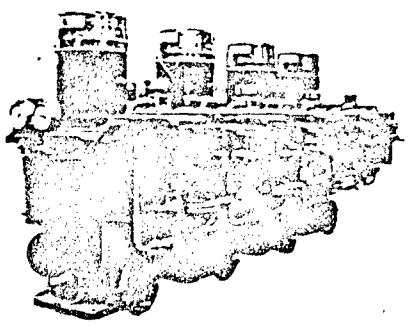
HAMWORTHY

DEFENCE EQUIPMENT

The Pump and Compressor Division of Hamworthy Engineering Limited, a member of the Powell Duffryn Group of Companies, designs, manufactures and markets a comprehensive range of products including, horizontal and vertical centrifugal and positive displacement pumps, air compressors, packaged sewage treatment plant and incinerators for liquid and solid waste disposal.

This leaflet serves to describe briefly some of the Division's products which are increasingly being specified for Defence applications.

BULK FUEL STORAGE



The popular range of Dolphin vertical centrifugal pumps is used extensively for bulk storage and transfer by all three defence services.

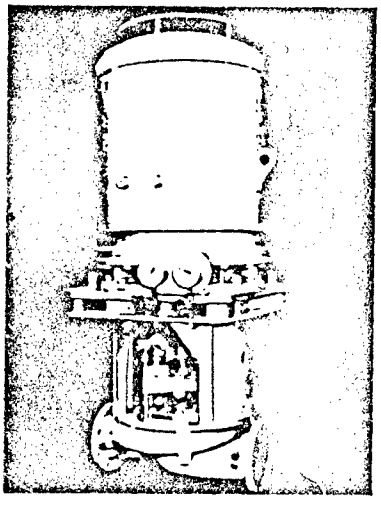
The pumps shown above are for air base fuel systems and are typical of the many units supplied for various outputs up to 200 m^3/h at 9.8 bar.

Other Dolphin pumps are operating in Ministry of Defence fuel storage depots for the off-loading and dispensing of high distilate fuels.

For underground storage installa-lations Hamworthy can supply multi stage centrifugal deepwell pumps, specially constructed in materials to suit specific applications and duties

Hamworthy positive displacement pumps of the twin and triple screw type are used for dockyard applications for medium and heavy fuel oil transfer duties.

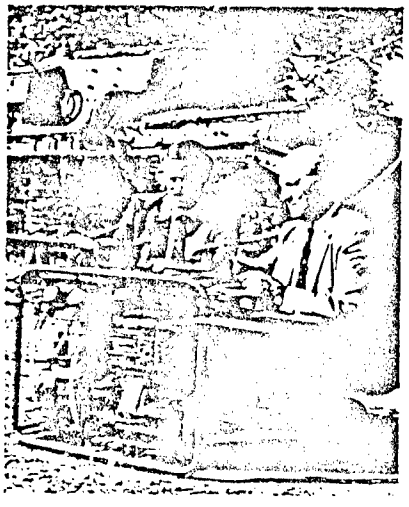
NAVAL PUMPS



Mid mounted Dolphin centrifugal pumps designed to withstand Grade 1 shock conditions during operation are used extensively in all types of naval vessels for supplying salt and fresh water services at medium and high pressures.

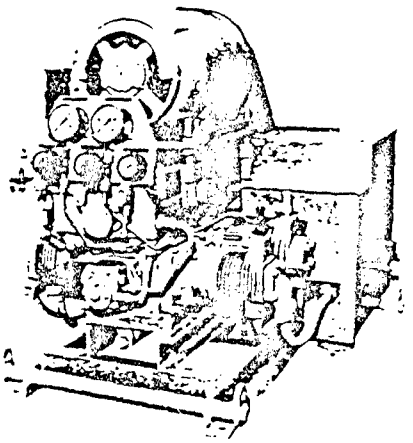
The success of these pumps for both commercial and fighting vessels has been due to the basic design concepts of wide performance range, installation flexibility, and accessibility for maintenance. The wide performance coverage of Dolphin pumps is obtained with a minimum of frame sizes, each size being available with a number of impellers so that any desired output may be met at optimum efficiency, even in severe operating conditions. Both centrifugal and positive displacement tank mounted pumps are supplied for lubricating oil duties.

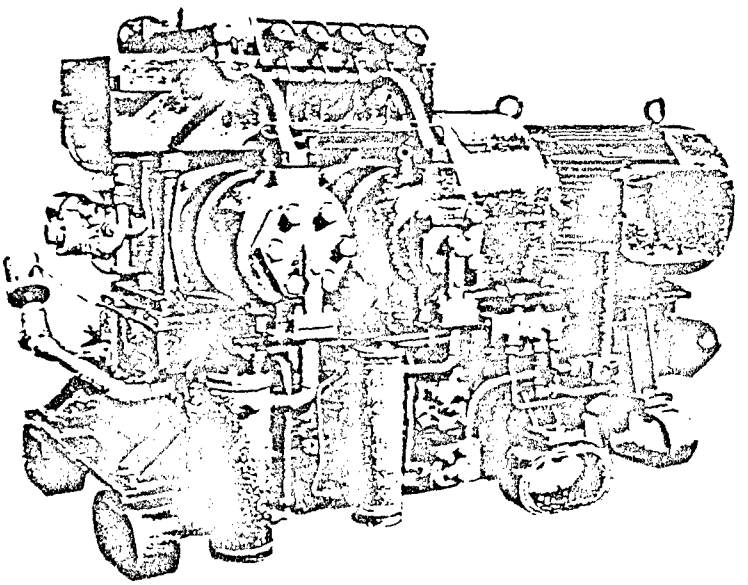
PORTABLE PUMP SETS



Specially designed to handle light distillate fuel or water in the field of military operations where quick effective fuelling of vehicles, tanks and aircraft requires support equipment to be robust, lightweight and portable. Water pumps are constructed in high quality stainless steel for safe handling of clean or brackish water for treatment with portable field purification equip-ment. Distillate fuel pumps are constructed in high grade aluminium. All portable pumps in the Hamworthy range are self priming and have capacities up to 680 litres per minute (150 gallons per minute) at heads up to 45 metres (150 feet). Their ability to prime automatically, even with entrained vapour, ensures immediate response to operators demand for fuel or water services.

COMPRESSORS





The Hamworthy range of air compressors is being extensively specified for a variety of defence requirements.

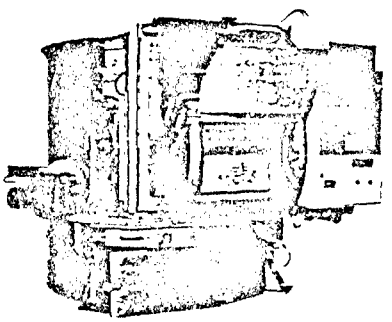
These machines have been approved and supplied for high pressure air systems on warships and are inherently shockproof.

Breathing air packages are based on the 35 and 50mm series high pressure horizontal compressors. The flexibility of design allows optimum compressor selection and when used with the Hamworthy charging panel provides clean air at high pressure for breathing air duties.

The 70mm and 100mm machines are available for larger capacities and are widely approved for dockyard services and specialised applications such as salvage duties, seismic survey work, image enhancement equipment and missile guidance systems.

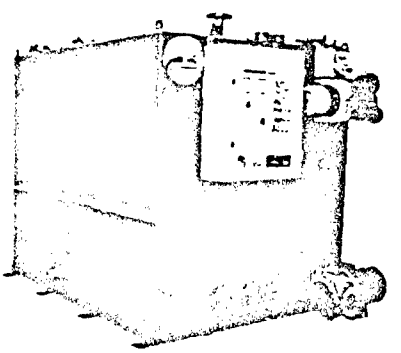
Direct or belt driven compressors can be provided with prime movers to suit operational requirements.

INCINERATORS



A cyclone tank incinerator complements the sewage treatment tank and provides a clean safe method of disposing of oil waste, sludge and solid garbage. The long residence of the combustion products within the unit produces a clean exhaust with minimal solids

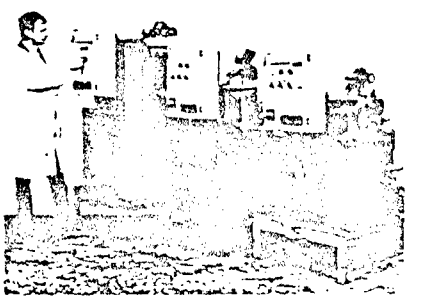
SEWAGE UNITS



As the world's largest supplier of marine waste treatment systems, Hamworthy is uniquely equipped to provide efficient and well designed units for use in naval vessels and shore depots.

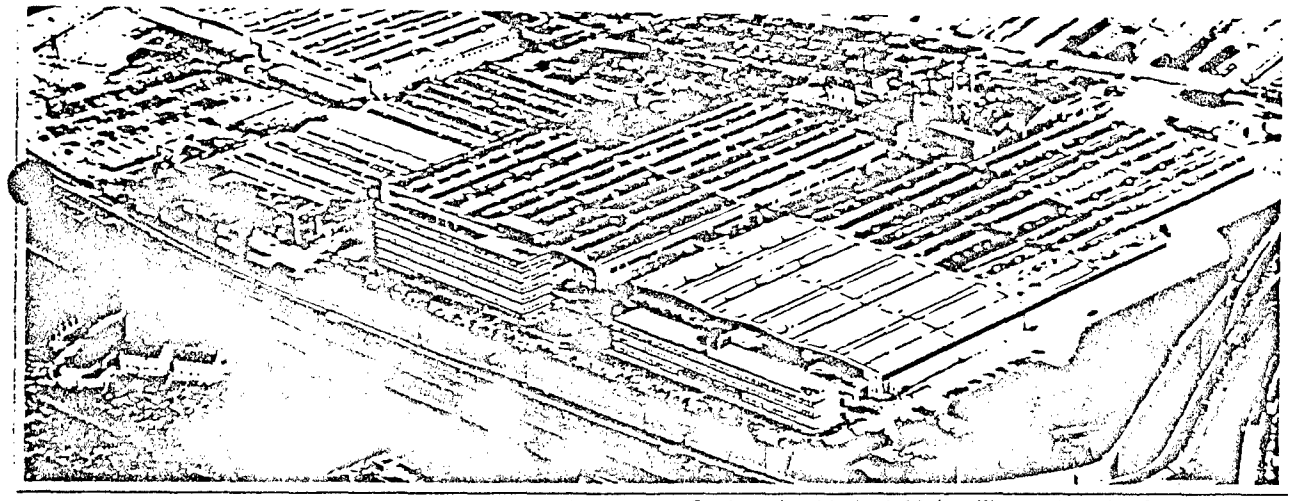
The Hamworthy Super Trident sewage unit operates on the extended aeration principle which

OILY WATER SEPARATORS



International legislation on the discharge of oil has boosted the development of oily water separator systems.

The Hamworthy unit is available in three sizes with capacities up to 5 tonnes per hour. All units are fully automatic with fail safe devices and the system does not require the use of filters and their



Hamworthy Engineering Limited. Main office and works, Poole, England.

The Hamworthy Organisation

Since its establishment in 1914, Hamworthy Engineering Limited has steadily expanded its engineering activities to become a highly successful international company. Today, its Pump and Compressor Division manufactures a wide range of centrifugal and positive displacement pumps, air compressors and marine pollution control equipment.

Advanced technical and manufacturing facilities, including a modern Foundry, all based at Poole on the South Coast of England, combine to provide first class engineering, renowned the world over. Modern techniques include electronic processing of design parameters and extensive use of computer programmed machine tools. These factors, coupled with stringent quality control have qualified Hamworthy for the distinction of becoming the first company in the world to receive quality assurance certification by Lloyds Register of Shipping, thus entrusting it with the issue of Lloyds Certificates for its full range of pump and compressor products. More recently the company has been registered under the National Accreditation scheme to BS 5750 Part 1 and NATO Quality Standard AQAP1, and is therefore able to accept orders under both British and NATO quality standards.

THE HAMWORTHY U.K. AND OVERSEAS ORGANISATION

Overseas Offices and Associate Companies

Australia:	Hamworthy Engineering Australia Pty. Ltd., Unit C, P.O. Box 475, Baulkham Hills, N.S.W. 2153.
Brazil	Tridente Industria E Comercio De Equipamentos Navais Ltda., Rio Branco N° 4-4°, andar-gr. 407/8/9 Rio de Janeiro/RJ-CEP 20000.
Canada:	Hamworthy Canada Ltd., 113-115 Cushman Road, St. Catharines, Ontario.
Denmark:	Hamworthy Engineering Ltd., Copenhagen Office, Fuglebaekvej 3, 2700 Kastrup
Holland:	Hamworthy Engineering Ltd., Benelux Office, Post Box 129, 3000AC Rotterdam.
Japan:	Japan Hamworthy & Company Ltd., 4-26, 2-Chome, Fukae-Kita, Higashinari-Ku, Osaka 537.
Norway:	Hamworthy Engineering Ltd., Oslo Office, Stromsveien 312, N-108. Leirdal, Oslo 10.
Singapore:	Hamworthy Engineering Ltd., 57 Shipyard Road, Singapore 2262.
South Africa:	Hamworthy Engineering Africa (Pty.) Ltd., P.O. Box 34, Cape Town.
U.S.A:	Hamworthy U.S.A. Inc., 10555 Lake Forest Blvd., Suite 1F, New Orleans, LA. 70127.

U.K. Offices

London:	Creechurch House, Creechurch Lane, London EC3A 5DJ.
Newcastle:	5th Floor Collingwood Buildings, Collingwood Street, Newcastle upon Tyne NE1 1JF.
Glasgow:	11 Sandyford Place, Charing Cross, Glasgow G3 7NB.

AND AGENTS THROUGHOUT THE WORLD

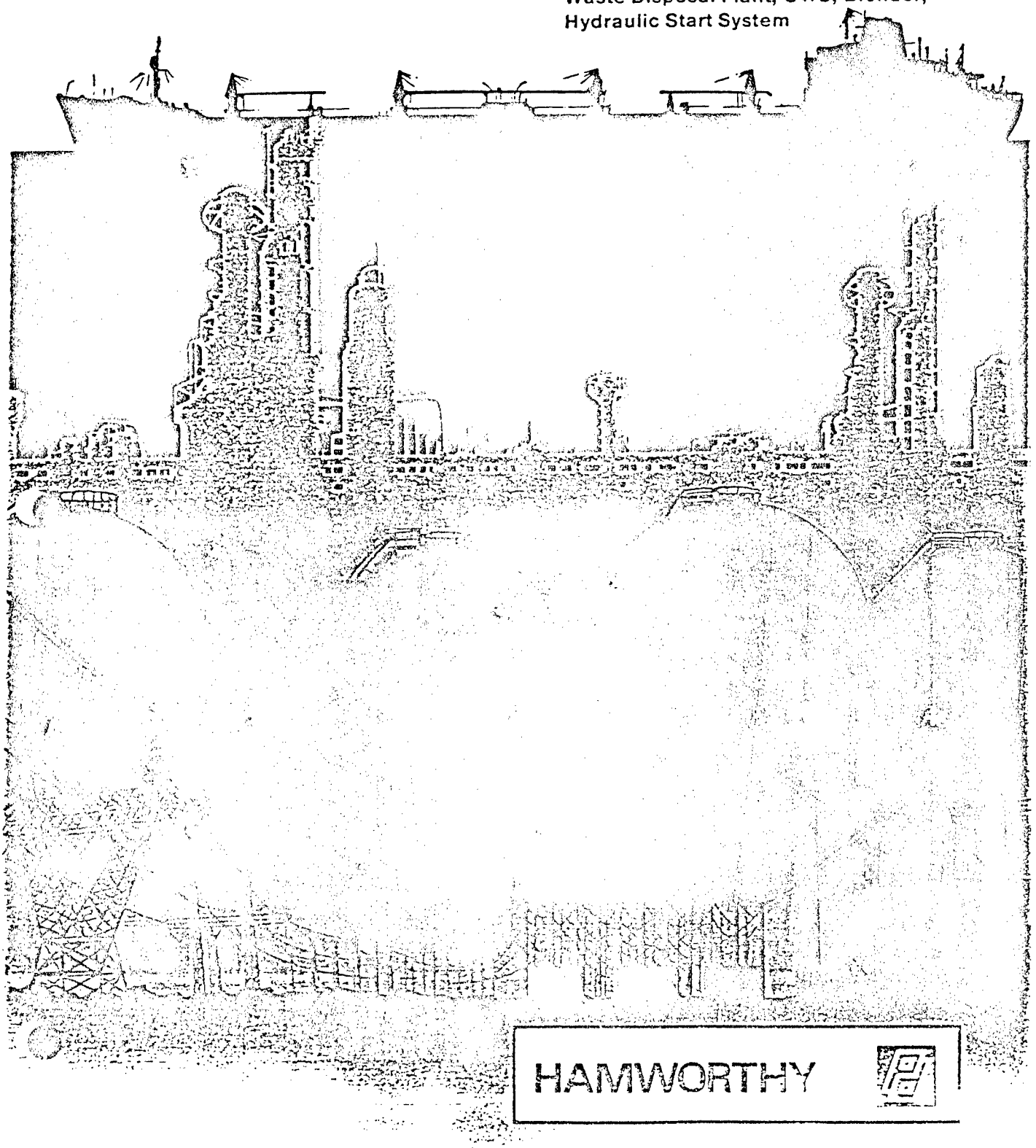
HAMWORTHY

HAMWORTHY ENGINEERING LIMITED
PUMP AND COMPRESSOR DIVISION
FLEETS CORNER, POOLE, DORSET BH17 7LA ENGLAND.
TEL: 0202 675123 TELEX: 41348 (HAMPAC G)

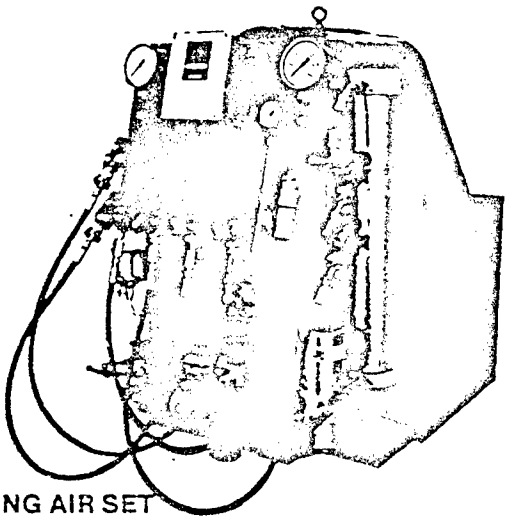
Hamworthy Engineering Ltd. is an international organisation with companies, offices and agents throughout [illegible]

Hamworthy USA, Inc.

Pumps, Compressors,
Waste Disposal Plant, OWS, Blender,
Hydraulic Start System



Air and Gas Compressors



BREATHING AIR SET

Air Quality

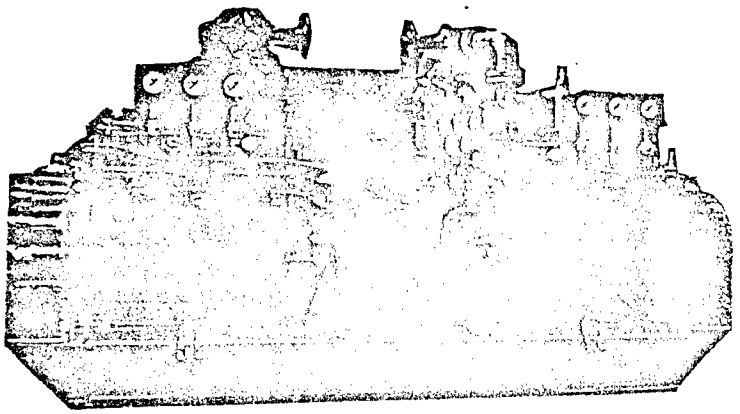
The air purification system supplied with the compressor and charging panel ensures that any impurities originating from the compressor or contained in the air drawn in are removed, and high purity air only can pass into the bottles. The 5 stage purification filter fitted includes a carbon monoxide conversion stage, and a visual saturation indicator. Air supplied from the breathing air package meets the requirements of British standard 4275, German standard DIN 3188 and U.S. standard OSHA, as well as other similar specifications.

Capacities: 10-150 cfm
Pressures : 2500-5500 psi

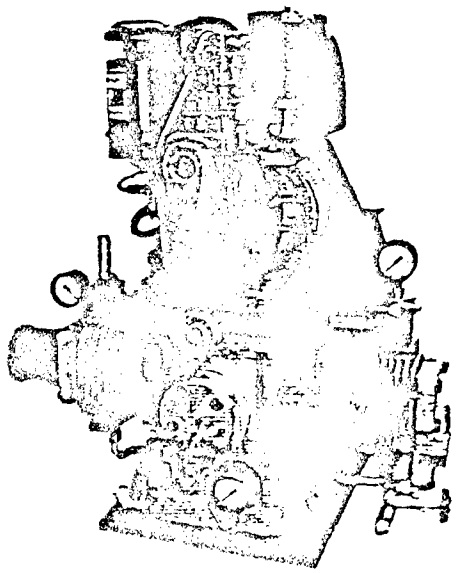
VERTICAL COMPRESSOR RANGE

Developed to meet the modular construction requirements of modern shipyards, Hamworthy compressor modules provide well-engineered, fully tested, compressor systems which simplify shipyard installation and reduce costs. Available for starting/general service/control air duties on motor ships and general service/control air duties on turbine vessels, each module comprises two or three fully automated compressors mounted on a common baseplate.

Capacities: 10-400 cfm
Pressures : 300-600 psi



2MF6 COMPRESSOR MODULE



Emergency Diesel Starting Air Set

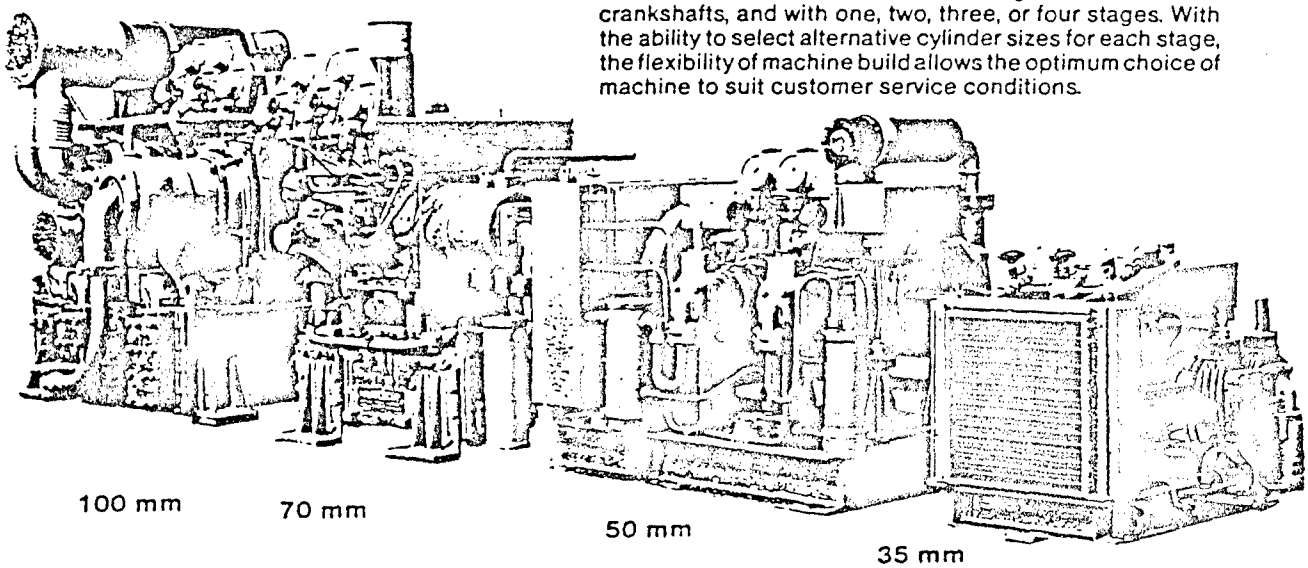
The Hamworthy 35 mm Distair compressor set is a self contained diesel engine driven unit developed primarily for emergency starting air duties. The compressor is a Hamworthy 2SM10A35 two stage air cooled horizontal machine, belt driven by a Hatz single cylinder air cooled diesel engine.

Capacity: 9cfm
Pressure: 435 psi

Air and Gas Compressors

HORIZONTAL COMPRESSOR RANGE
AIR & WATER COOLED
Capacities: 10-1000 cfm
Pressures : 100-6500 psi

This range of advanced machines with a large number of design options to cover low, medium and high pressures is particularly suitable for air, gas, and booster applications. The compressor is built around four basic frame sizes identified by the piston stroke—35mm, 50mm, 70mm and 100mm. Machines can be built with single or double throw crankshafts, and with one, two, three, or four stages. With the ability to select alternative cylinder sizes for each stage, the flexibility of machine build allows the optimum choice of machine to suit customer service conditions.



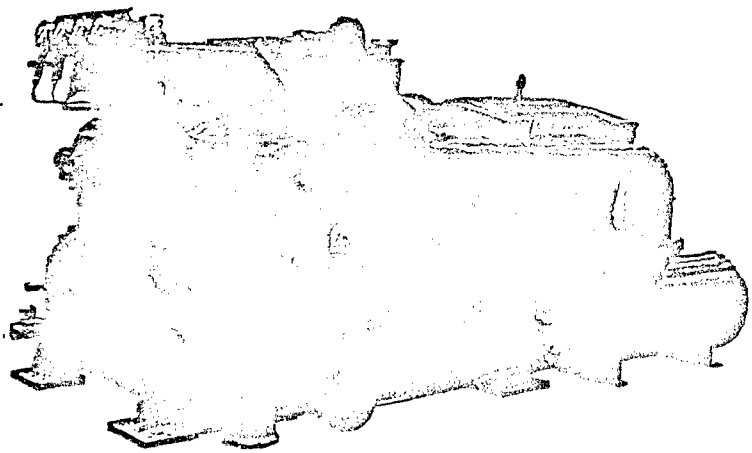
Applications

Hamworthy compressors are particularly well suited to mobile, marine and stationary applications where installation labor and space is at a premium and maintenance free operation of a clean air system is required.

Broad experience in the following areas underscores the versatility of application:

- Starting systems for large gas turbines and diesel engines on marine and stationary installations
- Plastic molding industry
- Human air breathing package (meets O.S.H.A. standards)
- Electric power generation air blast switch gear
- Hydroelectric plants
- Metals production
- Rolling mills
- Aerospace ground support equipment
- Underground mining
- Fire fighting and ocean exploration apparatus
- Seismic survey equipment
- Rig and drill string tensioning equipment
- Dockyard services
- Compressed Natural/Inert Gas
- Laboratory
- Valve testing
- Textile industry

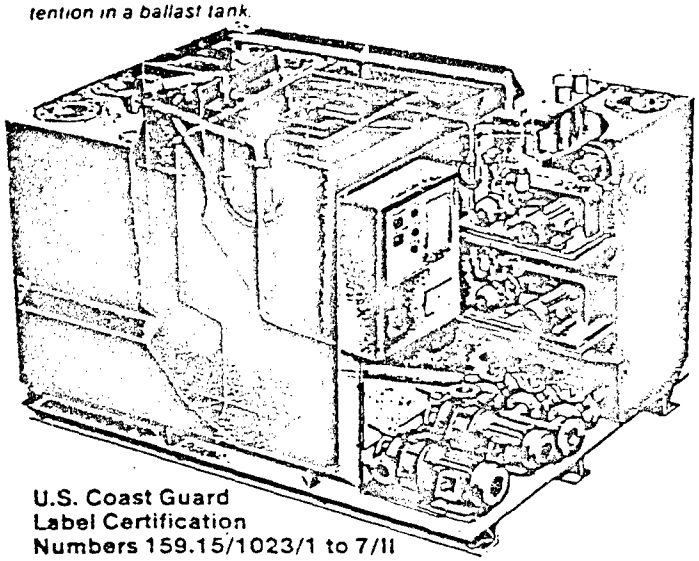
Contact your Hamworthy representative for applica-



Pollution Control Equipment

SEWAGE TREATMENT PLANT

The latest development from Hamworthy, the world's leading manufacturer of marine sewage treatment plants, operates on the extended aeration principle which accelerates natures own biological process to purify the sewage and produce a clean safe effluent suitable for overboard discharge or retention in a ballast tank.



U.S. Coast Guard
Label Certification
Numbers 159.15/1023/1 to 7/11

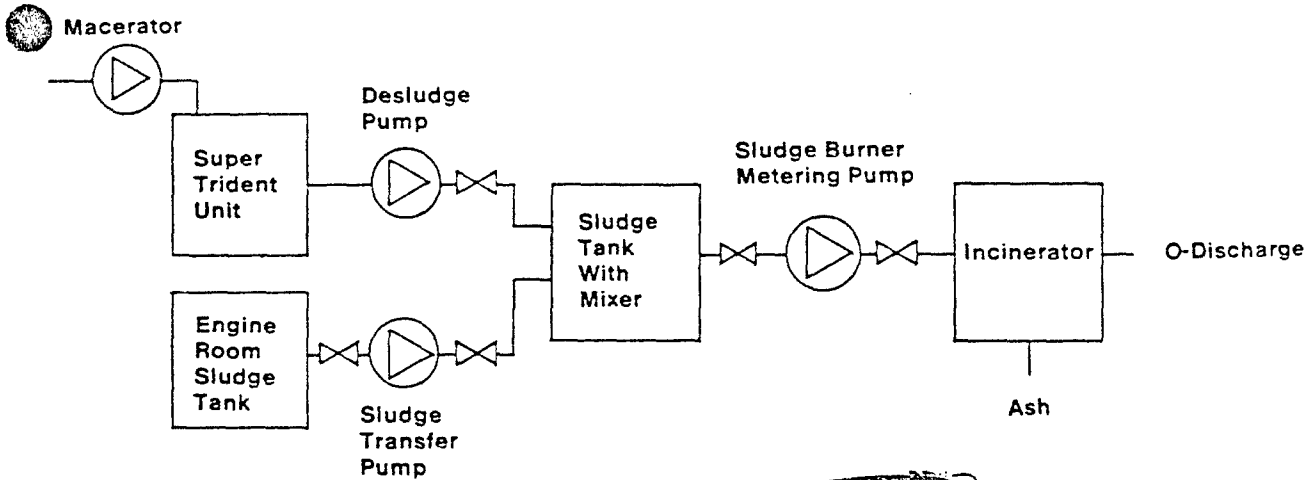
From the World Leaders in Marine Sewage Treatment

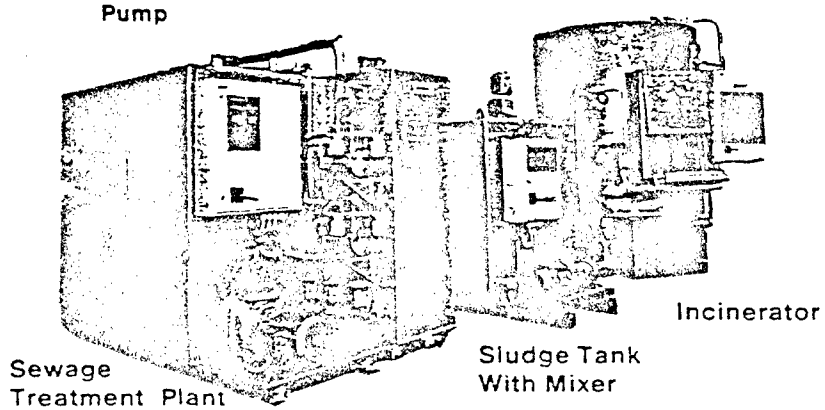
- Developed to meet all existing and anticipated requirements of I.M.O., U.S. Coastguard, Japanese Ministry of Transport, Register of Shipping of the U.S.S.R. and other authorities.
- The product of many years'experience in the design and manufacture of marine sanitation devices.
- Unattended operation, minumum maintenance.
- Compact modular construction, suitable for 'tween deck installation.
- Unaffected by ship's motion.

Effluent quality is better than:

B.O.D_5	-40 mg/l
Suspended solids	-40 mg/l
Coliform	-200/100ml

ZERO DISCHARGE SYSTEM





Pollution Control Equipment

15 PPM - OILY WATER SEPARATOR

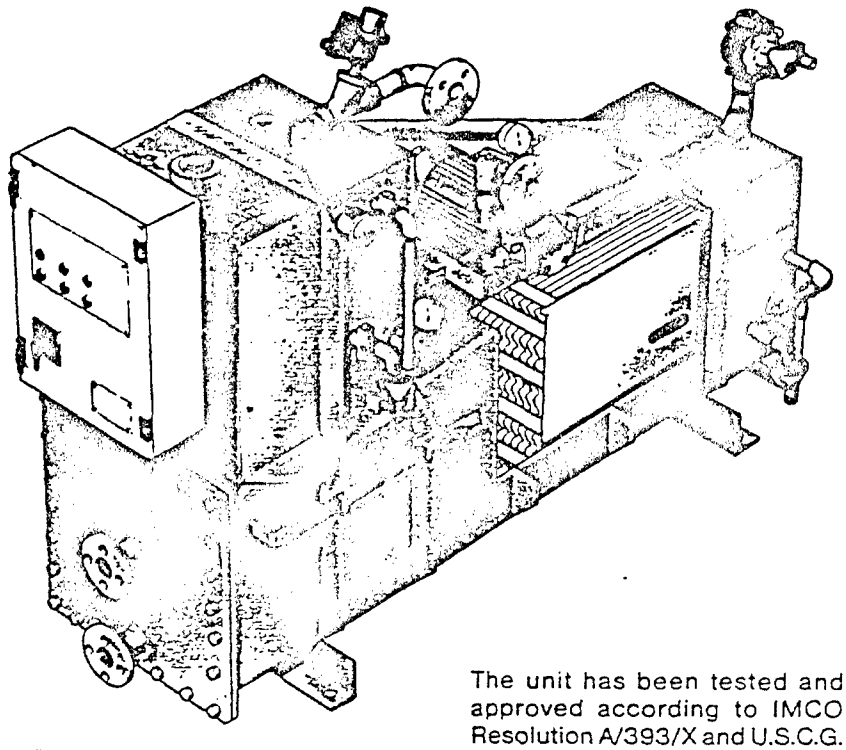
The separating principle is based on the differing specific gravities of oil and water.

The rising velocity of oil globules in water is relative to their diameter, i.e. a 60 micron diameter oil globule will rise 195 microns/sec., where a 30 micron globule will rise 50 microns/sec.

The particular arrangement of the Hamworthy oily water separator reduces the shear on the oil particles and enables a more compact plate pack to be used. This has been designed to produce optimum efficiency for its volume.

Oil globules passing through the pack will make contact and coalesce on the oleophylic plates until the globules are large enough to rise up through the pack.

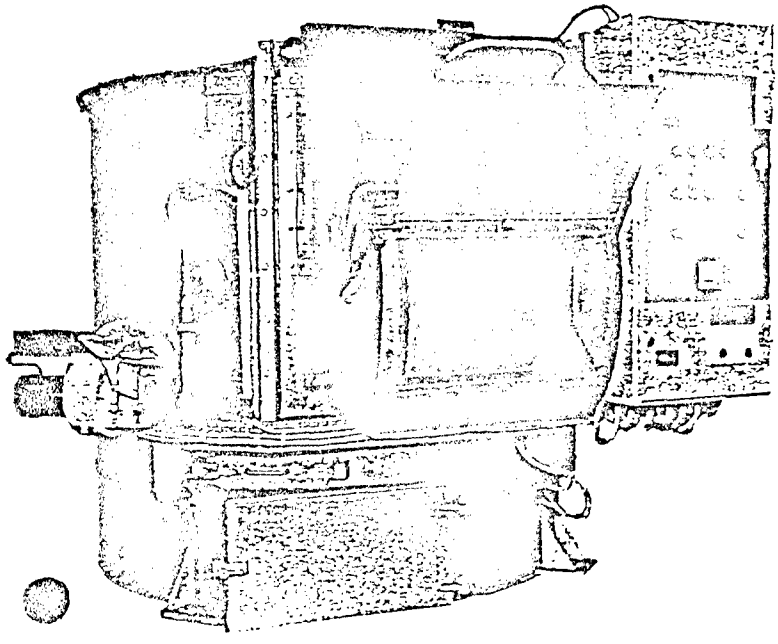
The plate pack configuration also allows solids drawn in with the liquids to gravitate down through the pack, to collect in a sump, thus preventing possible blockages caused by the build up of solid material



3 SIZES: HS 1 - 4.4 gpm
HS 2.5 - 11 gpm
HS 5 - 22 gpm

The unit has been tested and approved according to IMCO Resolution A/393/X and U.S.C.G. certificate Nos. 162.050/1164/5/6/0.

INCINERATOR



The Hamworthy Neptune Incinerator is of the vertical type with a unique rotating arm device to speed up the combustion process and remove ash and non-combustible material.

The specially developed sludge burner will dispose of sludge oil, water and sewage sludge either individually or when mixed together.

An auxiliary oil fired burner is fitted to ignite the refuse and oil sludge and is thermocouple controlled to reduce the fuel consumption to a minimum.

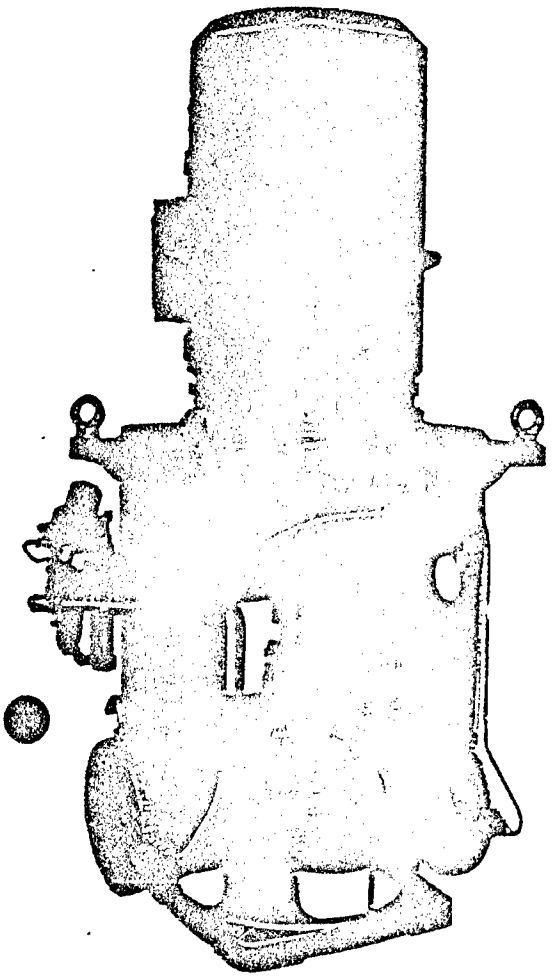
Combustion air is supplied by a forced draught fan which is located below the hearth together with the rotary arm drive mechanism.

The loading door for the refuse is pneumatically operated and is interlocked with the burner and F.D. fan which stop before the door opens and restart when the door closes.

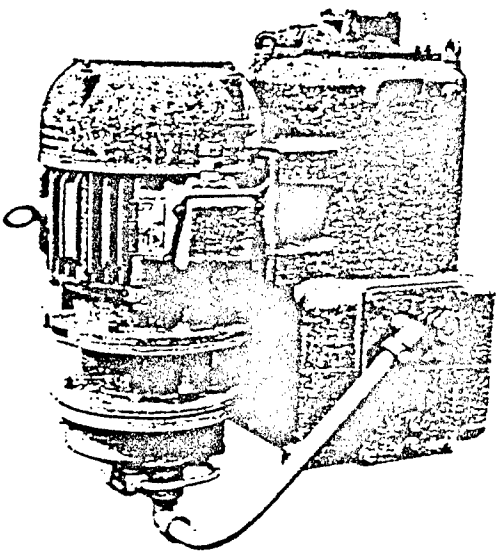
3 sizes: 1,500,000 BTU/hr
2,000,000 BTU/hr
3,000,000 BTU/hr

Pumps

The Hamworthy Dolphin range of pumps have won wide acclaim for their reliability, accessibility and efficiency and are supplied to every shipbuilding and major industrial country throughout the world. Dolphin pumps are ideal for water duties such as cooling, circulating, bilge, fire, transfer and general service. In addition, white oils and light lubricating oils can be handled with ease.
The outstanding features of these pumps are the wide range of outputs, the excellent accessibility permitting a complete strip down by unskilled labor in a matter of minutes, without disturbing the motor and pipes.

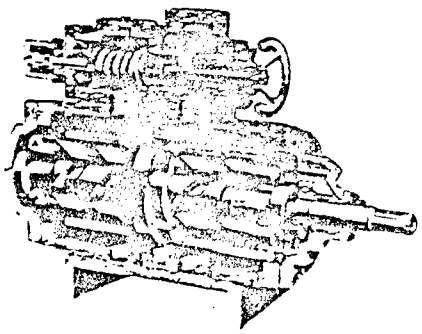


RANGE OF VERTICAL CENTRIFUGAL PUMPS (Single and Double Entry) 72 GPM up to 38,400 GPM with heads of 15 to 350 feet.



LRP 100M MOTOR DRIVEN LIQUID RING PRIMER

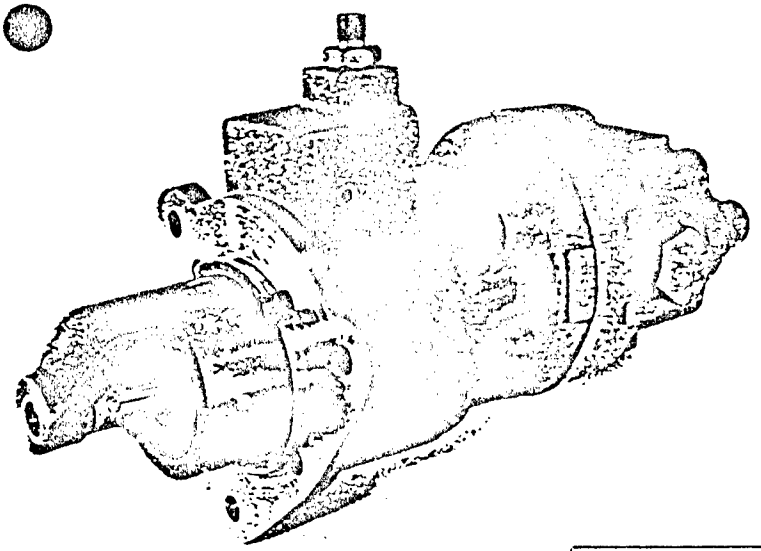
The unit comprises a motor driven liquid ring primer mounted vertically on the side of the air separator. Also available are the LRP 50 smaller capacity, central vacuum systems and air ejectors.



TRIPLE SCREW POSITIVE DISPLACEMENT PUMP

Hamworthy positive displacement pump series are horizontal and vertical triple screw pumps with renewable inserts suitable for handling all liquids having reasonable lubricating properties.

Pre-engage Motor Bendix

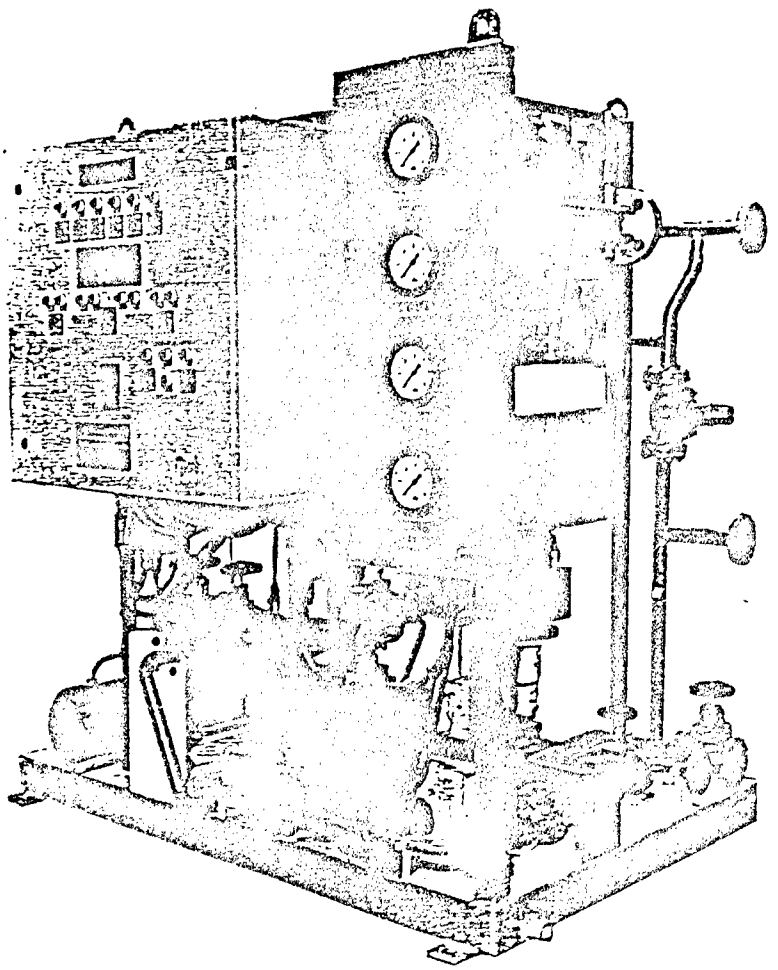


Startorque

- ★ Suitable for use with all engines fitted with a starter ring gear.
- ★ Compact design fits into existing engine starter mounting.
- ★ Simple construction with minimum of moving parts.
- ★ Rugged, to meet demands of multiple starts with large or small engines.
- ★ Simplified installation, can be used as retrofit into existing Startorque systems.

Application

This design which has patent applied for is the culmination of many years experience in engine starting. Used in conjunction with a special pinion-check-valve, the pinion is fully selected before full system pressure and flow are supplied to the motor. A clean engagement and disengagement is ensured to give long trouble-free operation.



HAMWORTHY

SEA STAR

Fuel Oil Supply & Blending Module

The 'Sea Star' is a compact fuel supply unit with pumps, heaters, filters and viscosity meter all in one module. It is equally suitable for the single fuel vessel where blending is not normally required, but is necessary when the quality of fuel falls below engine specification.

The 'Sea Star' has been tried and tested in service with many major operators. And there's the Hamworthy name as your guarantee of quality and service world wide.

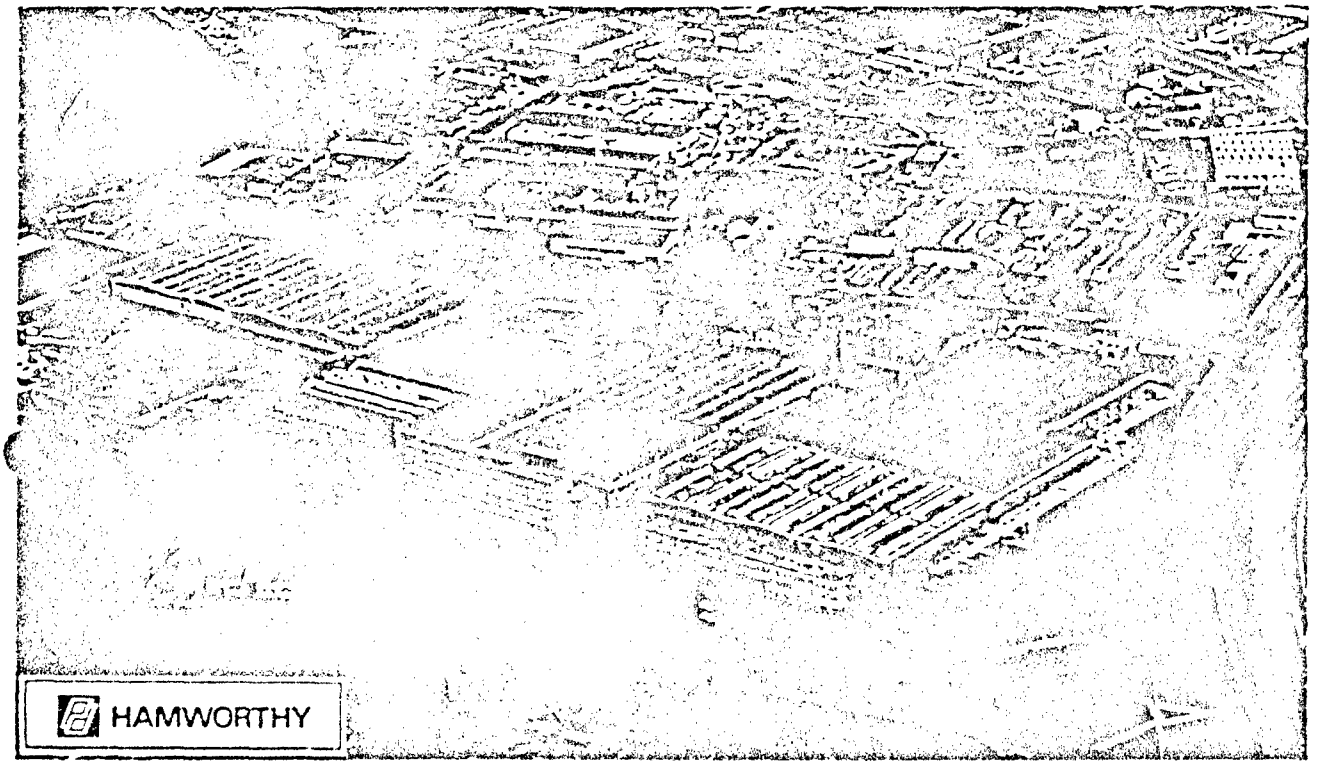
Hamworthy has been an OEM for more than 70 years, manufacturing pumps, compressors, pollution control equipment, hydraulic equipment, valves, and gear boxes.

Hamworthy is a modern industrial complex with one of the most up-to-date factories in the U.K. From the design stage using C.A.D. to computer controlled machining and extensive quality control facilities, a very high standard of product is maintained.

A network of companies, offices and agents is available worldwide for on the spot sales and service.

With our close connection with the marine industry over many years our spares organization is capable of meeting urgent requests in a matter of hours.

The strength of Hamworthy is also underlined by its parent Powell Duffryn plc which is an industrial holding company with subsidiaries engaged in engineering, distribution and transportation, principally related to energy, shipping, chemical and construction industries.



HAMWORTHY USA, INC.

10555 LAKE FOREST BLVD., SUITE IF
NEW ORLEANS, LA 70127

PHONE: (504) 244-9074 TELEX: 85-3884
TELEFAX: (504) 241-5160

ALLIED MARINE SERVICES, INC.
659 S. WASHINGTON STREET
ALEXANDRIA, VIRGINIA 22314 USA

Parent Company - Hamworthy Engineering Limited, Poole, Dorset, England

Subsidiary Companies & Branch Offices - Australia, Brazil, Denmark, Sweden, Finland, France, West Germany, Greece, Norway, Singapore, South Africa, Holland, India, Belgium, Canada

Agents - [illegible] Iraq, Israel, Italy, Kuwait, Libya, Mal[illegible]

INGERSOLL-RAND
AIR COMPRESSORS

Small Air Compressor Division
Ingersoll-Rand Company
6122 Hunt Road
P.O. Box 458
Pleasant Garden, N.C. 27313
(919) 674-3621
FAX: 919-674-2955

Tuesday, November 7th, 1989

Commander
Belvoir RD & E Center
Attn: STRBE-FMT (J. Leary)
Fort Belvoir, Virginia 22060-5606

Subject: MARKET SURVEY (Diving Air Compressor)

Gentlemen:

Upon review of the Army's existing diesel-driven breathing air compressors (as described in PD-4310-0039A, August 16, 1989) and the diving survey detailing the anticipated requirements for a portable system designed to support surface supplied diving equipment and a portable recompression chamber, we are pleased to submit the following for your review and future reference.

Based on the pressure and volume requirements for three divers at 250 feet, which have been detailed on the attached page entitled "I-R Diving Compressor", the compressor must be able to supply a minimum of 222 psig and 155 scfm. The pressure of 222 psi is the sum of 111.3 psia at 250 feet plus the MK12 regulator requirement of 110 psi over bottom pressure.

Pressure and volume requirements for the 236 cubic foot 3-man hyperbaric chamber are 1,180 scf and 74 psig.

We feel that these requirements would best be met by a high pressure, skid-mounted package with the following major components:

1. Ingersoll-Rand Model IR105D Compressor/Purifier complete with an Ingersoll-Rand 6R80-100 compressor block, a 124 horsepower Perkins Model T-6-3544 diesel engine, and an Ingersoll-Rand Model 50LB12 Air Purification System
2. Main Storage Bank consisting of six Model HC 6000 DOT Cylinders
3. Reserve Storage Bank consisting of three Model HC 6000 DOT Cylinders

Diver volume and pressure requirements would be met by the compressor alone to a depth of 132 feet, and for two divers, to a depth of 200 feet. Beyond these limits, the Main Storage Bank would supplement the compressor output as indicated on the attached "Compressor and Main Storage Supply Duration at Depth" chart.

ENCLOSURE 3C PAGES 1-11

Hyperbaric chamber pressure and volume requirements would be met with the Reserve Storage Bank. Under normal circumstances, the compressor would not be required to meet hyperbaric chamber requirements.

The compressor would be utilized to refill depleted storage banks. The time requirement for refilling the depleted Main Storage bank would be a maximum of 27 minutes. The Reserve Storage bank could be refill in 14 minutes or less.

The proposed unit is packaged on a single, self-contained skid measuring 120 inches long, 50 inches wide, and 81 inches high. The approximate weight is 8,000 pounds.

We would be pleased to provide more detail on the above proposal and to provide additional information on other alternate solutions, including a low pressure alternative.

Please respond with your questions and comments.

Sincerely.

Mike Sexton

Mike Sexton
Operations and Business Manager
Breathing Air Products

encl: I-R Diving Compressor Charts
Drawing # 6315
HC 6000 Brochure

cc: R. Stevenson
J-P Riviere
B. Santoli

Attn: Construction, Rails, and Diving Team
Ref: U.S. Army Market Survey

Pressure & Volume Requirements

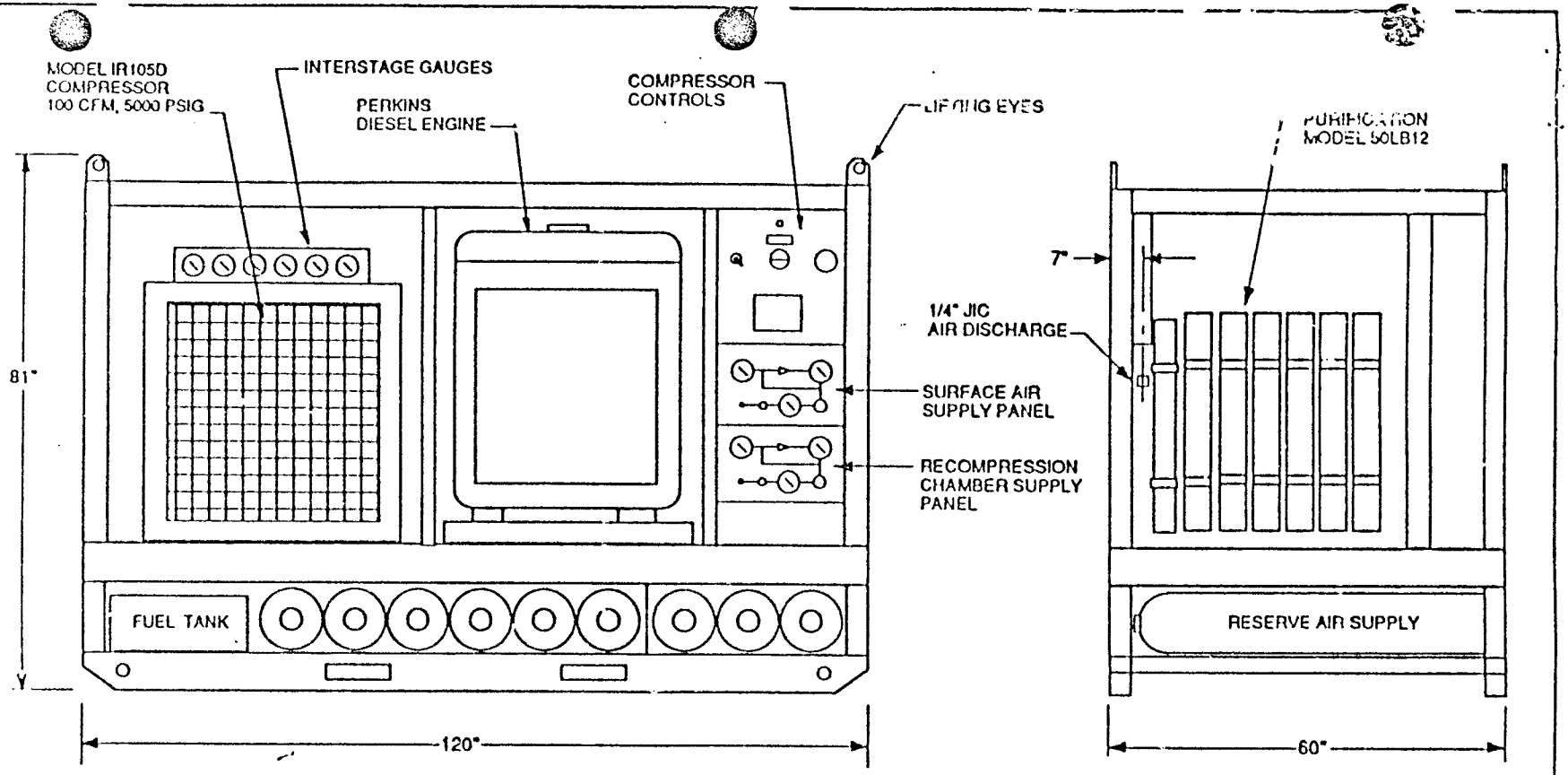
Depth (Feet)	Depth PSIG	PSIG plus 110 psi	SCFM for 1 Man	SCFM for 2 Men	SCFM for 3 Men
33	14.7	124.7	12.0	24.0	36.0
66	29.4	139.4	18.0	36.0	54.0
99	44.1	154.1	24.0	48.0	71.9
132	58.7	168.7	30.0	60.0	89.9
165	73.4	183.4	36.0	71.9	107.9
200	89.0	199.0	42.3	84.7	127.0
250	111.3	221.3	51.4	102.8	154.2

Compressor & Storage Data

Compressor scfm	Compressor Max psig	Main Storage SCF at 5000 psig	Main Storage SCF above 500 psi	Reserve Storage SCF at 5000 psig	Reserve Storage SCF above 500 psi
100	5,000	2,982	2,682	1,491	1,341

Compressor & Main Storage Supply Duration at Depth

Depth (Feet)	Depth PSIG	PSIG plus 110 psi	One Man	Two Men	Three Men
33	14.7	124.7	Continuous	Continuous	Continuous
66	29.4	139.4	Continuous	Continuous	Continuous
99	44.1	154.1	Continuous	Continuous	Continuous
132	58.7	168.7	Continuous	Continuous	Continuous
165	73.4	183.4	Continuous	Continuous	2.8 hours
200	89.0	199.0	Continuous	Continuous	0.8 hours
250	111.3	221.3	Continuous	5.6 hours	0.4 hours



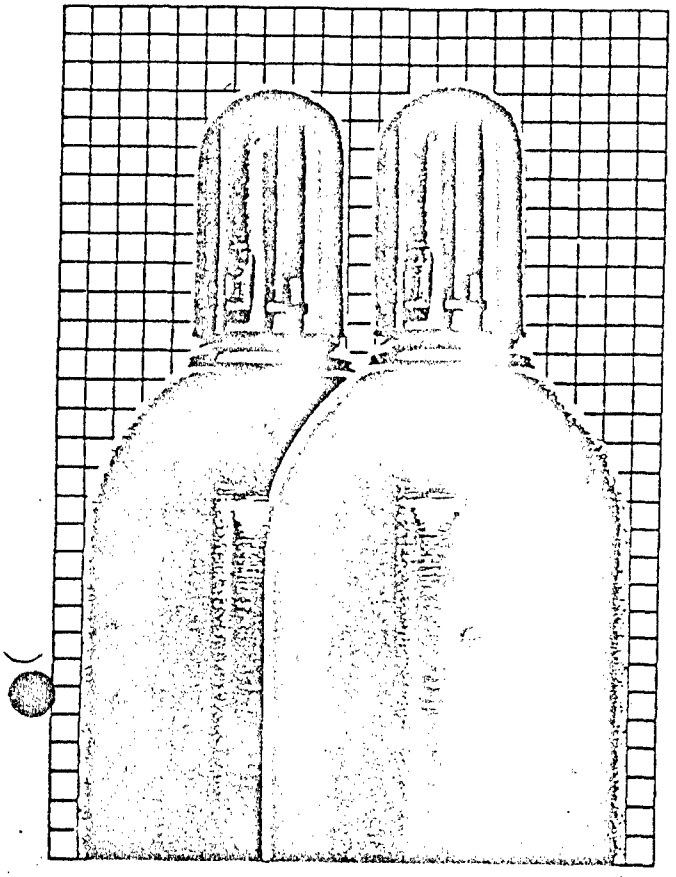
FRONT VIEW

END VIEW

PROPOSAL
11-7-89

REV.A	DOT STORAGE ADDED	11-7-89
INGERSOLL - RAND COMPANY PLEASANT GARDEN, N.C.		
IR105D COMPRESSOR 50LB12 PURIFICATION		
DATE 10/24/89	SCALE	
SHT. 1 OF 1	BY AW	DRW. 6315

LightWeights



HC Series Specifications

	HC 500	HC 6000
DOT classification	DOT-E 9421-4500	DOT-E 9909-6000
Internal diameter	8¾"	8½"
Outside diameter	9 5/16"	9 9/32"
Height	51"	51"
Weight (empty)	144 lbs.	188 lbs.
Service pressure*	4500 psi	6000 psi
Air capacity at service pressure and 70°F (cubic feet)	444	509
Minimum water capacity (cu. inch)	2750	2640
Tapping	¾-14 NGT 24 Threads Oversize	¾-14 NGT
CGA recommended valve outlet for air service	347	702

All dimensions and capacities referenced are nominal.

*Under no circumstances are these cylinders to be filled to a pressure exceeding the marked service at 70°F.

HC 500
HC 6000

The HC-500 and HC-6000 are advanced, computer designed, steel cylinders that lead the industry in weight-to-capacity ratios.

In Air Service the HC-500, with a working pressure of 4500 psi, has 25% more capacity than the typical 3600 psi cylinder. And it weighs only 144 pounds. That's a 23% weight reduction.

The HC-6000 weighs only 188 pounds compared to 300 pounds for a standard D.O.T. 3AA 6000 psi cylinder. A 37% weight reduction while maintaining the 6000 psi working pressure.

DOT cylinders in air service can be used horizontally or vertically in vehicles.

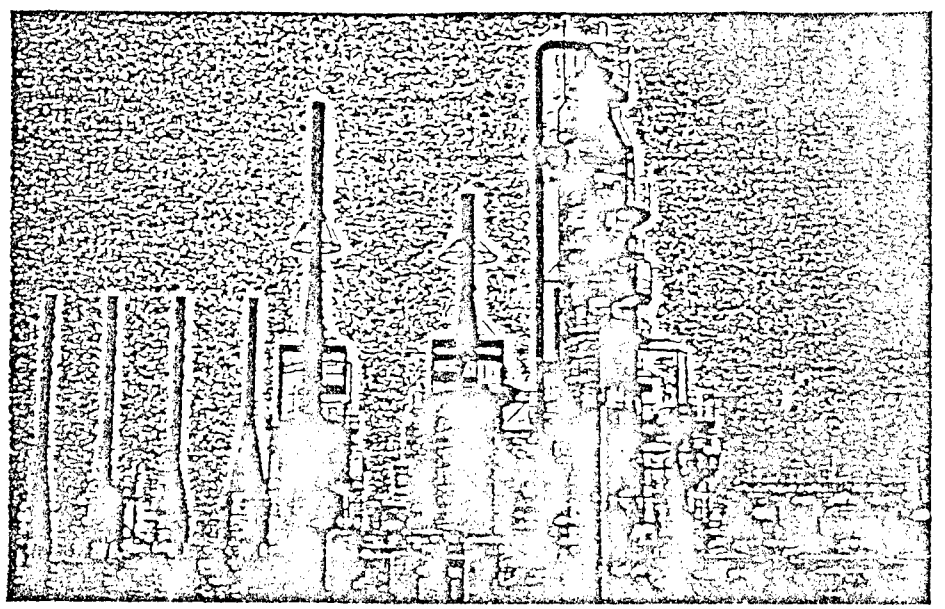
Top Works II, an easier, better, quicker, cap system is supplied as standard equipment.

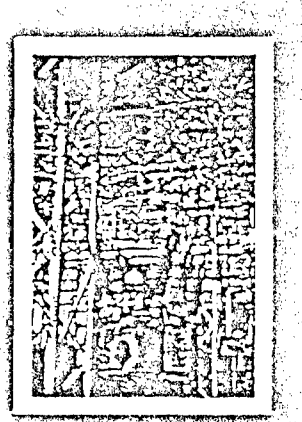
Taylor-Wharton
Harrisburg Operations
P.O. Box 2365
Harrisburg, PA 17105

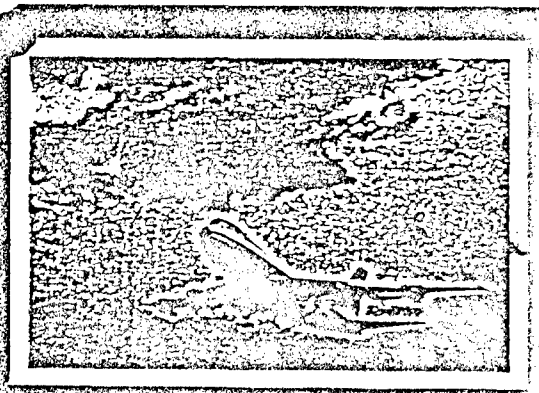
TAYLOR-WHARTON
Division of Plant City Steel-HARSCO Corporation

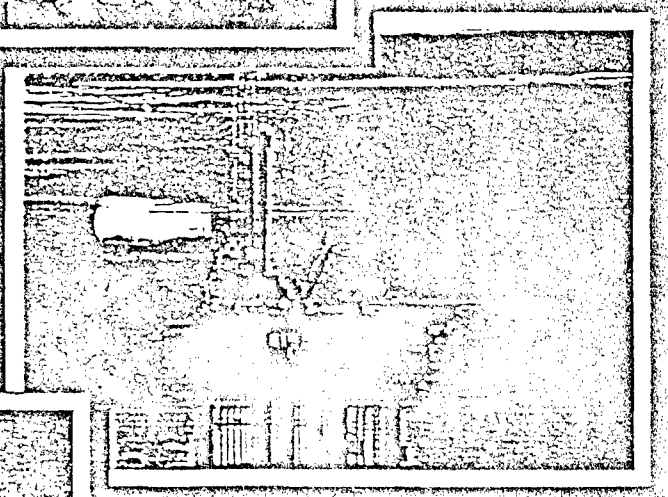
High Pressure Air-Cooled Air Compressors

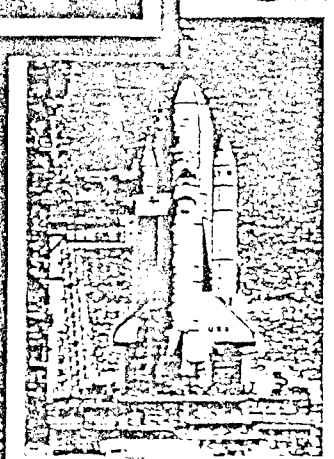
2-100 HP/300-6000 PSIG (21 to 413.7 Bar)











INGERSOLL-RAND

AIR COMPRESSORS

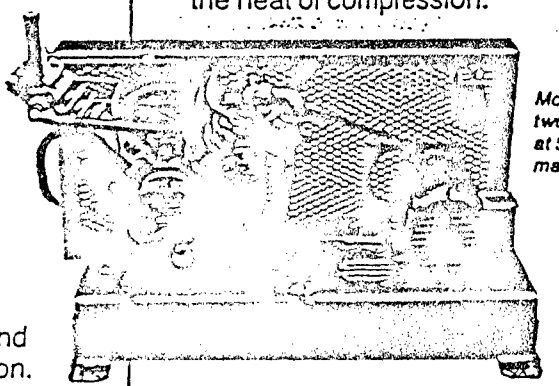
Dependable Type 30® Air Compressors Designed Specifically for High Pressure Operation

Standard Features

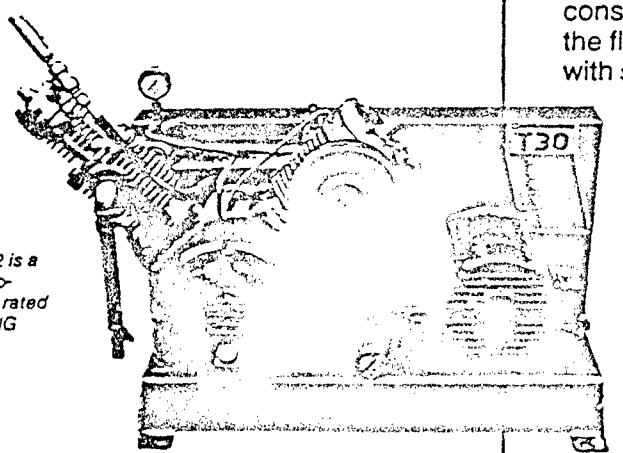
Frame–Cylinders and crankshaft with bearings are frame (crankcase) supported. The frame is of close grained cast iron, completely sealed against dirt to protect the running parts, and provides a large oil sump. The oil filler plug is so located to prevent over-filling. The frame interior has maximum accessibility due to the overhung type crankshaft.

Crankshaft is of the over hung type, provided with two liberally sized ball bearings, and counterweighted. It is one-step finish ground to ensure perfect alignment of running parts, and balanced for smooth running operation.

Cylinders are separately cast and individually flange bolted to the frame. Cylinders are precision honed for compatibility with the pistion rings and employ deep radial fins to help remove the heat of compression.



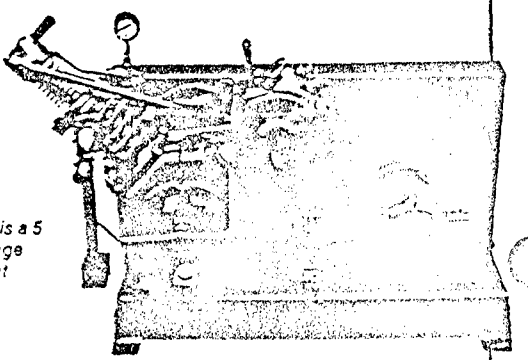
Model 231 is a 2 HP, two-stage unit rated at 500 PSIG maximum pressure.



Model 7T2 is a 10 HP, two-stage unit rated at 500 PSIG maximum pressure.

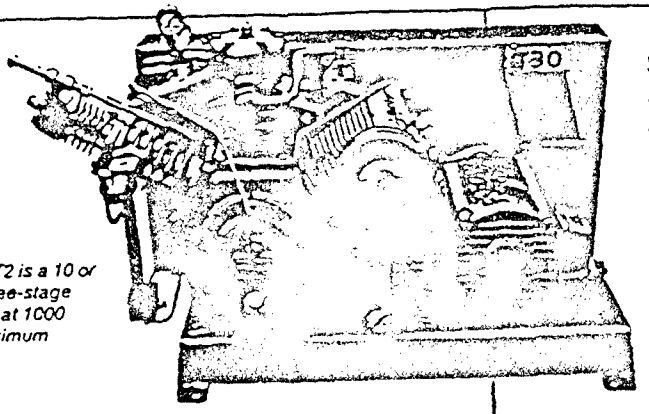
Intercoolers are of finned-tube construction and are located directly in the flywheel air blast. They are provided with safety valves. Interstage pressure gauges are provided on all units except Models 231 and 223.

Aftercooler–The aftercooler is finned-tube type and mounted in same area as the intercoolers within the blast of air from flywheel. Aftercoolers provide discharge air temperature approximately 40°F above ambient. Manual drains are standard on the 231, 7T2 and the 7T4 while an automatic drain is standard on the 223, 15T2 and 15T4.



Model 7T4 is a 5 HP, two-stage unit rated at 1000 PSIG maximum pressure.

Connecting Rods are of the solid-end precision type. There is no need for adjustment–no parts to come loose. This sturdy one-piece construction, permitted by the overhung crankshaft design, results in maximum strength and minimum weight.



Model 15T2 is a 10 or 15 HP, three-stage unit rated at 1000 PSIG maximum pressure.

Safety Protection Devices– Standard devices are selected for operational protection of the compressor and vary depending upon compressor model.

Flywheel–The flywheel fan produces a "cyclone" air blast to provide cooling for the deep finned cylinders, intercoolers and aftercooler.

Base is of heavy steel construction with provision for motor movement to facilitate "V" belt adjustment.

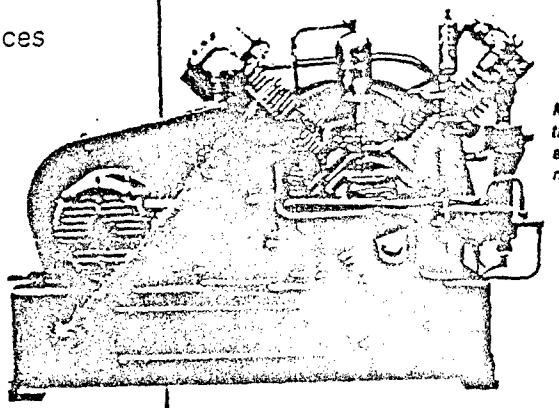
Drive–V belt

Motor–NEMA frame drip-proof 1800 RPM with full service factor. Other popular enclosures are available.

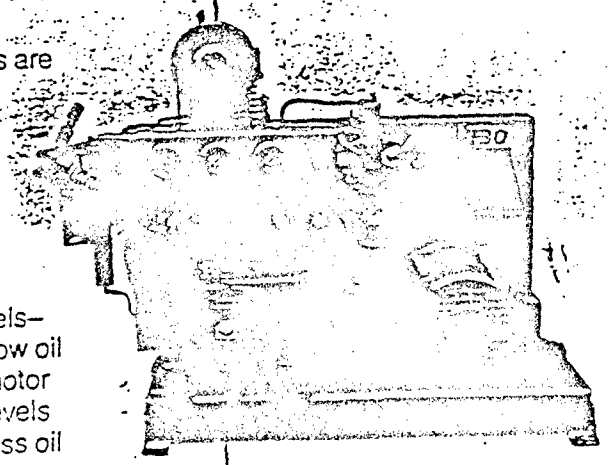
Belt Guard–Totally enclosed OSHA Type guard provides operator protection on all sides.

Regulation–These machines are normally provided less regulation. All models are available with auto start and stop control, constant speed control (except Model 223) and dual control.

"Full-Time" Low Oil Level Switch– optional on all models– provides protection against low oil level. The compressor and motor are shut down at unsafe oil levels and cannot be restarted unless oil is added.



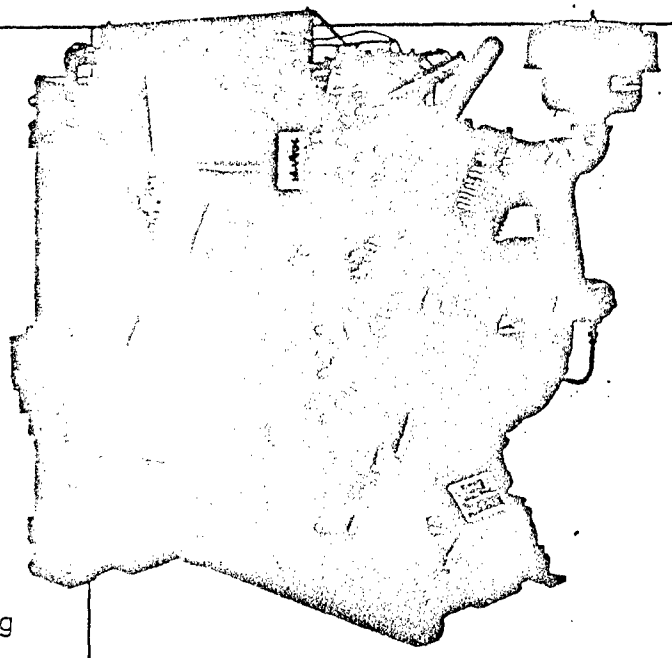
Model 223 is a 5 HP, three-stage unit rated at 3000 PSIG maximum pressure.



Model 15T4/H15T4 are 10, 15 and 20 HP, four stage units with the 15T4 rated up to 3500 PSIG while the H15T4 is available for 5000 PSIG.

6R Series Air Compressors

- 1000 to 6000 PSIG (68.95 to 413.7 bar) pressure
- 75 through 100 horsepower
- Compact design–available either belt driven or direct connected to flange mounted motor
- Bare compressor available for custom applications



Standard Equipment

- Oil bath inlet filter/silencer.
- Frame supported cylinders and crankshaft with bearings.
- One throw on the crankshaft utilizing a master and articulated rod set construction which provides excellent balance, minimum vibration and compactness.
- Separately cast cylinders which are individually flange bolted to frame.
- A six (6) bladed fan that is mounted on the end of the compressor crankshaft opposite the drive end provides cooling air for the radiator intercooler/ aftercooler assembly and the finned cylinders.
- Dual channel valves in the first and second stages and dual K-type plate valves in the 3rd, 4th and 5th stages.
- Force feed lubrication with vane type oil pump and full flow filter.
- Air cooled finned-tube radiator type 25°F (13.9°C) after cooler with interconnecting piping and support base.
- Moisture separator and trap after each intercooler and the aftercooler.
- Automatic condensate drainage of each separator trap.
- Automatic starting unloading.
- Panel mounted interstage, discharge and oil pressure gauges.
- Mounted NEMA1 pressure switch for low oil pressure shutdown.
- Safety valves on all stages with shear disc safety valve on fifth stage.

Accessories

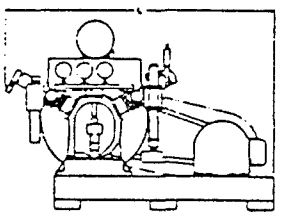
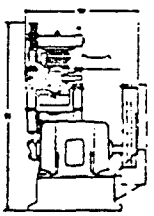
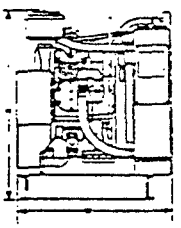
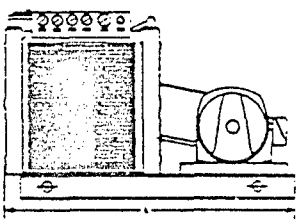
- Automatic start and stop control, including time delay relay.*
- Constant-Speed control.
- Dual control, including time delay relay.*
- High discharge air temperature shutdown switch.
- Timed condensate drain system (timer shipped loose).

* Time delay relay is required with low oil pressure shut down for motor driven units.
Standard control circuit voltage is 115/1/60.
Time delay relay is not mounted.

High Pressure Air-Cooled Air Compressors 2-100 HP/300-6000 PSIG (21 to 413.7 Bar)

Engineering Data

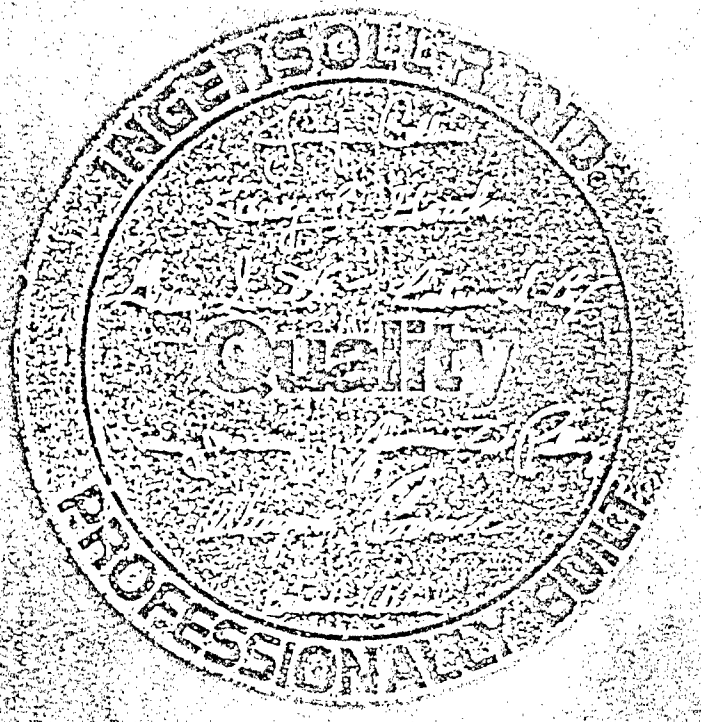
Max. Press.		P. D.		Motor Rating				Dimensions						Weights			
								Length		Width		Height		Bare		Base Mtd.	
PSIG	Bar	CFM	M³/Min.	HP	KW	Model	RPM	IN.	MM	IN.	MM	IN.	MM	Lbs.	Kg.	Lbs.	Kg.
500	34.5	7.4	0.21	2	1.5	231	660	38	965	22	559	21	533	130	59	325	147
500	34.5	36.0	1.01	10	7.5	7T2	800	51	1295	26	660	30	762	420	191	700	318
500	34.5	49.5	1.40	15	11.2	15T2	900	55	1397	34	864	34	864	650	295	900	408
800	55.2	30.3	0.86	10	7.5	15T2	555	55	1397	34	864	34	864	650	295	825	374
1000	68.9	41.2	1.17	15	11.2	15T2	750	55	1397	34	864	34	864	650	295	900	408
1000	68.9	13.1	0.37	5	3.7	7T4	800	48	1219	27	686	31	787	420	191	700	318
3000	207	11.0	0.31	5	3.7	223	985	42	1067	22	559	28	711	400	181	450	204
3500	241	23.2	.657	10	7.5	15T4	631	58	1473	29	737	43	1092	750	340	940	426
3500	241	32.7	.926	15	11.2	15T4	890	58	1473	29	737	43	1092	750	340	940	426
3500	241	36.8	1.04	20	14.9	15T4	1000	58	1473	29	737	43	1092	750	340	1200	544
5000	345	23.2	0.66	10	7.5	H15T4	631	58	1473	29	737	43	1092	750	340	940	426
5000	345	32.7	0.93	15	11.2	H15T4	890	58	1473	29	737	43	1092	750	340	940	426
5000	345	36.8	1.04	20	14.9	H15T4	1000	58	1473	29	737	43	1092	750	340	1200	544
2000	137.9	148.0	4.19	75	55.9	6R100	1800	76	1930	41	1041	51	1295	1800	816	3150	1429
6000	413.7	122.7	3.47	75	55.9	6R80	1800	76	1930	41	1041	51	1295	1800	816	3150	1429
6000	413.7	148.0	4.19	100	74.6	6R80-100	1800	76	1930	41	1041	51	1295	1800	816	3150	1429

The following is standard with each compressor package:

	Equipment	231	7T2	7T4	15T2	223	15T4 H15T4	6R100	6R80	6R80-100
Bare Units	Dry-type Inlet Filter (Oil Bath on 6R)	●	●	●	●	●	●	●	●	●
	Splash Lubrication (Force Feed on 6R)	●	●	●	●	●	●	●	●	●
	Air-cooled Intercoolers	●	●	●	●	●	●	●	●	●
	Intercooler Pressure Gauges		●	●	●		●	●	●	●
	Safety Valve on Intercoolers	●	●	●	●	●	●	●	●	●
	Condensate Traps on Intercoolers				●[1]	●[1]	●[1]	●	●	●
	Air-cooled Aftercooler	●	●	●	●	●	●	●	●	●
	Condensate Trap on Aftercooler	●	●	●	●	●	●	●	●	●
	Safety Valve on Aftercooler	●	●	●	●	●	●	●	●	●
	Automatic Condensate Drain System	●[2]	●[2]	●[2]	●	●	●	●	●	●
	Check Valve on Air Outlet from Aftercooler	●[2]	●[2]	●[2]	●	●	●	●	●	●
	Discharge Pressure Gauge on Last Stage							●	●	●
	Shear Disc. Valve on Last Stage					●	●	●	●	●
	[1]No Condensation Trap on 1st Stage Intercooler [2]Optional Component									
Base-plate Units	Baseplate and V-belt drive	●	●	●	●	●	●	●	●	●
	NEMA frame motor for V-belt drive	●	●	●	●	●	●	●	●	●

[illegible] to D Flange Motor



INGERSOLL-RAND
AIR COMPRESSORS

RIX INDUSTRIES
Air and Gas Compressor Manufacturers
Since 1878

October 30, 1989

Department of the Army
U.S. Army Belvoir Research
Development and Engineering Center
Fort Belvoir, Virginia 22060-5606

Attention: Commander
Belvoir RD&E Center
ATTN: STRBE-FMT (J.Leary)
Fort Belvoir, VA 22060-5606

Dear Mr. Leary:

Enclose please find general information regarding RIX compressors. We are very interested in meeting specifications to be developed by the U.S. Army for this application.

Sincerely,

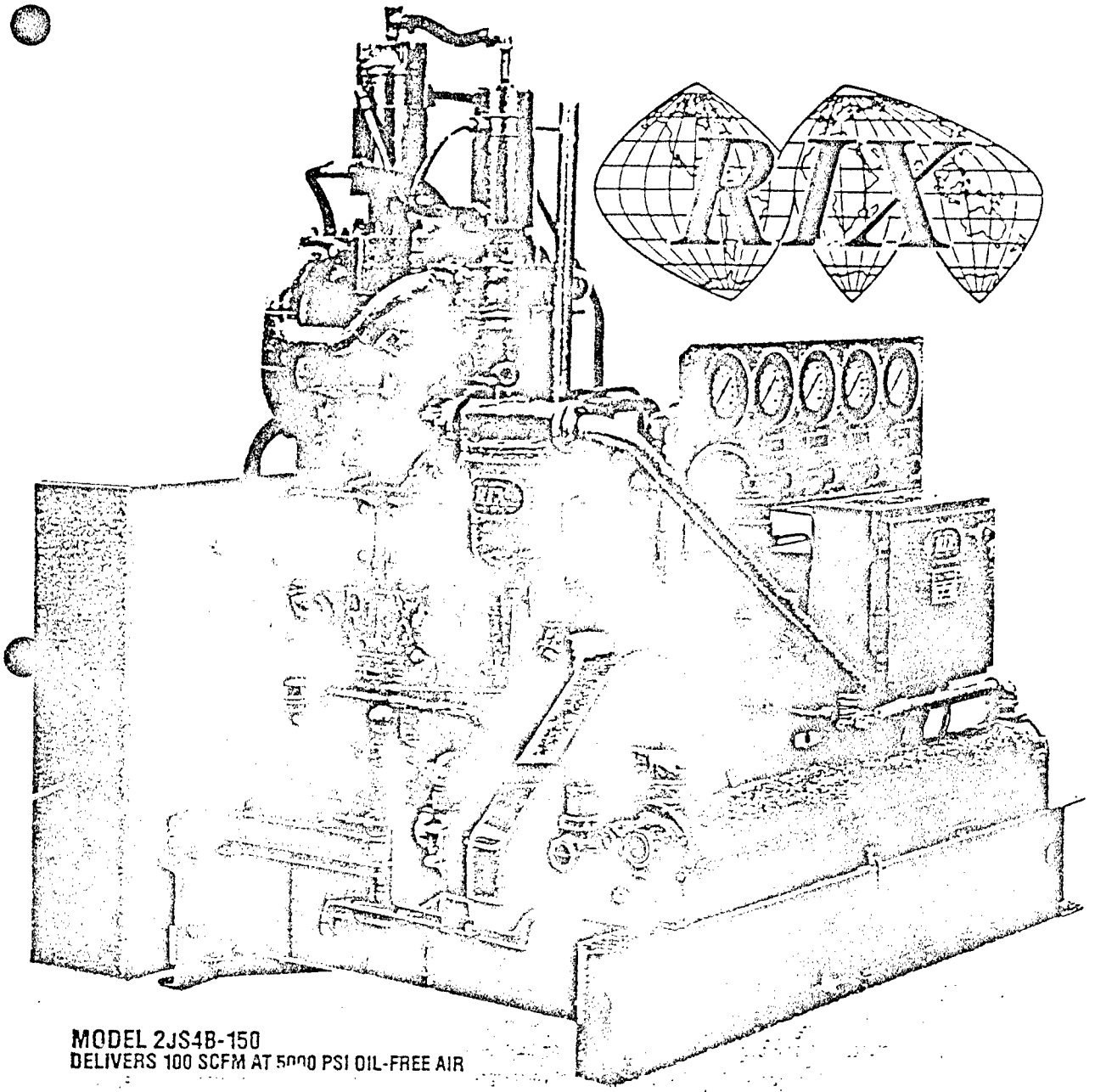
Michael G. Parker

Michael G. Parker
Marketing Manager

MGP:

enclosure

6400 Hollis Street Oakland, CA 94608-1035 USA Phone 415-658-6275 FAX 415-428-9102 Telex 33-7724



RIX

MODEL 2JS4B-150
DELIVERS 100 SCFM AT 5000 PSI OIL-FREE AIR

COMPRESSORS

RIX INDUSTRIES 6460 HOLLIS STREET • P.O. BOX [illegible] • OAKLAND CA 94662-0605 USA
415-658-5275 TELEX [illegible]

RIX High Pressure Compressors

RIX Compressors have been manufactured in the San Francisco Bay Area since 1878, when Mr. E.A. Rix began building compressed air machinery to replace steam equipment in the California gold mines. As a young engineering graduate of the University of California, he obtained many patents on air and gas machinery. This tradition of designing and manufacturing high technology compression equipment has continued for over 100 years.

Today RIX is well known for its expertise in engineering and manufacturing high pressure, continuous duty, air and gas compressor systems. Both non-lubricated (oil free) and oil-lubricated units are manufactured, in single through five stage designs. RIX compressors range in size from 3 to 500 horsepower at discharge pressures to 10,000 psi. Water cooled designs predominate, although some air cooled models are available.

In addition to standard units, RIX often supplies compressors that are 'custom built' to meet the buyers performance and equipment needs. A wide selection of time proven crankcases and compression cylinders allows the manufacture of units for nearly any application without compromising quality, performance or size. 'Booster' applications for example, requiring small displacements combined with a high rod load rating, are often supplied by RIX. Compressors in both basic and fully packaged configurations are available.

Typical users of RIX compressors include the hydrocarbon processing, chemical, industrial gas and food processing markets, as well as utilities, manufacturers, geological survey groups, NASA and the military. Many applications require compressors built to customer specifications, typically involving those from the military, Coast Guard, professional/industrial organizations, and safety codes.

Oil-free breathing air compressors have always been and remain today a major product of RIX Industries. Other gases commonly handled by RIX compressors include: Acetylene, ammonia, argon, CO_2, helium, heliox, hydrogen, nitrogen, oxygen, natural gas and the full range of hydrocarbon gases. RIX is the leading supplier of natural gas compressors for CNG automotive refueling stations.

CURRENT MODELS

2EZ: 2 cylinder, 2 stage gas compressor, - ideal as a small flow booster. To 7½ HP.

1KX: 1 cylinder, 1 or 2 stage - often used as a medium pressure gas booster. To 40 HP. Alternate model: 1JS (not shown) 75 HP.

2K-2KX: 2 cylinder, 1 through 4 stages, medium flow at all pressures. Used commonly in high purity process systems. To 75 HP.

3K-3KX: 3 cylinder, 3 stage compressor – often selected for small to medium flow high pressure breathing air, heliox and other pure gases. To 60 HP. Alternate model: 3KM-75 HP.

3J-3JM: 3 cylinder, 3 stage – typically a high pressure air or gas booster. To 200 HP.

2JS-2JJS: 2 cylinder, 1 through 4 stage - many uses, from low pressure breathing air to high flow, high pressure air or gas boosters. To 250 HP.

2FX: 2 cylinder, 2 or 4 stage, good for high volume air or gas applications. To 250 HP.

2D: 2 cylinder, 1 to 4 stage, extra heavy crankcase suitable for high load booster applications. To 500 HP.

4JY: 4 cylinder, 4 stage - designed for high volume, high pressure applications. To 400 HP.

HW: 6 cylinders, 3 - 6 stage, air cooled, air compressor suitable for high pressure air supply. To 125 HP (not shown).

3W: 3 or 4 cylinder, 3 or 4 stage, air cooled, natural gas boosters. To 30 HP.

HG-CG: Encapsulated natural gas compressors. Oil-cooled.

SA: 3 & 5.5 cfm, 3[illegible] to 5000 psi, air cooled, oil free breathing air units.

[illegible]

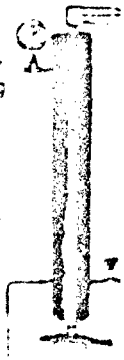
Standard Design Features

- ☐ Oil-free or oil-lubricated compression cylinders.
- ☐ Compression cylinders isolated from the crankcase by crosshead distance pieces.
- ☐ Closed systems for rare or hazardous gases.
- ☐ Single through five-stage construction.
- ☐ Water-cooled compression cylinders, heads, inter/aftercoolers and crossheads allowing continuous operation.
- ☐ Fully pressure-lubricated crankcase, rated for continuous duty.
- ☐ Vertical cylinder construction assuring compactness, accessibility of components, and ease of installation. Horizontal inertia loads and eggshaped cylinder wear experienced with horizontal designs are eliminated.
- ☐ Standard or complete 'custom-built' packaged units with customer choice of accessories and controls. On-site engineering assistance available.

RIX ACCESSORIES

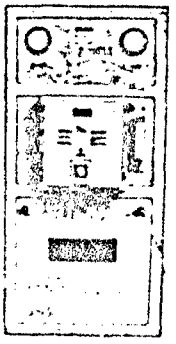
HEAT EXCHANGERS

RIX inter- and after coolers are specially engineered for efficient gas to liquid cooling in compressor service. Modern fabrication technology and materials are combined with our compressor "know-how" to incorporate design features of compactness, maintainability and RIX proven reliability.



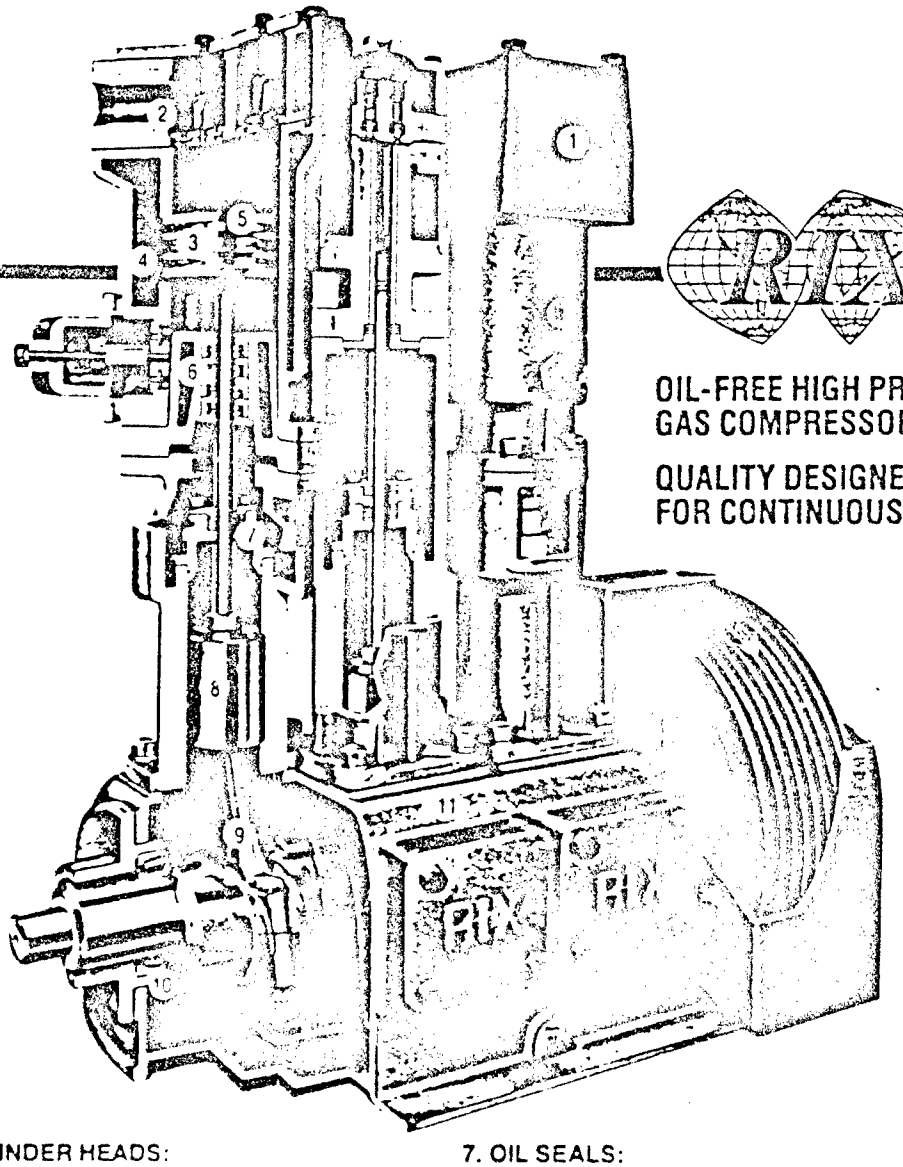
HIGH PRESSURE AUTOMATIC MOISTURE SEPARATOR

Efficient and reliable, this patented RIX engineered product provides continuous separation of condensed moisture from the product gas, eliminating periodic blow-downs with wasteful loss of gas. Solid state electronics combined with high pressure technology offer trouble-free performance over a pressure range of [illegible] other standard models are available.



DEHYDRATION EQUIPMENT

RIX offers a wide range of drying equipment including both replaceable cartridge type and semi or fully automatic dual tower self-reactivating dehydrators. A selection of desiccants is available to insure process gas purity for every application.

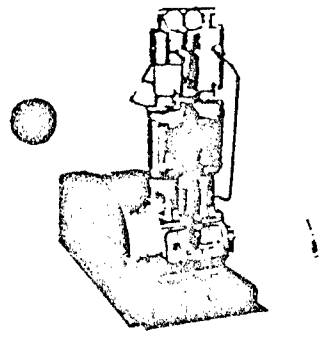


OIL-FREE HIGH PRESSURE GAS COMPRESSOR

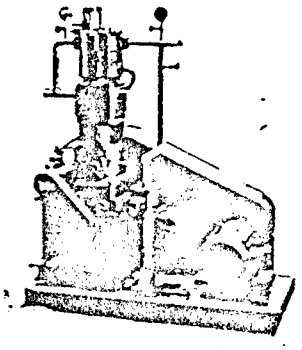
QUALITY DESIGNED FOR CONTINUOUS SERVICE

1. **CYLINDER HEADS:**
   Corrosion resistant, Gas Compatible Materials. O-ring Sealing.
2. **VALVES:**
   Stainless Steel Discs or Poppets with O-Ring Sealing.
3. **PISTON RINGS:**
   Self-lubricating PTFE
4. **WATER JACKETS:**
   Large Passages throughout Cylinders, Heads and Crosshead Guides.
5. **PISTONS:**
   Aluminum Alloy, Stainless Steel, Bronze or other materials appropriate for the application.
6. **GAS SEALS:**
   Self-lubricating
7. **OIL SEALS:**
   Effective Isolation of Crankcase Oil from Compression Cylinders.
8. **CROSSHEADS:**
   High Strength Ductile Iron. Water Cooled as needed.
9. **CON RODS:**
   Heavy Duty, Rifle Drilled for Wrist Pin Oiling. Precision Steel Backed Insert Bearings.
10. **MAIN BEARINGS:**
    Anti-friction roller Bearings
11. **CRANKSHAFT:**
    Rifle Drilled for Pressure Lubrication. Deep Sump Oil Reservoir with Full Flow Oil Filter.

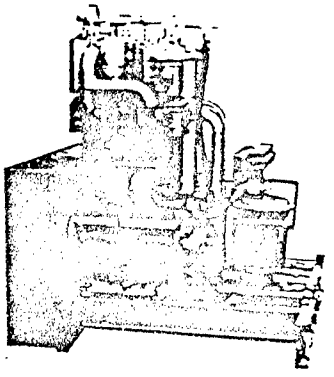
MODEL 2EZ



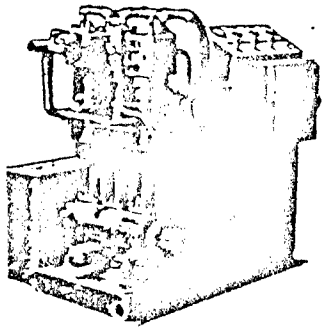
MODEL 1KX



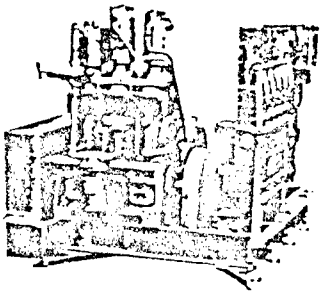
MODEL 2KX



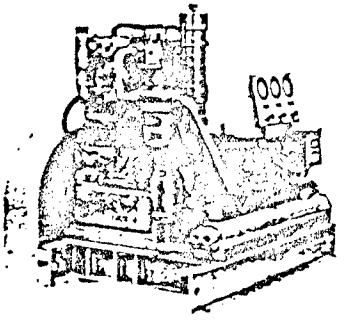
MODEL 3K



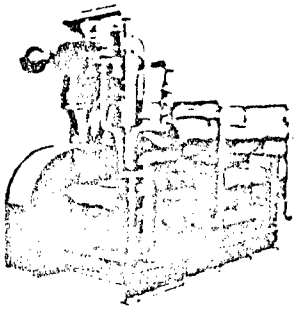
MODEL 3J



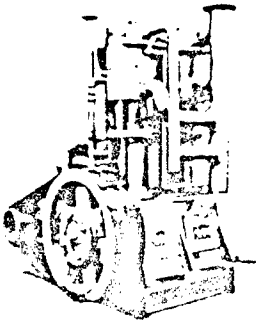
MODEL 2JS



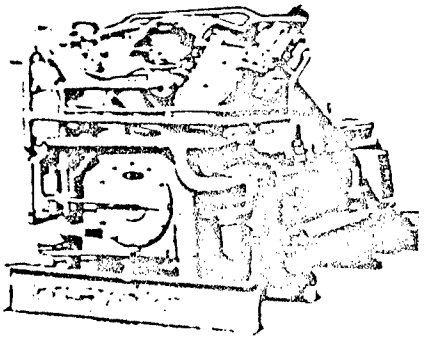
MODEL 2FX



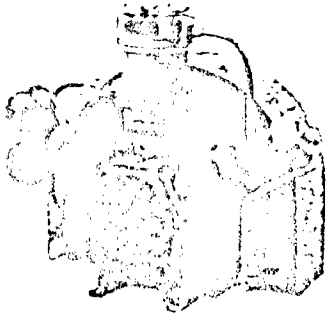
MODEL 2D



MODEL 4JY

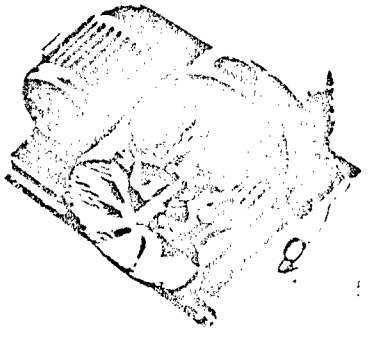


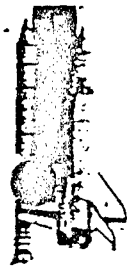
MODEL 3W

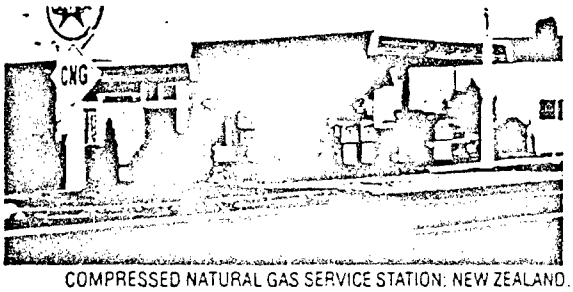


HOM-GAS & COM-GAS

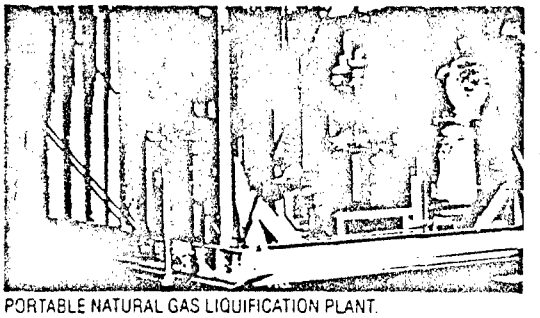
SA SERIES





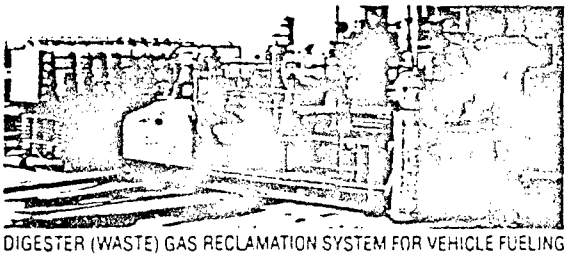


COMPRESSED NATURAL GAS SERVICE STATION: NEW ZEALAND.

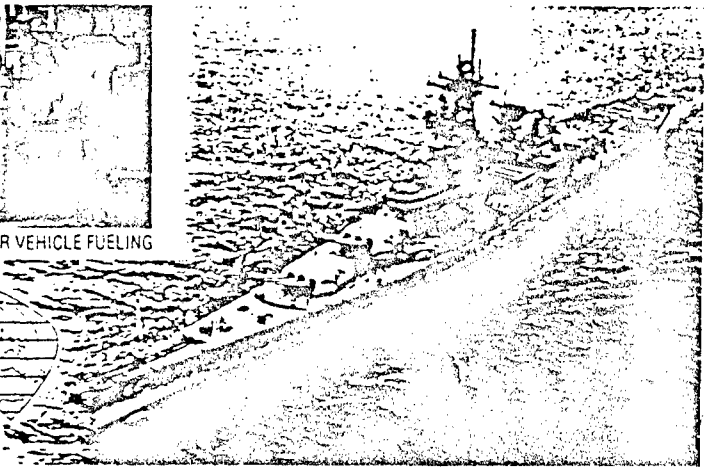


PORTABLE NATURAL GAS LIQUIFICATION PLANT.

GROUND SUPPORT BREATHING AIR FOR SPACE SHUTTLE OPERATIONS.

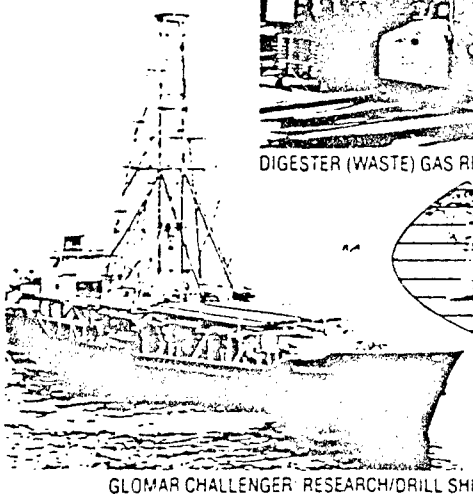


DIGESTER (WASTE) GAS RECLAMATION SYSTEM FOR VEHICLE FUELING

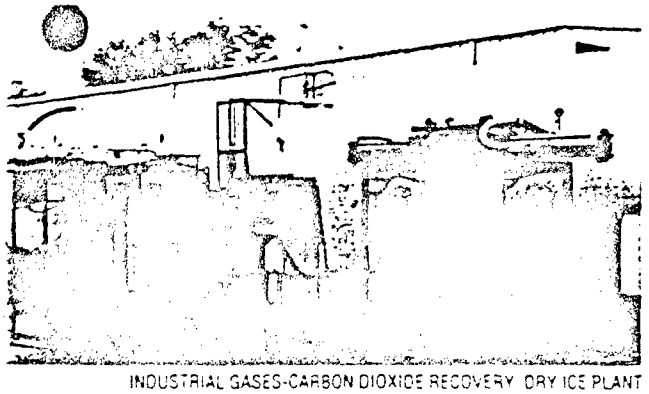


BATTLE SHIP: U.S.S. NEW JERSEY.

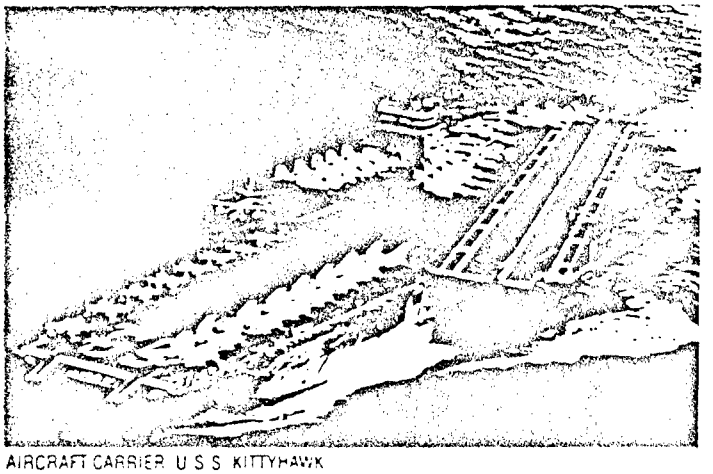
RIX AT WORK



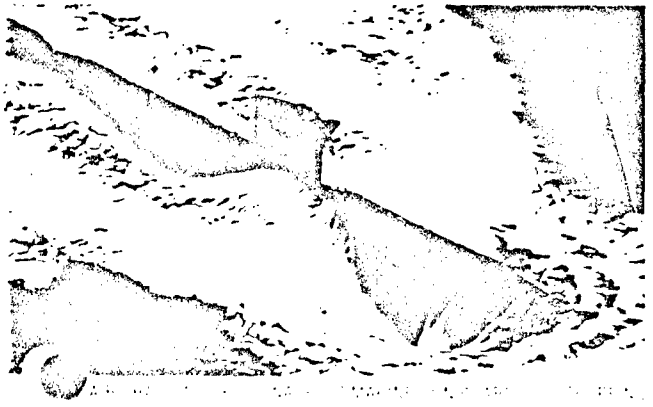
GLOMAR CHALLENGER RESEARCH/DRILL SHIP.

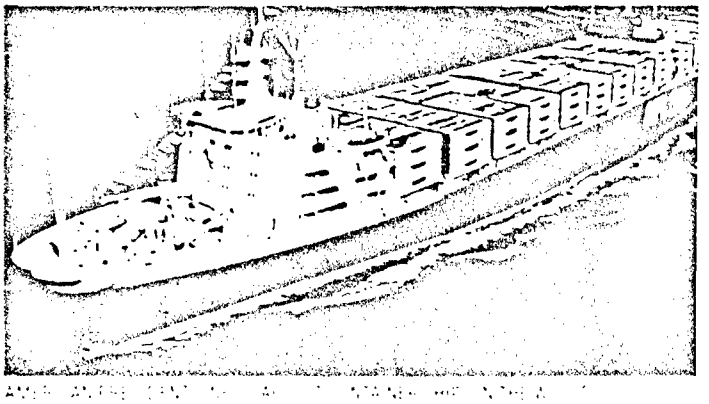


INDUSTRIAL GASES-CARBON DIOXIDE RECOVERY DRY ICE PLANT



AIRCRAFT CARRIER U.S.S. KITTYHAWK





RIX INDUSTRIES
Air and Gas Compressor Manufacturers
Since 1878

RIX INDUSTRIES
Air and Gas Compressor Manufacturers

6460 Hollis Street
Oakland, CA 94608-1035 USA

Phone 415-658-5275
FAX 415-428-9102
Telex 33-7724

Michael G. Parker
NEW MARKET DEVELOPMENT

On San Francisco Bay Since 1878

COMPRESSOR INQUIRY QUESTIONNAIRE

Thank you for considering RIX Industries for your compressor requirements. RIX has been building compressors for military and industrial use since 1878. We build compressors for all types of gases in all different applications. Compressors for air, nitrogen, oxygen, argon, helium, hydrogen, ethylene, carbon dioxide, natural gas and mixed gases to name a few.

Applications include industrial gas producers, universities, research labs, manufacturers, gas processors, petrochemical, medical, pharmaceutical, heavy industrial, food processing, military accounts, fire departments, and scuba shops. While specializing in oil-free, high pressure compressors, RIX builds compressors of 1 to 300 BHP, oil-free and oil-lubricated, one to five stage, air and water cooled, and with a wide range of inlet and discharge pressures and temperatures.

In order for us to be responsive to your inquiry, please fill out the following questionnaire and return to us. Upon receipt of this information, we will be pleased to submit a bid or give budget pricing only, as needed. For budgetary quotes, limited information may be supplied at your discretion.

Note: For firm price quotations the requested information is only the minimum desired. Any other information which would have a bearing on your quotation should be included in your inquiry. Please be as complete as possible.

Should you have questions about filling out this request for information, please call us to discuss your compressor application.

Please indicate your name, company name, address (including country), phone number, fax number and/or telex number on the enclosed form, or when making a fax or telex inquiry.

Very truly yours,

RIX INDUSTRIES

Michael G. Parker
Marketing

INFORMATION REQUIRED FOR QUOTATIONS - AIR/GAS COMPRESSORS

1. Please give a general description of the compressor application _____

_____

_____

2. What gas is being compressed (include Cp/Cv if unique gas mixture) _____

_____

_____

3. Is the gas wet or dry? Please state humidity level if known _____

_____

4. Quantity or flow rate of gas (SCFM or SCFH)? _____

5. What is the design inlet pressure and temperature (for the above specified flow rate)? _____

_____

Please specify pressures as either "gauge" or "absolute" (psig or psia)

6. What is the atmospheric pressure or elevation at plant site? _____

7. What is the inlet pressure range? High _____ and low _____

Can inlet pressure be regulated if it is variable? _____

8. Inlet temperature range? High _____ and low _____

9. Discharge pressure? Design _____

and range: High _____ and low _____

10. What type of capacity control is needed? _____

Auto start/stop _____; Hand start/auto stop _____

Load/unload-bypass to suction* _____

Variable flow-bypass to suction* _____

*Specify whether control (logic) will be inlet or discharge pressure sensing.

11. What is the expected duty cycle and/or operating conditions of unit? _____

_____

12. Are oil-free or oil-lubricated compression cylinders required? _____

_____

13. What materials of construction will not be compatible with the gas being compressed? (Copper alloys, aluminum, viton, etc.) _____

With the cooling water system? _____ the environment? _____

14. What type, temperature, and pressure of cooling water is available? _____

Can cooling water pressure be reduced if in excess of 30 psig? _____

Is a water-to-water heat exchanger required? _____

Is a radiator required? _____ Skid mounted or remote? _____

15. Will compressor be packaged for indoor (Nema 1) _____ Outdoor (Nema 3R) _____

watertight (Nema 4)? _____ or explosion-proof (Nema 7)? _____

What type of motor enclosure is required? ODP (indoor) _____TEFC (outdoor) _____

TEFC (mill and chem) _____; XP (explosion proof) _____

16. What of electrical power is available? Voltage _____ phase _____ frequency _____

17. Is the motor starter to be supplied by RIX? _____; by customer? _____

If supplied by Rix: to be mounted on compressor skid? _____; remote? _____

What NEMA requirement for starter (Nema 1, 3R, 4, 4X, 7 or 12)? _____

18. Are first-out shutdown indicating lights required? _____

Is a programmable controlled desired? _____General Electric or Allen Bradley? _____

19. What are the minimum and maximum ambient temperatures at the job site. _____

20. Any other pertinent information? _____

_____

Please give us the following information:

YOUR NAME:(Print) _____

COMPANY: _____

ADDRESS: _____

CITY, STATE, ZIP (COUNTRY): _____

TELEPHONE: Area Code (_____) _____

FAX NUMBER: Area Code (_____) _____

TELEX NUMBER: Area Code (____) _____

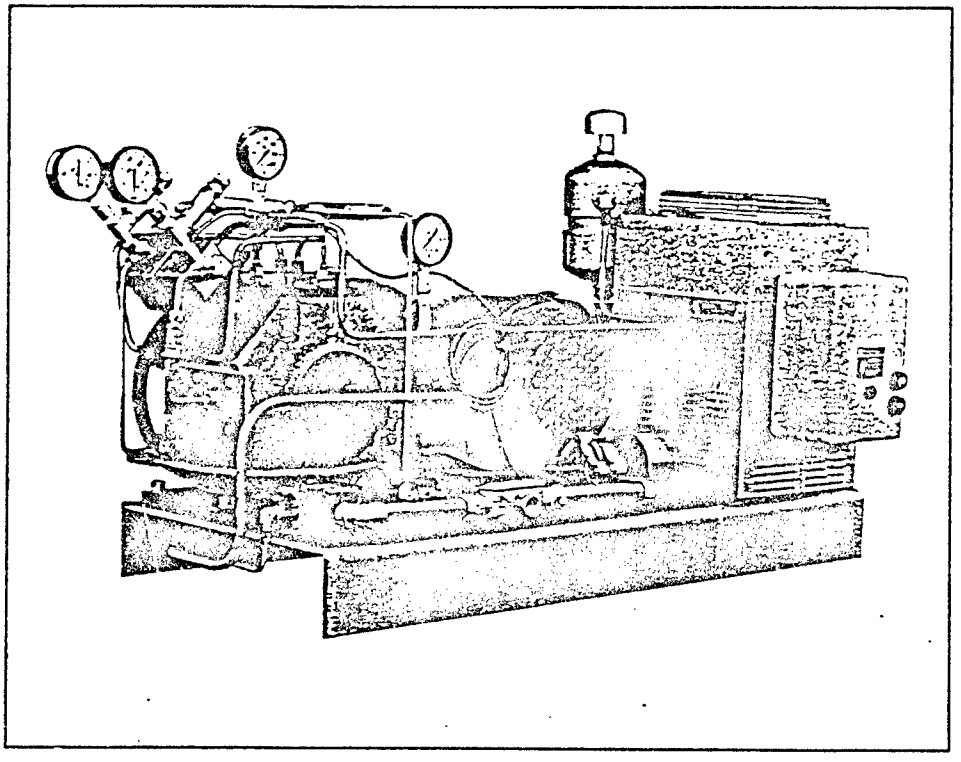
Thank you for this information. We will respond as soon as possible.

RIX-O_2

4N3BG
OXYGEN COMPRESSORS

To 2500 psig @ 1.7 to 6.7 scfm (100 to 400 scfh)

FEATURES
- Oil-less Design
- Proven Safety Features
- Compact, Lightweight
- Low RPM for Long Service Life
- Continuous Around-The-Clock Operation



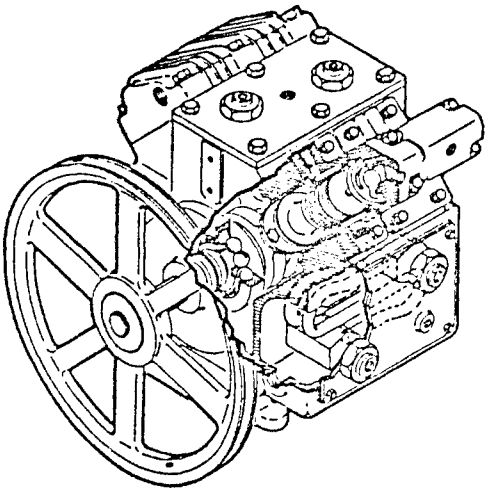
DESCRIPTION

RIX Oxygen Compressors have been developed specifically for the exacting requirements of safe, reliable oxygen compression service. The 4N3BG Series incorporates design features developed over several decades for a variety of industrial and military oxygen compressor applications. These compressors are also well suited for the compression of other clean, dry gases to 3000 psig.

4N3BG three-stage compressors employ four oil-less single-acting cylinders on a "V" type crosshead design crankcase. Heat exchangers, crankcase, and compression cylinders are watercooled. The free-floating third stage piston allows the piston and rings to be changed without disconnecting the cooling water piping. Replacement of the floating piston assembly typically requires only about one-half hour. The ring-life of the third stage, at 2400 psig, has proven to be more than 2500 hours. Service life of the other cylinders is considerably longer.

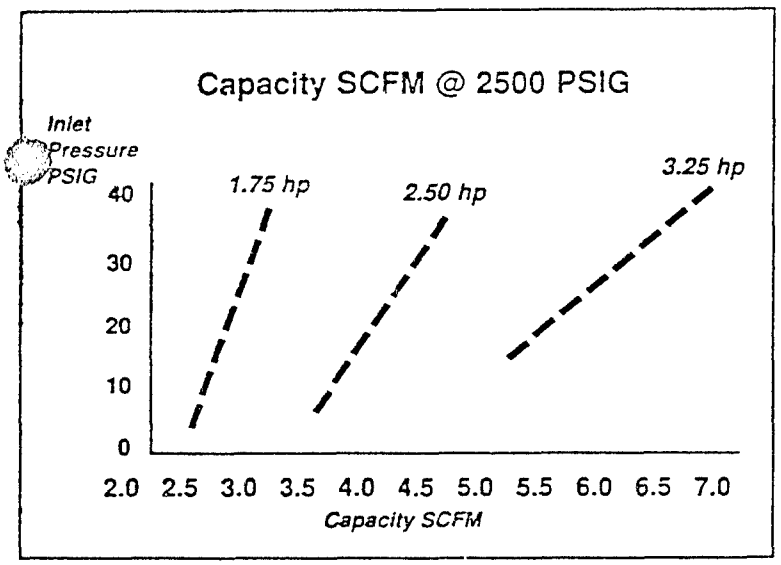
4N3BG Oxygen Compressor

Oxygen Compatible
Oil-Less Design/Sealed Bearings
4 Cylinder "V" Type Reciprocating Piston Design
3-Stages
Sealed Crankcase



Specifications

Size, Bare	14.5"w x 13.25"l x 12.75"h
	(36.8cm x 33.7cm x 32.4cm)
Size, Mounted Package	18"w x 33"l x 17" h
	(45.7cm x 83.8cm x 43.2cm)
Weight (w/o Flywheel)	85 lbs. (38.6 kg)
Weight (Package)	175 lbs. (79.5 kg)
Power	2, 3, or 5 hp motor size
Compressor Speed	400 to 1000 RPM
Suction	5 psig to 40 psig
Max. Discharge, O_2	to 2500 psi
Discharge, Other Gases	to 3000 psi
Flow Rate	1.7 to 6.7 scfm (100 to 400 scfh)



Standard Components

***Bare Compressor:**
- 4N3BG Compressor
- Intercoolers, watercooled
- Aftercooler, watercooled
- Crankcase, watercooled
- Flywheel
- Stainless Steel Plumbing
- Relief Valves
- Filters
- Oxygen Clean

***Compressor Package:**
- Compressor
- Bedplate
- V-Belt
- Belt Guard
- Motor
- Starter
- Start/Stop Buttons
- Hour Meter
- High Temperature Shutdown
- High Pressure Shutdown
- Low Inlet Pressure Shutdown
- Oxygen Clean

***Optional Closed Circuit Cooling Package:**
- Radiator
- Water Pump
- Electric Fan & Starter
- Bedplate Mounted

**Factory tested on oxygen to customer specifications.*

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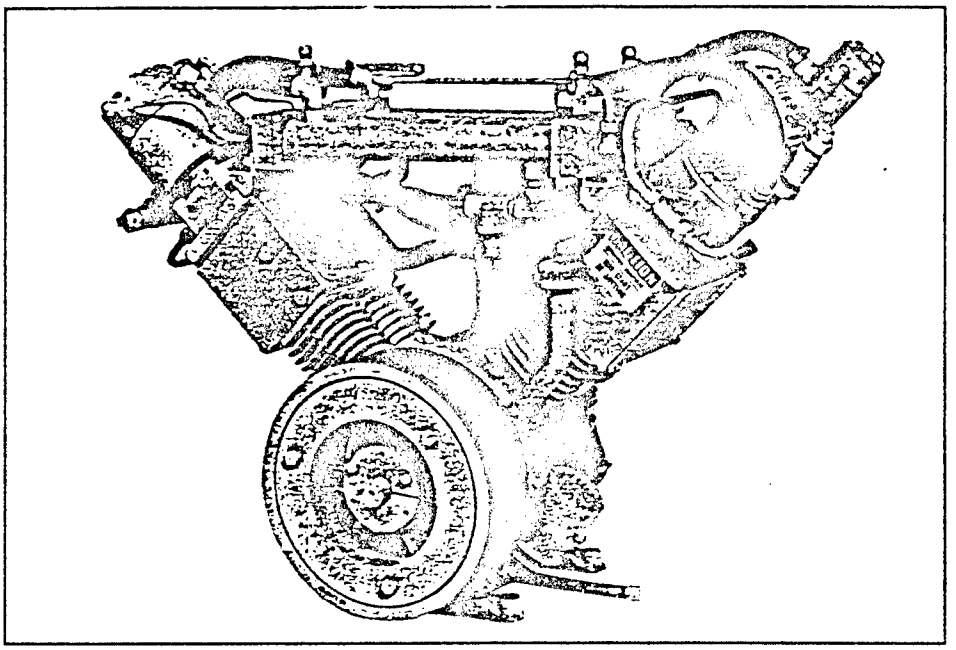
On San Francisco Bay since 1970

RIX-O2

4V4BG
OXYGEN COMPRESSORS

To 3000 psig @ 10 to 17 scfm (600 to 1000 scfh)

FEATURES
- Oil-Free Design
- Proven Safety Features
- Low RPM for Long Service Life
- Continuous Around-The-Clock Operation



DESCRIPTION

RIX Oxygen Compressors have been developed specifically for the exacting requirements of safe, reliable oxygen compression service. The 4V4BG Series incorporates design features developed over several decades for a variety of industrial and military oxygen compressor applications. They are also well suited for the compression of other clean, dry gases to 5000 psig.

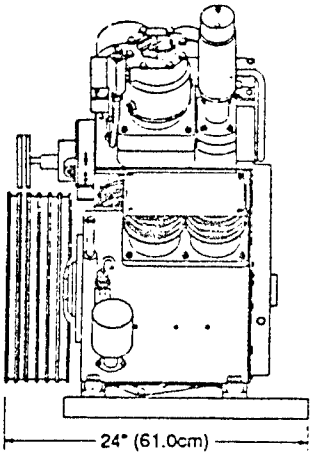
4V4BG four-stage compressors employ four oil-less single-acting cylinders in a "V" type crosshead design crankcase. Heat exchangers and compression cylinders are fresh water cooled. The crankcase is splash-lubricated with oxygen compatible oil.

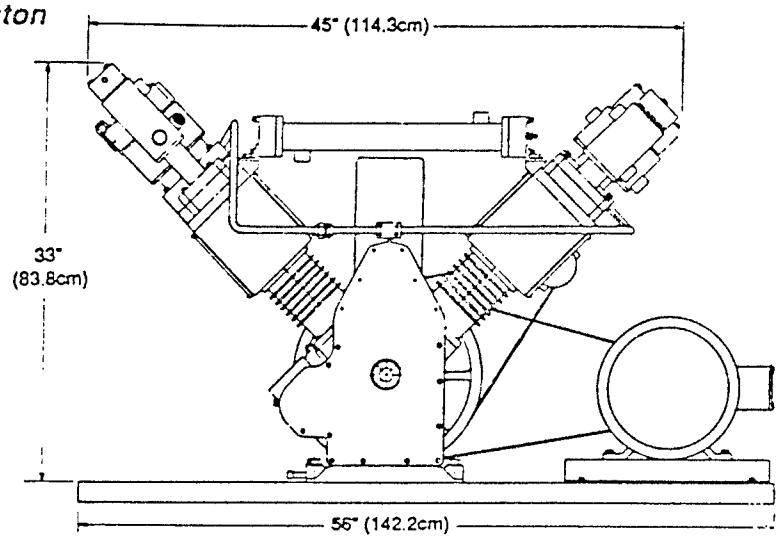
The 3rd and 4th stage pistons are free-floating. This allows piston and ring change-out without cylinder or piston rod removal. All heads are air cooled and can be removed without disconnecting the cooling water piping. Replacement of a floating piston assembly typically requires only one-half hour.

The proven ring-life of the 4th stage, compressing oxygen at 2400 psi, is more than 3000 hours. Service life of the other cylinders is considerably longer.

4V4BG Oxygen Compressor

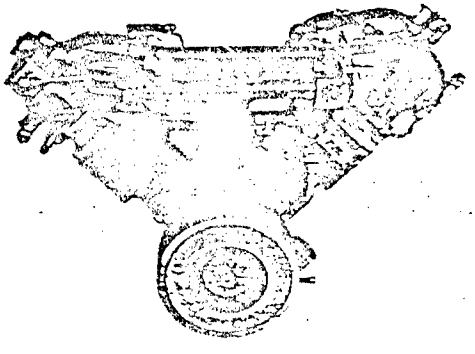
Oxygen Compatible
Oil-Free Design/Splash Lubricated Bearings
Cylinder "V" Type Reciprocating Piston





Specifications

Size, Bare	24"W x 45"L x 33"H
	(61.0cm x 114.3cm x 83.8cm)
Size, Base Mounted	31"W x 56"L x 36"H
	(78.7cm x 142.2cm x 91.4cm)
Weight, Pump Only	475 lbs. (215.9 kg)
Weight, w/15 HP Motor	800 lbs. (363.6 kg)
Power	10 or 15 hp Motor Size
Compressor Speed	500 or 650 RPM
Suction	5 to 12 psig
Max. Discharge, O_2	to 3000 psi
Discharge, Other Gases	to 5000 psi
Flow Rate	10 to 17 scfm:
10 scfm (600 scfh), 500 RPM @ 5 psig Inlet	
17 scfm (1000 scfh), 650 RPM @ 12 psig Inlet	



Standard Components

***Bare Compressor:**
- 4V4BG Compressor
- Intercoolers, watercooled
- Aftercooler, watercooled
- Relief Valves
- Inlet Filter
- Flywheel
- Back-Pressure Regulator
- Stainless Steel Interconnecting Plumbing
- Oxygen Clean

***Compressor Package:**
- Bedplate
- Belt, Belt Guard
- Motor Starter, Start/Stop Buttons
- Hour Meter
- High Temperature Shutdown
- High Pressure Shutdown
- Low Pressure Shutdown
- Oxygen Clean

***Optional Closed Circuit Cooling**
- Radiator
- Water Pump
- Electric Fan and Starter

**Factory tested on oxygen to customer specifications.*

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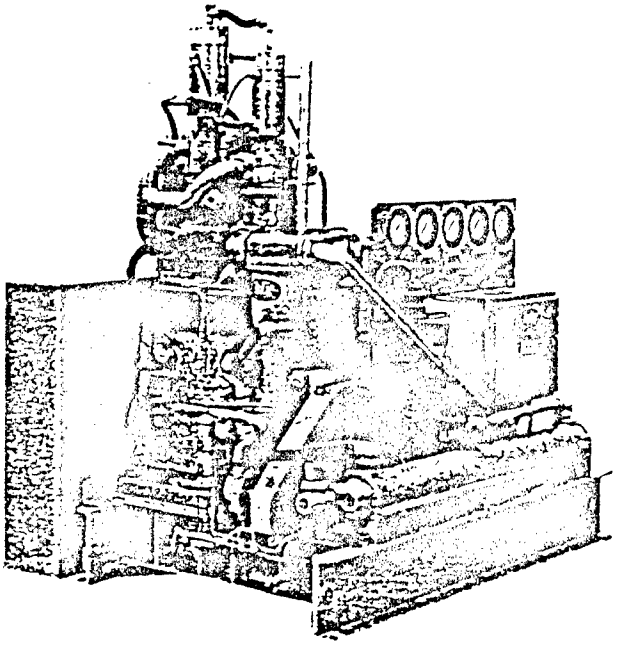
• Telex 33-7724
On San Francisco Bay since 1971

2JS B-SERIES
OIL-FREE AIR or GAS COMPRESSORS
For High Pressure Service to 5,000 PSIG

FEATURES

- OIL-FREE OR OIL-LUBRICATED CYLINDERS
- 1 TO 4 STAGE COMPRESSION
- CONTINUOUS DUTY, WATER-COOLED DESIGN
- CROSSHEAD CONSTRUCTION
- PRESSURE-LUBRICATED CRANKCASE



APPLICATIONS

BREATHING AIR: Fire Fighting, Industrial, SCUBA Diving.
FOOD & DRUG: Processing, Recycling, Recovery of Valuable Gases.
CHEMICAL PROCESSING: Process or Recycle Gases, High Pressure Storage.
INDUSTRIAL: Plant Air, Product Testing, Engine Starting.
GEOPHYSICAL: Air Guns (Lubricated Model)
VEHICLE FUELING: Natural Gas Storage for Medium to Large Size Fleets (Lubricated Model).

SPECIFICATIONS*

GENERAL: The exclusive RIX oil-free compressor design protects the air or gas from contamination during compression by utilizing non-lubricated cylinders and corrosion-resistant materials in all gas passageways. 2JS Series compressors feature heavy-duty, crosshead construction with two vertical, in-line cylinders, one to four-stage compression and water cooling. The guide cylinder and crankcase are cast into a single piece to assure extra strength and rigidity.

CRANKCASE: Enclosed type, full pressure lubricated, with filtered vent and full-flow oil filter.

BEARINGS: Main bearings; tapered roller. Connecting rod; replaceable steel-backed inserts. Wrist pin; removable bronze bushing.

POWER DRIVE: V-Belt drive with OSHA guards and electric motor or other driver.

CYLINDERS: Low Pressure Stage; nickel-plated alloy cast iron. Intermediate and High Pressure Stages; replaceable stainless steel liners.

PISTONS: Low Pressure; aluminum alloy. Intermediate and High Pressure; stainless steel or bronze. All piston rods are stainless steel. Piston rings, rider rings, and packing rings, all self-lubricating – fabricated from specially compounded TFE materials. (Oil-lubricated models use cast iron compression rings.)

VALVES: RIX concentric ring or poppet design. All stainless steel.

PLUMBING: Inter- and aftercoolers with moisture separators as required. Safety valves and gauges after each stage.

UNIT MOUNTING: Fabricated steel base.

OPTIONS: (1) Hazardous or corrosive gas applications. (2) Cylinder lubrication with TFE Rings. (3) Custom controls. (4) Desiccant and refrigerated dryers. (5) Filters. (6) Pulsation Dampeners. (7) High pressure receivers. (8) Radiator or raw water cooling. (9) Shipboard applications. (10) Custom design and development.

*SPECIAL CONSTRUCTION AND MATERIALS MAY BE USED WHERE OPERATING CONDITIONS DICTATE

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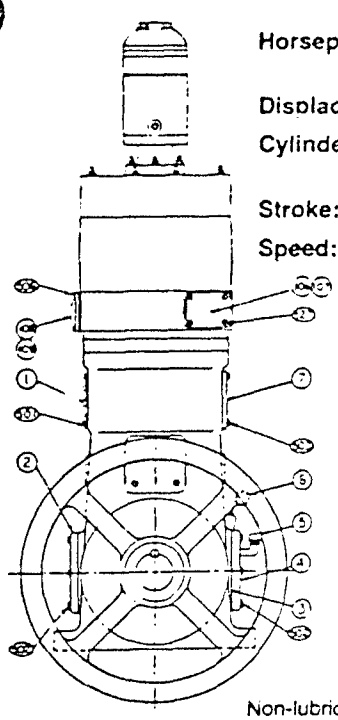
RIX COMPRESSORS
2JS SERIES



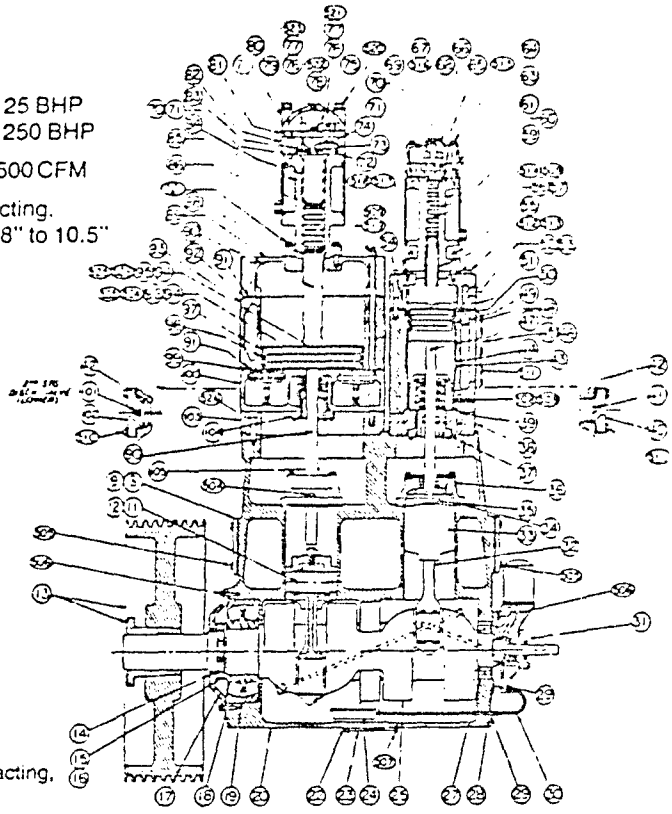
Horsepower Range: 2JS to 125 BHP
2JJS to 250 BHP

Displacement Range: Up to 500 CFM

Cylinders: Single or double acting.
Diameters from 7/8" to 10.5"

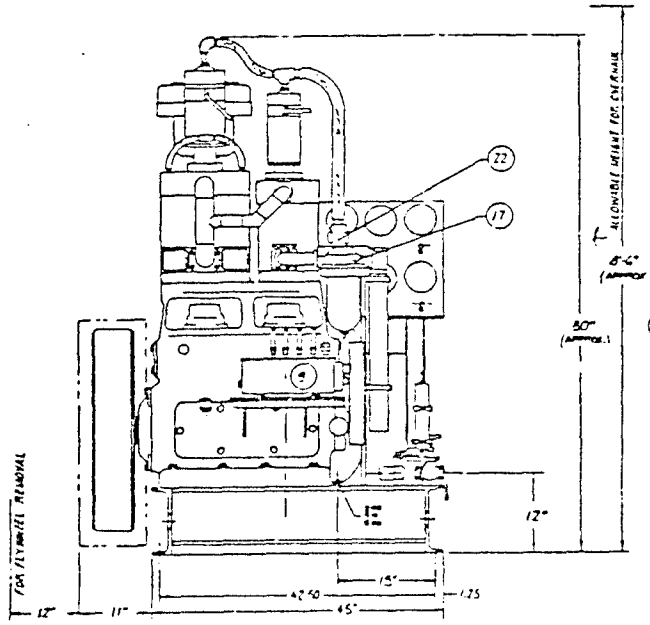
Stroke: 5 inches

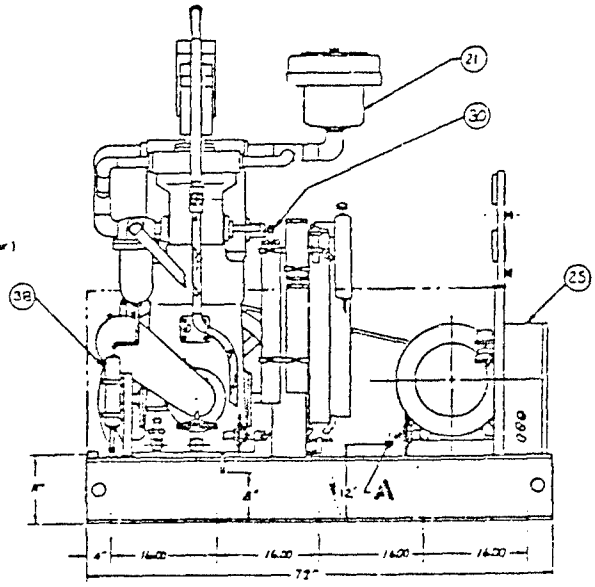
Speed: 300 to 720 RPM



Non-lubricated four stage, double acting, high pressure air/gas compressor.

Dimensions shown are typical





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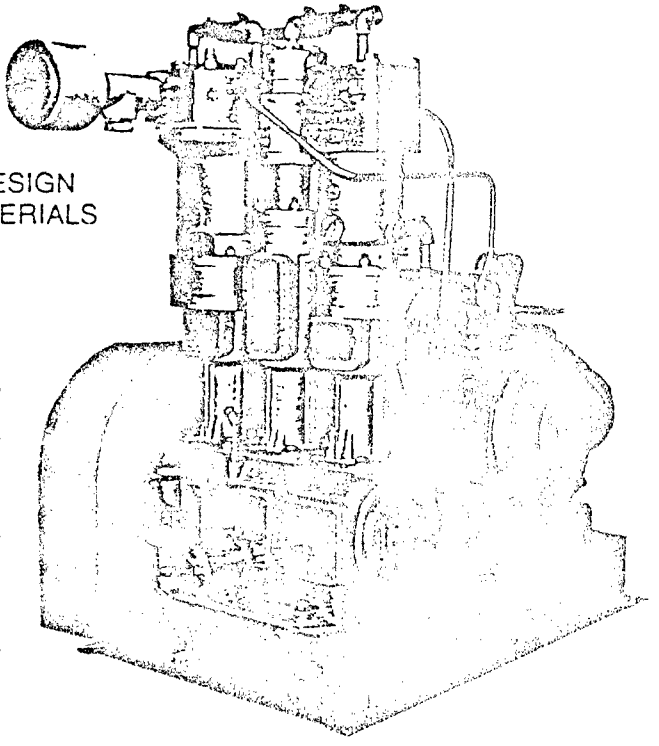
3K3B SERIES
OIL-FREE AIR or GAS COMPRESSORS
For High Pressure Service to 5,000 PSIG

FEATURES

- OIL-FREE CYLINDER CONSTRUCTION
- 3-STAGE COMPRESSION
- CROSSHEAD CONSTRUCTION
- CONTINUOUS DUTY, WATER-COOLED DESIGN
- CORROSION-RESISTANT CYLINDER MATERIALS
- PRESSURE-LUBRICATED CRANKCASE



APPLICATIONS

BREATHING AIR: Fire departments, industrial, SCUBA diving.
FOOD & DRUG: Processing, recycling, recovery of valuable gases.
CHEMICAL PROCESSING: Process gases, recycle gases, high pressure storage.
METAL WORKING: Pad-air for rolling mills, extruders, and forging presses.
PRODUCT TESTING: High pressure valves, actuators, control equipment.
PRESSURE MAINTENANCE: Pad-air or gas for high pressure process and electric switchgear arc suppression.

SPECIFICATIONS *

GENERAL: The exclusive RIX oil-free compressor design protects the air or gas from contamination during compression by utilizing non-lubricated cylinders and corrosion-resistant materials on all air passageways. 3K3B Series compressors feature heavy-duty, crosshead construction with three vertical, in-line cylinders, three-stage compression and water cooling.

CRANKCASE: Enclosed type, full pressure lubricated, with filtered vent and full-flow oil filter.

POWER DRIVE: Belt drive with OSHA guards and electric motor or other prime mover. Please specify driver type when ordering. (See TABLE for required BHP ratings.)

CYLINDERS: First stage; nickel-plated alloy cast iron. Second and third stage; replaceable stainless steel liners.

PISTONS: First stage; aluminum alloy. Second and third stage; machined from solid stainless steel. All piston rods are stainless steel. Piston rings, rider rings, and packing rings, all self-lubricating, fabricated from specially compounded TFE materials.

COOLERS: Inter- and after-coolers with moisture separators. All stainless steel.

BEARINGS: Main bearings: tapered roller. Wrist pin; removable bronze bushing. Con. rod; replaceable steel-backed inserts.

CON RODS: Forged steel.

VALVES: RIX improved design with stainless steel discs and seats.

AUXILIARIES: Units are supplied with safety valves and gauges after each stage. Safety pressure relief system for cooling water circuit.

UNIT MOUNTING: Fabricated steel base.

OPTIONS: (1) Hazardous or corrosive gas applications. (2) Special drives – including engines. (3) Custom controls. (4) Desiccant and refrigerated dryers. (5) High pressure receivers. (6) Filters and scrubbers. (7) Shipboard applications. (8) Cylinder lubrication. (9) Custom super high pressure boosters. (10) Automatic drain traps. (11) Custom design and development.

*SPECIAL CONSTRUCTION AND MATERIALS MAY BE USED WHERE OPERATING CONDITIONS DICTATE

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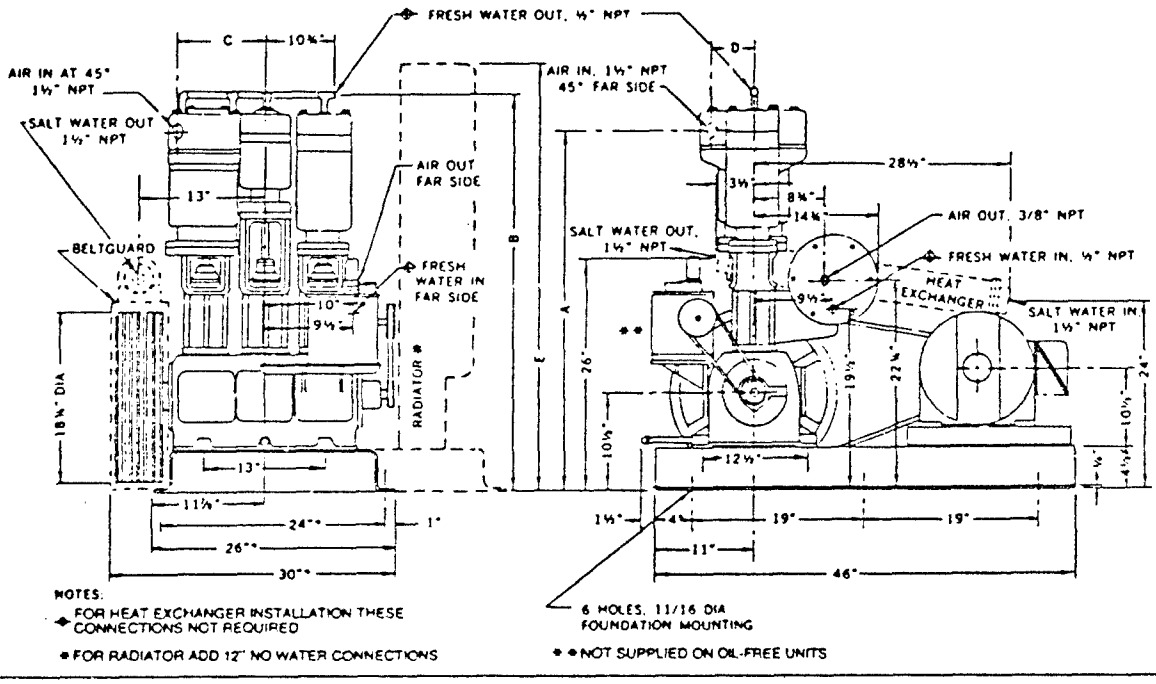
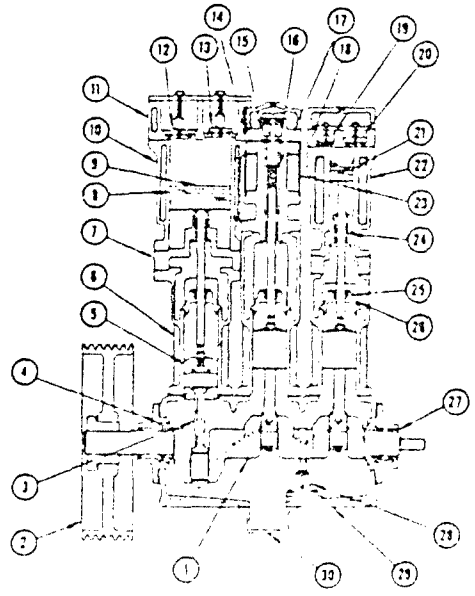
3K3B MODEL SELECTION TABLE

MODEL	MOTOR BHP	CAPACITY (SCFM) @ 3,000 PSIG*	MAXIMUM HEIGHT	LBS. WEIGHT
3K3B-20	15	13	44"	1250
3K3B-30	20	20	46"	1275
3K3B-44	30	30	46"	1390
3KX3B-60	40	40	49"	1650
3KX3B-88	50	52	49"	1775
3KX3B-98	60	60	49"	1900

*Models to 5,000 PSIG available.
Oil lubricated cylinders are available as an option on all models. A selection chart of other size units is available on request.

QUALITY COMPRESSORS FROM RIX





1	Crankshaft	16	Discharge Valve – 3rd Stage
2	Flywheel	17	Piston Rings – 3rd Stage
3	Connecting Rod	18	Cylinder Head – 2nd Stage
4	Tapered Roller Bearing	19	Discharge Valve – 2nd Stage
5	Guide Piston	20	Inlet Valve – 2nd Stage
6	Guide Cylinder	21	Piston Rings – 2nd Stage
7	Gas Seal Box	22	Cylinder – 2nd Stage
8	Piston Rings – 1st Stage	23	Cylinder – 3rd Stage
9	Piston and Rod	24	Gas Seal Rings
10	Cylinder – 1st Stage	25	Oil Seal Rings
11	Cylinder Head – 1st Stage	26	Oil Seal Box
12	Inlet Valve – 1st Stage	27	Crankshaft Oil Seal
13	Discharge Valve – 1st Stage	28	Oil Pump
14	Cylinder Head – 3rd Stage	29	Crankcase
15	Inlet Valve – 3rd Stage	30	Deep Oil Sump

Note: This cross section drawing shows the Rare Gas Closed System [illegible] For normal atmospheric air [illegible]

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On San Francisco Bay since 1978

RIX INDUSTRIES
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Since 1878

November 3, 1989

Commander
Belvoir RD&E Center
ATTN: STRBE-FMT (J. Leary)
Fort Belvoir, VA 22060-5606

Dear Mr. Leary:

Enclosed is more information with regards to the Diving Compressor Packages. I am attaching specification sheets for both the 2JS4B-150 and 2JS2B-300 as well as a photograph of the 150. We need more information from you in order to determine what you will need for your application. We will be in touch by phone to gather more information.

With Regards,

RIX INDUSTRIES

Michael G. Parker
Marketing Manager

MGP:ew

enclosure

[illegible] Oakland CA 94621-1035 USA Phone 415-568-5175 FAX [illegible] 428-9102 Telex [illegible]

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Conoco Oil
Consolidated Steel
Dow Chemical
Dupont
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Exxon
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Guild Associates
Gulf Oil
Hamilton Standard
Hawaii Undersea Research Labs
Howe-Baker Engineers
Lawrence Livermore National Lab.
Linde
Liquid Air
Liquid Carbonic
Litton Industries
Lockheed
Los Alamos Labs
Lucky Goldstar
McDermott
McDonnell Douglas
Melamine Chemicals
Mohalk Lube
Monsanto
Moosehead Breweries
NASA
NAVAIR
Nestle
Newport News Shipbuilding
NOAA
Pacific Gas & Electric
Petro-Canada
Phillips Petroleum
Procter & Gamble
Quantum Chemicals
Sandia National Lab.
Scott Environmental
Shell Oil
Southern Calif. Gas Co.
Standard Oil
Stanford University
Texaco
Texas Eastman
Texas Instruments
Tomco
Tosco Refinery
Tracor Aerospace
TRW
U.S. Armed Forces
U.S. Coast Guard
U.S. Postal Service
U.S. Steel
Union Carbide
Union Oil
University of California
University of Hawaii
University of Rhode Island
University of Texas
University of Washington
Warner Lambert
Westinghouse
Xytel
Xytel-Bechtel

SPECIFICATION SHEET

RIX MODEL 2JS2B-300 - MEDIUM PRESSURE

APPLICATIONS: BREATHING AIR

PRESSURE RANGE: 125 - 500 PSIG

FLOW RATE: 150 - 250 SCFM

HORSEPOWER REQUIREMENT (BHP)

SCFM	(125 PSI)	(200 PSI)	(300 PSI)	(400 PSI)	(500 PSI)	RPM
150	43	50	57	62	69	380-430
200	56	66	76	83	90	510-575
250	70	83	95	104	113	640-720

Note: For motor sizing round up to next standard size

DESCRIPTION:

Two vertical, oil-free, double-acting cylinders on a crosshead design, fully pressure lubricated crankcase. Two stage compression. Fresh water cooling of heads, cylinders, after- and intercooler.* All corrosion-resistant construction of cylinders and plumbing. Automatic moisture separators.

*A closed system using a radiator or fresh-to-raw water heat exchanger is available.

DESIGN ADVANTAGES:

a. Oil-free construction allows use of high dewpoint air directly out of compressor. The need for oil removing filters and alarms is eliminated.

b. Slow speed operation and full water cooling allows for continuous unattended operation (at full pressure) and long life. Reduced operating temperature due to water cooling minimizes water content in discharge air.

c. Unit is compact, smooth running and quiet (average 85 dBA at 3 ft.) and all parts are easily accessible. Floor mounting preferred but not required. Radiator, if used, can be skid mounted or mounted remote to optimize location.

d. Has bronze cylinder/head castings for maximum corrosion resistance and stainless steel cylinder bores for maximum piston ring life.

e. Unit is approved by NAVSEA & NASA for breathing air applications.

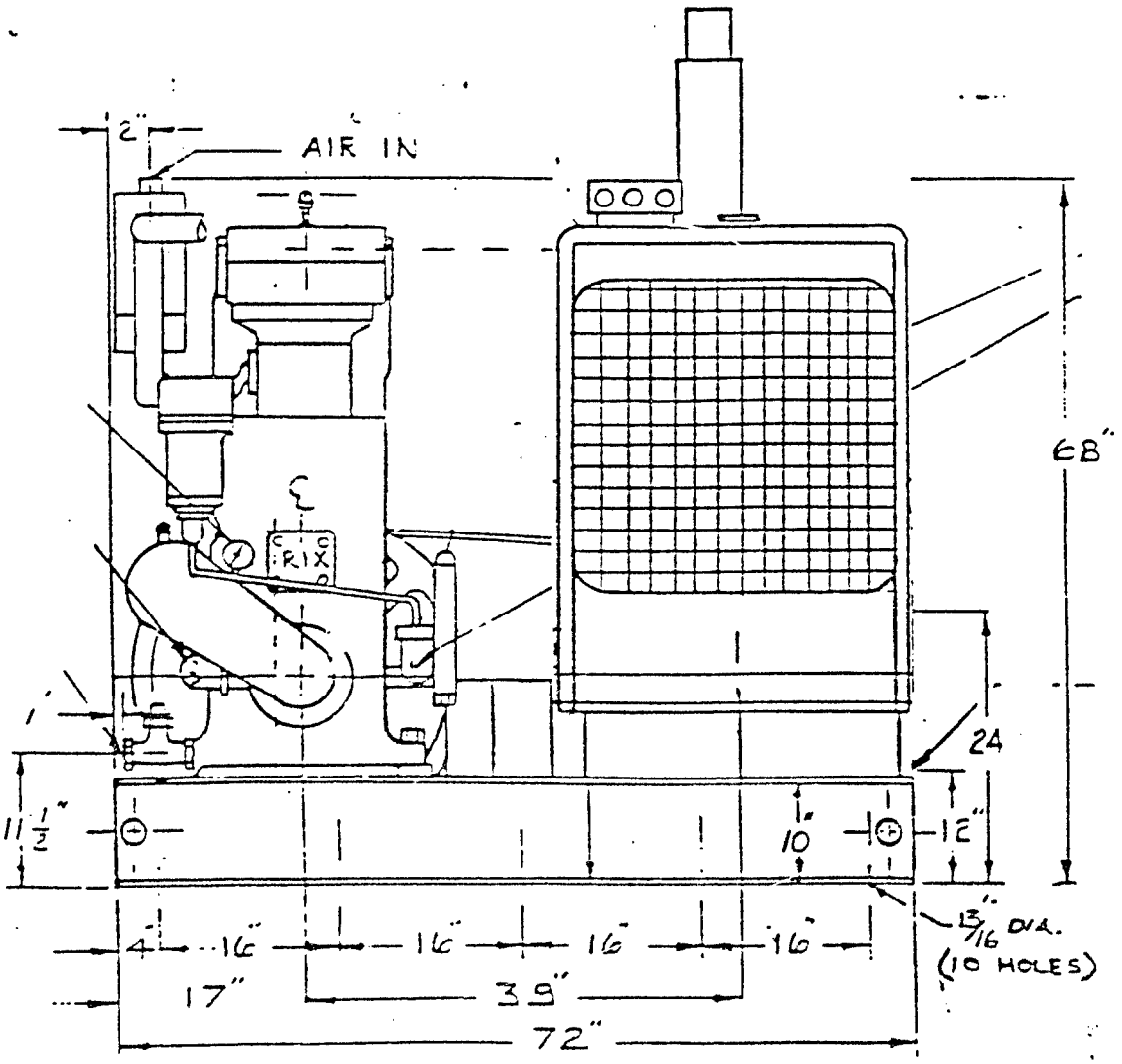
SIZE: 57W x 72L x 62H - Basic unit (motor driven)
57W x 78L x 62H - w/Motor starter skid mounted
57W x 84L x 62H - w/Raw water exchanger and motor starter
75W x 78L x 62H - w/Radiator and motor starter

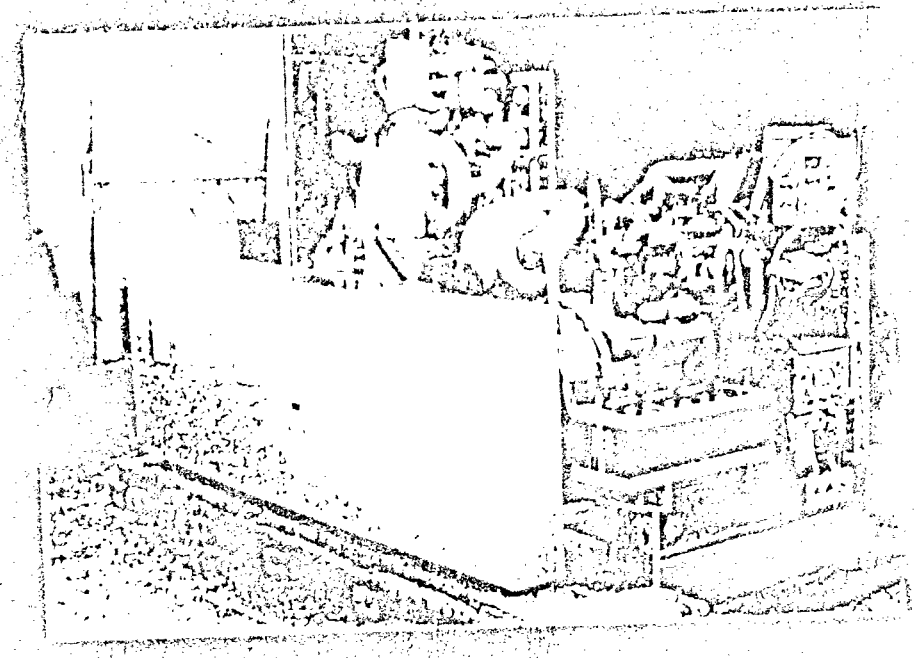
WEIGHT: 4500 lbs; 6000 lbs. w/radiator

COOLING WATER: 0.25 GPM fresh water per horsepower (double for raw water cooling)

11/88

2JS2-300
INSTALLATION ARRANGEMENT





SPECIFICATION SHEET

RIX MODEL 2JS4B-150 - HIGH PRESSURE

APPLICATIONS: BREATHING AIR

PRESSURE RANGE: UP TO 5000 PSIG

FLOW RATE: 60 - 100 SCFM (14.7 PSIA & 60°F Inlet)

SCFM	MOTOR HP: (3,000 PSI)	(5,000)	RPM
68	60	75	420
80	60	75	480
100 *	75	100	600

* 30 CFH (cubic ft/hr) at 3000 psi; 18 CFH at 5000 psi

DESCRIPTION:

Four vertical, oil-free cylinders on a two throw, crosshead design, fully pressure lubricated crankcase. Four stage compression - 1st and 2nd stages on downstroke, 3rd and 4th stages on upstroke. Fresh water cooling of heads, cylinders, after- and intercoolers.* All corrosion-resistant construction of cylinders and piping. Automatic moisture separators.

*A closed system using a radiator or fresh-to-raw water heat exchanger is available.

DESIGN ADVANTAGES:

a. Oil-free construction allows use of high dewpoint air directly out of compressor. The need for oil removing filters and alarms is eliminated.

b. Slow speed operation and full water cooling allow for long life and continuous unattended operation at full pressure. Water cooling keeps discharge temperature low; minimizes moisture carryover and improves performance of dryer/purification systems.

c. Unit is compact, smooth running and quiet (average 85 dBA at 3 ft.) and all components are easily accessible. Floor mounting preferred but not required. Radiator, if used, can be skid mounted or mounted remote to optimize location.

d. Floating piston and RIX patented spiral ring design on high pressure stage provides unequaled reliability and allows 1/2 hour ring change out at a minimum cost (approximately $100).

e. Unit is approved by NAVSEA for Navy breathing air applications.

SIZE: 57W x 78L x 81H - with motor starter(s) and water pump on skid.
Size may vary with optional items - contact RIX sales for further information.

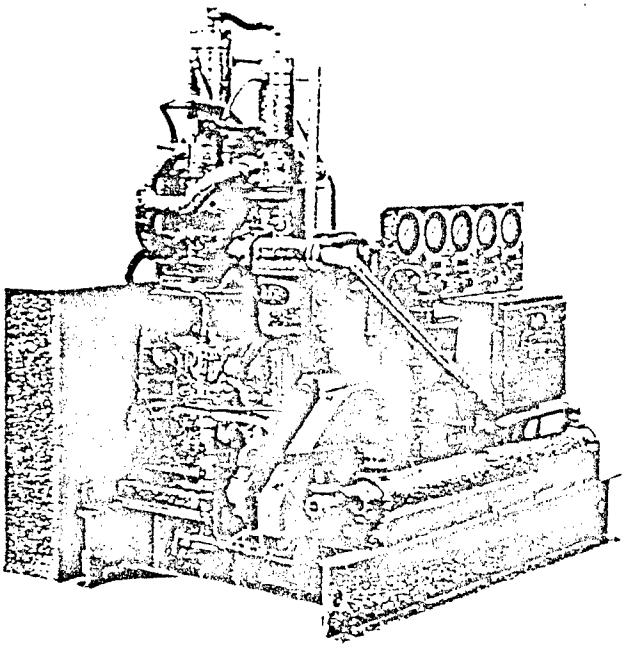
WEIGHT: 5500 lbs.

COOLING WATER: 15-20 GPM (30-40 GPM required with raw water heat exchanger)

2JS B SERIES
OIL-FREE AIR or GAS COMPRESSORS
For High Pressure Service to 5,000 PSIG

FEATURES

- OIL-FREE OR OIL-LUBRICATED CYLINDERS
- 1 TO 4 STAGE COMPRESSION
- CONTINUOUS DUTY, WATER-COOLED DESIGN
- CROSSHEAD CONSTRUCTION
- PRESSURE-LUBRICATED CRANKCASE



APPLICATIONS

BREATHING AIR: Fire Fighting, Industrial, SCUBA Diving.
FOOD & DRUG: Processing, Recycling, Recovery of Valuable Gases.
CHEMICAL PROCESSING: Process or Recycle Gases, High Pressure Storage.
INDUSTRIAL: Plant Air, Product Testing, Engine Starting.
GEOPHYSICAL: Air Guns (Lubricated Model)
VEHICLE FUELING: Natural Gas Storage for Medium to Large Size Fleets (Lubricated Model).

SPECIFICATIONS*

GENERAL: The exclusive RIX oil-free compressor design protects the air or gas from contamination during compression by utilizing non-lubricated cylinders and corrosion-resistant materials in all gas passageways. 2JS Series compressors feature heavy-duty, crosshead construction with two vertical, in-line cylinders, one to four-stage compression and water cooling. The guide cylinder and crankcase are cast into a single piece to assure extra strength and rigidity.

CRANKCASE: Enclosed type, full pressure lubricated, with filtered vent and full-flow oil filter.

BEARINGS: Main bearings; tapered roller. Connecting rod; replaceable steel-backed inserts. Wrist pin; removable bronze bushing.

POWER DRIVE: V-Belt drive with OSHA guards and electric motor or other driver.

CYLINDERS: Low Pressure Stage; nickel-plated alloy cast iron. Intermediate and High Pressure Stages; replaceable stainless steel liners.

PISTONS: Low Pressure; aluminum alloy. Intermediate and High Pressure; stainless steel or bronze. All piston rods are stainless steel. Piston rings, rider rings, and packing rings, all self-lubricating – fabricated from specially compounded TFE materials. (Oil-lubricated models use cast iron compression rings.)

VALVES: RIX concentric ring or poppet design. All stainless steel.

PLUMBING: Inter- and aftercoolers with moisture separators as required. Safety valves and gauges after each stage.

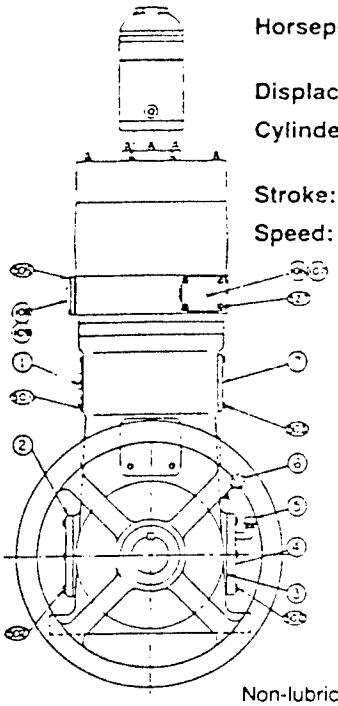
UNIT MOUNTING: Fabricated steel base.

OPTIONS: (1) Hazardous or corrosive gas applications. (2) Cylinder lubrication with TFE Rings. (3) Custom controls. (4) Desiccant and refrigerated dryers. (5) Filters. (6) Pulsation Dampeners. (7) High pressure receivers. (8) Radiator or raw water cooling. (9) Shipboard applications. (10) Custom design and development.

*SPECIAL CONSTRUCTION AND MATERIALS MAY BE USED WHERE OPERATING CONDITIONS DICTATE

RIX INDUSTRIES • P.O. Box 8605 • Oakland, CA 94662 USA • TLX 337724 • (415) 658-5275

RIX COMPRESSORS
2JS SERIES



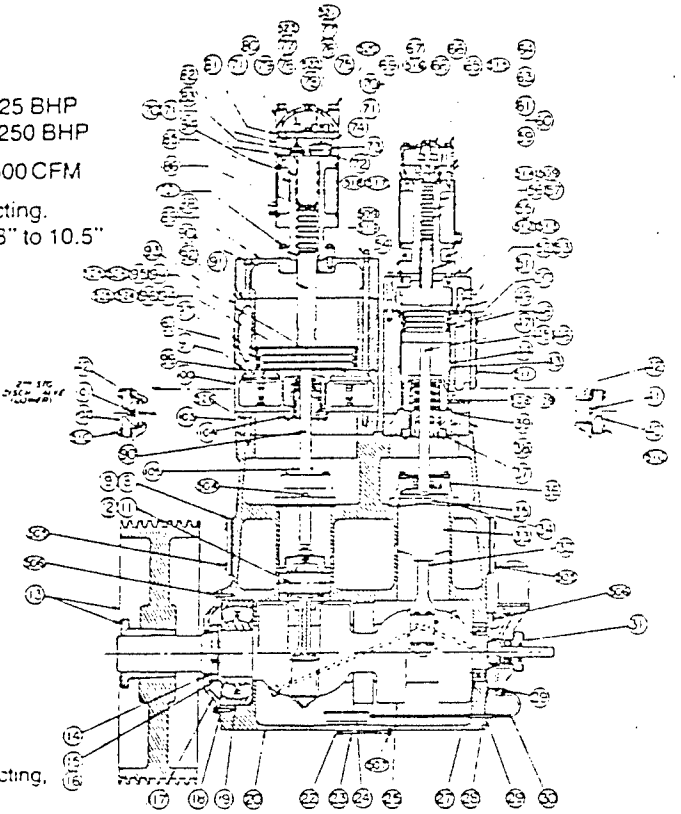
Horsepower Range: 2JS to 125 BHP
2JJS to 250 BHP

Displacement Range: Up to 500 CFM

Cylinders: Single or double acting.
Diameters from 7/8" to 10.5"

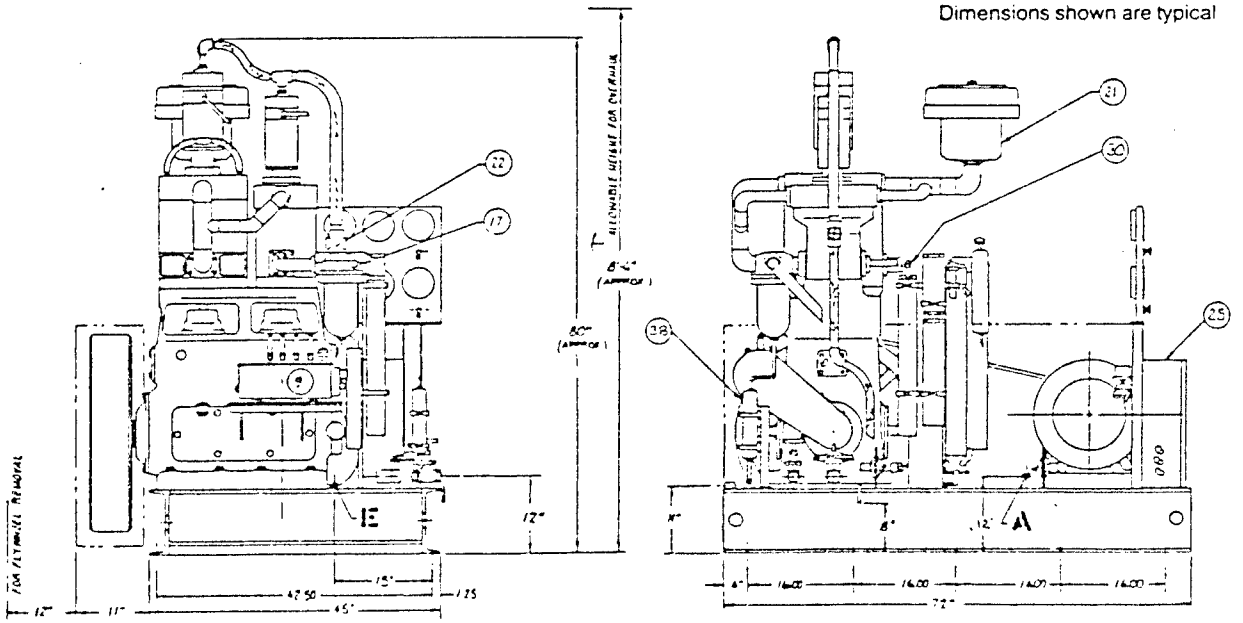
Stroke: 5 inches

Speed: 300 to 720 RPM



Non-lubricated four stage, double acting, high pressure air/gas compressor.

Dimensions shown are typical



DISTRIBUTED BY:

Manufactured by **RIX INDUSTRIES**
6460 Hollis Street • Oakland CA 94608 USA
P.O. Box 8605 • Oakland CA 94662 USA

RIX INDUSTRIES
Air and Gas Compressor Manufacturers
Since 1878

March 20, 1990

Phillip Cartner & Co, Inc.
Management and Service Division
700 N. Fairfax St. Ste 400
Alexandria VA 22313

Attention: Mr. Gregory Nau

Dear Mr. Nau:

Enclosed please find a copy of a report from Franklin Research Center in Philadelphia, Pennsylvania commissioned by the U.S. Navy in 1982. RIX Model 2JS4B-150 air compressor is currently in service with the U.S. Navy and has seen many improvements and innovations over the years.

Please let us know if we can provide more information.

Sincerely,

RIX Industries

Michael G. Parker
Marketing Manager

MGP:ew

enclosure

UPS Overnight

6460 Hollis Street Oakland, CA 94608-1035 USA Phone 415-658-5275 FAX 415-428-9102 Telex 33-7724

HIGH PRESSURE AIR COMPRESSORS

PURPOSE OF STUDY

The purpose of the study was to identify a high-reliability low maintenance high pressure air compressor (HPAC) for shipboard service on the DD963 class ships. The HPAC was to supply air at 67 scfm and 3000 psi. It also was to be water cooled and able to operate in ambient temperatures of 140°F. Both domestic and foreign manufacturers were to be considered, and cost was not held as a factor.

APPROACH

The approach was similar to the approach used to identify a suitable LPAC. Since only reciprocating type compressors are used to produce high pressure air, no survey of general compressor types was necessary, as it was with the LPAC. The first step of the study was to contact as many manufacturers of HPAC's as possible. Table A presents a list of the HPAC manufacturers or distributors who were contacted. The list is divided into two columns, depending on whether the compressors were oil-free (using self-lubricating PTFE rings) or oil-lubricated.

It was important quite early in the study to determine whether an oil-free HPAC would give better reliability and lower maintenance than an oil-lubricated HPAC. It was important to consider not only reliability of the compressor itself but also the reliability of peripheral equipment necessary for each of the two types. For example, an oil-lubricated air compressor requires oil removal equipment to produce the desired product, oil free air,

while oil-free compressors have a much higher rate of maintenance on piston rings. In order to make a decision on this question information was gathered from three major sources:

1. Technical papers. A review of technical papers provided background information, test data, and technical information on state-of-the-art designs.

2. Manufacturers of HPAC's. Manufacturers were asked many questions about their products and about the entire industry. Some manufacturers were visited so that more detailed knowledge of compressors could be obtained.

3. HPAC users, principally military. This includes everyday experience obtained by users including maintenance and repair records. This included a visit to a Belgian Frigate and a U.S. Navy submarine rescue ship.

It was determined that an oil-free high pressure air compressor will give greater reliability and lower maintenance for shipboard service for the following reasons: (NEXT PAGE)

The Decision Regarding the Choice of a HPAC Should be Based Upon These Factors.

Reliability: This includes: previous experience with the design; design conservatism; the reliability of vital parts, such as automatic condensate drain systems, forced oil lubrication of the running gear, moisture separators, and oil removal systems; the service life of high wear parts, such as piston rings, rod seals, inlet and discharge valves; and statistical considerations such as number of parts and mean time between failure (MTBF).

Maintenance: This includes: the frequency and difficulty of routine maintenance tasks or repair tasks, accessibility of high-maintenance items, ease of problem diagnosis, skills required to perform diagnosis and repair, quality of repair manual.

Shock Resistance: It must be demonstrated that the unit passes Navy shock tests.

Inherent Qualities of Design: What choices has the manufacturer made which make his design standout?

Planned Maintenance: A minimum is desireable.

Industrial and Fleet Experience with Identical or Similar Units

HPAC

Table A. Manufacturers or Distributors of High-Pressure Air Compressors

Oil-Free		Oil-Lubricated	
Bristol American	D*	Bristol American	D*
Dreser Clark	B	Davey	S
Hardie Tynes	N	Dresser Clark	B
Ingersoll Rand		Fluitron	DM
ITT	S	Hamworthy	
Norwalk	B	Ingersoll Rand	
Poseidon	N	Joy	D
Pure-Pac	B	Kellogg-American	D
Rix		LMF	
Worthington		Luchard	N
		Mako/Bauer	
		Norwalk	B
		Poseidon	N
		Reavell	
		Rix	
		Worthington/Atlas Copco	
		Weir-Alley	N

*Key: B compressors too big
D distributor of compressors
DM diaphragm type only
N no information or no longer made
S To SMALL

!Doc. No. 5723P/ajo!

INGERSOLL-RAND

HPAC

Meeting with Bill O'Gorman. Noted by C.H.R. Topics which were discussed during the meeting:

Chief blame for failures of Ingersoll Rand high pressure air compressors was given to:

1. Failure in the part of ship's force to follow the instruction manual.
2. The Navy practice of obtaining replacement parts such as valves, rings, seals, and so on, from lowest bidders, who usually turn out to be non-original-equipment manufacturers.
3. Improper interface between compressor and ship, for example, overpressure and excessive flow in the salt water cooling water supply, leading to cooler failures. This happens on the FFG class ships.
4. Limitations which current will specs impose upon the compressor design.
5. Lack of proper training among ship's forces to adequately maintain the compressors.

Comments:

1. Ingersoll Rand and Worthington high pressure air compressors are very similar in design, "comparing apples to apples", while RIX compressors are seen in "comparing apples to oranges". This comment is important because it means W. O'Gorman sees a RIX in a different catagory than IR or Worthington. He did not elaborate why.
2. Bill questioned whether RIX, with 4-stage compression, is actually able to keep below the 340°F temperature limit at each stage of compression.
3. Major failure item on Ingersoll Rand HPAC is the third stage rod seal.

BASIC DESIGN CONSIDERATIONS - HPAC

	RIX	INGERSOLL RAND (IR)	WORTHINGTON
Block Type	vertical, water cooled	vertical, water cooled	vertical, water cooled
Number of Throws	two	three	three
Number of Stages	four	five	five
Ring Type	carbon-filled PTFE for oil-free compression	filled PTFE for oil-free compression sleeve seal on high stages	filled PTFE for oil-free compression sleeve seal on high stages
Model Number	2JS8-150	N20NL-10	13 SLANT 20 NL-30
Pressure	3000 (to 5000) psig	3000 (to 3500) psig	3000 (to 4500) psig
Capacity	60-100 scfm	67 scfm	67 scfm
Power	40-67 HP (belt drive)	48 BHP	55 HP
Weight	4300 lbs.		5550 lbs.
Drive	belt	direct	direct

20 cfm-3000
67

BASIC DESIGN CONSIDERATIONS - IPAC (Continued)

	RIX	INGERSOLL RAND (IR)	WORTHINGTON
Compressor Action	third stage tandem above first stage fourth stage tandem above second stage stages 1 and 2 compresson downstroke stages 3 and 4 compress on upstroke	first stage double acting on center throw fourth stage tandem above second stage fifth stage tandem above third stage stages 2, 3 compress or downstroke stages 4, 5 compress on upstroke	first stage double acting, motor end fifth stage tandem above third stage on center throw fourth stage tandem above second stage outboard end.

OVERALL DESIGN - HPAC

	RIX	INGERSOLL RAND (IR)	WORTHINGTON
	A simple, basic, effective design Compressor does not appear cluttered. Having four stages rather than five keeps complexity to a minimum. The design is a great deal simpler than the IR design, especially the piping system. RIX is built heavy and rugged.	A more complex design than the RIX, and only because it has one more stage of compression The amount of and complexity of piping is an obvious feature of the IR IR is built heavy and rugged	Essentially the same design as the IR Equal complexity, and no obvious advantages or improvements compared to the IR design Worthington and IR use essentially the same coolers, temerature monitors, auto drain systems, separators.
SPECIAL TOOLS	Does not require special maintenance tools.	Requires special maintenance tools	

RELIABILITY - HPAC
AUTOMATIC CONDENSATE DRAIN SYSTEMS

	RIX	INGERSOLL RAND (IR)	WORTHINGTON
Approach	Demand type drain system, sensitive to actual rates of condensate accumulation	Clock-type drain system operating on a fixed cycle, insensitive to rate of condensate accumulation.	IR shear-seal valve (Barksdale) design was borrowed from Worthington.
Problems and Experience	Drain nozzles occasionally become plugged and must be cleared (10 minute job) During test by DTNSRDC, the float-actual [illegible] magnetic reed switches performed erratically (April 78). Rix thinks differently about this. Says problems have been remedies.	Malufnctions of this system have been a major cause of compressor unreliability. Condensate reentrainment is occurring on some units.	Worthington mentioned a new cam shaft method to be used on condensate drain system. Present system is the Barksdale with ultrasonic water detector. System has been problem prone.

RELIABILITY - HPAC

DESIGN CONSERVATISM AND NUMBER OF PARTS

ESIGN CONSERVATISM	When Rix comes up with a design that works well, they do not change it; for example, their basic compressor is exactly the same unit for both LP and HP. Result: reliable designs and many interchangeable parts between HPAC and LPAC	IR is not conservative when it comes to component changes and system complexity. The IR HPAC seems to get more complex with time rather than less complex.	No interchangeable parts between HP and LP.	
UMBER OF PARTS	The Rix HPAC has fewer parts than the IR or Worthington HP compressors have			

RELIABILITY - HPAC.
VALVE TYPES AND VALVE LIFE

	RIX	INGERSOLL RAND	WORTHINGTON	
INLET VALVE TYPE				
1st Stage	case hardened plate valve	channel valve	feather valve	
2nd	case hardened plate valve	Ring Valve w/split springs	feather valve	
3rd	poppet valve	Ring Valve w/ split springs	plate valve	
4th	poppet valve	Ring Valve w/ split springs	poppet valve	
5th	N/A	Ring Valve w/ split springs	poppet valve	
DISCHARGE VALVE TYPE				
1st Stage	case hardened plate valve	Channel Valve	feather valve	
2nd	case hardened plate valve	Ring Valve w/ split springs	feather valve	
3rd	poppet valve	Ring Valve w/ split springs	plate valve	
4th	poppet valve	Ring Valve w/ split springs	poppet valve	
5th	N/A	Ring Valve w/ split springs	poppet valve	
			the same valve is type is used for inlet and discharges just flip it over.	
VLVE LIFE			Stages 3, 4, 5 2000 hours Stages 1, 2 6000 hours.	

MAINTENANCE - HPAC
ACCESSIBILITY TO HIGH MAINTENANCE PARTS

	RIX	INGERSOLL RAND	WORTHINGTON	
OVERALL	Excellent.	Not Acceptable		
COMMENTS	The most notable feature of the RIX to those who work on them is how very easy they are to work on. Everything is simple and basic. Nothing mysterious. Parts are accessible.	Users seem to find IR compressors difficult to service A major problem is the complex piping system. Often piping must be removed to perform basic maintenance tasks, such as ring changeout. Case in point: to adjust the seawater regulating valve requires the removal of numerous pipes, making a simple adjustment very time-consuming.	same as IR.	

MAINTENANCE - HVAC

PISTON RINGS

	RIX	INGERSOLL RAND	WORTHINGTON	
Ring Life:				
5th Stage	N/A		2000 h	
4th Stage	1000 h	2000 h	2000 h	
3rd Stage	~2400 h	2000 h	10,000 h (predicted)	
2nd Stage	~2400 h	2000 h	8,700 h (predicted)	
1st Stage	~18000 h.	6000 h	30,000 h (predicted)	
		6000 h		
me to Change Rings				
5th Stage	N/A		(4h combined stages)	
4th Stage	30 minutes (floating piston)		4 and 5, sleeve seals	
me to Change All Rings in Compressor	15 man-hours		40 ih rough estimate.	
st for set of high-stage rings	$93.00, 10 rings, fourth stage		$1000.00	
			Third stage rings and seals are the least accessible.	

MAINTENANCE - HPAC
SHUTDOWN AND PROBLEM DIAGNOSIS

	RIX	INGERSOLL RAND	WORTHINGTON	
	Control system has first-out indication; so that cause of shutdown can be traced. automatic shutdown for protection against over pressore, overtemperature, high water in moisture separators	automatic shutdown for protection against overpressure, over-temperature; high water in moisture separators also has first-out indication to trace source of shutdown.	Very similar to IR system.	

ADDITIONAL ADVANTAGES / DISADVANTAGES - HPAC

	RIX	INGERSOLL RAND	WORTHINGTON	
ock Tested HPAC	Rix does not presently make a shock tested HPAC, but will have no trouble producing them	IR presently makes a shock-tested HPAC.	Worthington has shock tested units.	
anual	Rix manual is much less detailed than the IR manual. Considerably more detail will be needed for ships forces.	IR manual is very detailed. Very generous with drawings and paragraphs on every item. Question: is the manual so detailed that it is confusing or imposing?		

Rix Industries – Features of HPAC

1. Lots of interchangeable parts

   - Same block, crankshaft, bearings for LPAC, MPAC, HPAC compressors

   - if they find something that works well they do not change it; use it on all models.

2. Free-floating 4th stage piston for easy changeout.

3. Channel by-pass system used on fourth stage cylinder to obtain seal against cylinder walls.

   How it works: compressed air from high pressure region passes through drilled channel to the inside of the next lower pressure ring. There it expands on O-ring, which causes teflon spiral ring to expand against cylinder wall.

4. Achieves 3,000 psi compression with four stages instead of five. Fewer rings, valves, and moving parts.

5. Uses automatic level sensing devices to operate the automatic condensate drain system, one for each interstage moisture separator. Ingersoll Rand and Worthington use the clock (rotary drain valve) system instead.

6. Rix uses disk valves on stages 1 and 2, poppet valves on stages 3, and 4. Apparently have achieved good performance. Valve seats are casehardened for longer life. Ingersol Rand uses channel valves on stages 1, 2, and 3 and ring valves on stages 4 and 5.

7. Rather than try to obtain the MIL spec 2,000 hour life on 4th stage rings, Rix attains 1,000 hour life on the 4th stage rings and instead makes it very easy to change the rings. Remember the fourth stage is a floating piston.

8. Rix compressors are very easy to work on; high maintenance items are very accessible and the general layout is simpler than Ingersoll Rand or Worthington designs.

!Doc. No. 5723P/ajo!

TRIP REPORT: VISIT TO RIX INDUSTRIES

May 24, 1982

C. H. Robinson, Research Engineer, Franklin Research Center

PURPOSE OF TRIP:

The purpose of the trip was to develope a greater technical knowledge of RIX Industries HP and LP air compressors, to have a look at their manufacturing facilities, to meet RIX engineering and mechanical personnel, and to visit air compressor installations where RIX compressors are being used.

OBTAINED

1. Technical Manual, Compressor, 125 psi, 100 scfm, oil-free, general service air Model 2JS2B-150. Operating, maintenance, and installation instructions published by direction of Commander, Naval Sea Systems Command S6220-AZ-MMD-010/2JS2B-150. The compressor is made by RIX Industries, 6460 Hollis Street, Emeryville, California 94608

2. RIX Industries Company Profile: facilities, management, references and users list

3. 40-hour Performance Test data for initial run-in of a RIX 2JS2B-150 LPAC

4. List of contacts with experience using RIX HP and LP air compressors

5. Photographs, technical drawings, and technical information on RIX Model 2JS2B-150, -130, and 2JS4B-150 LP and HP air compressors

6. Diagram of RIX moisture separator condensate dumping system with failure shutdown

7. Navy Maintenance Task sheet for equipment test and maintenance of RIX 2JS3B-150

8. Start-up and Periodic Maintenance schedules used at Navy Land Based Breathing Air Facility at Coronado Island, San Diego, CA, for two RIX 2JS2B-150 LP air compressors

RESULTS OF VISIT

A. Date: 5/20/82

Place: RIX Industries LPAC Production Facility, 855 Stenari Way, Sparks, Neveda

People: Bert Otterson, Vice President, RIX Industries,
Mike Povey, Mechanical Technician, RIX Industries
Frank Tadder, Material Manager, RIX Industries

Action: Observed and inspected a RIX Model 2JS2B-150 LP air compressor (the B signifies oil-free). Asked many questions about reliability, access to high-maintenance parts, design features, design or operational limitations, and so on. Traced the flow of air through each valve, cylinder, pipe separator, and cooler. Traced out flow of seawater cooling system, freshwater cooling loop, and condensate removal system. Looked at every regulator and sensor. Identified features such as water pump, oil pump, solenoids, oil dipstick, and so on. Handled valves, rod seals and items such as condensate level sensors from the parts stock.

FINDINGS OR OBSERVATIONS

1. Valve changes are simple to do and require about 20 minutes to change for a given stage. For example, the inlet and discharge valves for the second stage would take about 20 minutes to replace. Time required for other maintenance tasks will be given later.

2. Observe that the RIX 2JS2B-150 is very solidly built. There is nothing mysterious about the layout of the piping. Everything on the unit makes sense, and there is nothing there that doesn't make sense.

3. Heat transfer efficiency is increased by direct use of salt water cooling in 1st and 2nd stage counter flow air-to-water heat exchangers instead of using a prior salt-to-fresh-water heat exchanger. A salt-to-fresh-water heat exchanger is used to coll freshwater for jacket cooling.

4. Condensate carryover is never a problem for the first stage, so first stage ring life can be very good. At 6,000 hours the first stage rings generally show almost zero wear.

5. The RIX moisture separator condensate dumping system appears good. A guided float in the bottom of the separator trips magnetic sensors in the guide to indicate high level or low level of condensate. Should the high level sensor not work a still higher shut-off sensor is provided. The signal form the level sensor operates a solenoid drain

valve. Each stage has an independent level sensor and drain valve. Manual drains are of course provided. Valves and solenoids are easily accessible.

6. The one problem with the condensate drain systems is that small particles can foul or plug the drain nozzles. Should this happen, the high-condensate level sensor will shut off the compressor. Condensate can still be drained manually. It takes 30 minutes to dissassemble the drain valve, clear it, and reassemble it. I saw this done.

7. The controls indicate the source or cause of a shutdown. whether due to over-pressure, over-temperature, plugged drain, or other causes.

B. Date: 5/21/82

Place: RIX Industries, 6460 Hollis Street, Emeryville, CA

People: Bert Otterson, Vice President
John Below, Chief Engineer
Ernie Harper, Field service
Ron Ronenburg, Mechanic
Jack Hall, Sales Manager

Action: a) Observed and inspected RIX Model 2J4B-150, which is used for charging Navy LSD high-pressure flasks. The unit is a self-contained, housed HPAC with closed freshwater cooling loop (radiator-cooled water) and replaceable cartridge-type HP air dehydrators. Traced air and cooling water flow routes. Gave particular attention to the 3rd and 4th stage cylinders since these were the major change from the 2J2B-150. Asked many questions as before.
b) Viewed RIX production facility and talked with several engineers and mechanics.
c) Examined valves and rods taken from stock. Particular attention to poppet valves.

FINDINGS OR OBSERVATIONS

1. The RIX HPAC is as sensibly laid-out as the LPAC, the chief differences being:

    a. addition of 3rd stage above 1st stage, and 4th stage above 2nd stage

    b. stages 1 and 2 compress on the downstroke and stages 3 and 4 on the upstroke

    c. inlet and discharge valves of stages 1 and 2 are somewhat less accessible in the HP design because they cannot be accessed through the top of the cylinder, but must be reached through access plates in the sides of the cylinders. Still, valves are accessible and easy to change.

    d. the addition of coolers and separators and condensate drain systems for the high stages.

2. The rings on stages 3 and 4 are very easy to change. It is a half-hour job for either one. For the 4th stage the cylinder head is removed, and the floating-type (slug) piston is easily drawn out by screw threads. For the 3rd stage the cylinder can be carefully lifted off the piston to replace the rings. The cylinder can than be settled back into place.

C. DATE: 5/21/82

Place: Naval Land Based Breathing Air Facility, Naval Surface Force, U.S. Pacific Fleet, Coronado Island, San Diego, CA

People: Chief Fred Baker, full responsibility for operation of two RIX HPAC's for Navy Land Facility
Bert Otterson, Vice President, RIX Industries

Action: Observed and asked questions about the two prototype RIX Model 2JS2B-15 units installed in their facility since 1977. Examined spent valves and a blown moisture separator. Obtained sheets on maintenance taks schedule. Had a look at two newly-installed RIX Model 2JS4B-150 units.

FINDINGS OR OBERSVATIONS

1. Chief Baker likes the RIX's very much, intends to order two more. His chief praise is that the compressor are so very easy to work on.

2. Ring life obtained on these prototype unit:

   - 800 hours on 4th stage rings
   - 2,400 hours on 3rd stage rings
   - no estimate on 2nd stage rings
   - never had to change 1st stage rings

   the rings are carbon or bronze-filled TFE.

3. The problem of excessive wear on valve plates and seats for the prototype has been solved by case-hardening the seats and plates in all present versions. Worn valves were occasionally reconditioned by lapping.

4. It would take three men 5 hours to replace all the rings on the HPAC.

5. The prototype compressors have aluminum heads which suffer from a corrosion problem due to the (chemically-hard) cooling water passed through the compressor in a single pass arrangement. All later models have stainless or bronze heads, which do not suffer the corrosion problem.

6. Obtained a Planned Maintenance System (PMS) list of monthly checks and a list of sample pressure readings.

D. Date: 5/21/82

Place: ASR Florikan (Auxiliary Submarine Resuce Ship) Naval Surface Force, San Diego, CA

People: Charlie Moore, Master-diver
Bert Otterson, Vice President, RIX Industries

Action: boarded the Florikan and was admitted to the engine room to have a look at the ship's compressors:
- two High Pressure Air Compressors (HPACs) 2J4B-150 (100 scfm, 3,000 psi) (in service since 1977)
- two Medium Pressure Air Compressors (MPAC) 2JS2B-150 (150 scfm, 400 psi) (in service since 1981)

FINDINGS AND OBSERVATIONS

1. Filters and separators were installed in-line with the compressed air but no dehydrator was used, either for the MPACs or the HPACs.

2. C. Moore's answers to questions about his RIX compressors: He said that no rings have been replaced yet on two HPACs installed in 1977, and that the chief replacement item was valves (discharge or inlet?). No record of time in operation was available. The manuals could not be found. The maintenance logs unfortunately were sent out and were to be returned during the following week, but Chief Baker offered to obtain the compiled maintenance report of the Navy on all its RIX compressors and to send a copy to FRC.

3. The compressors and the entire engine room were kept very clean and well painted. Motors were DC powered.

CONCLUSION OF REPORT

A good deal of technical and practical knowledge was obtained. Useful contacts were made with Navy and RIX personnel. The RIX plants were observed in operation. Through Chief Baker it will now be fairly easy to get access to Navy Pacific Fleet experience with air compressors and related equipment.

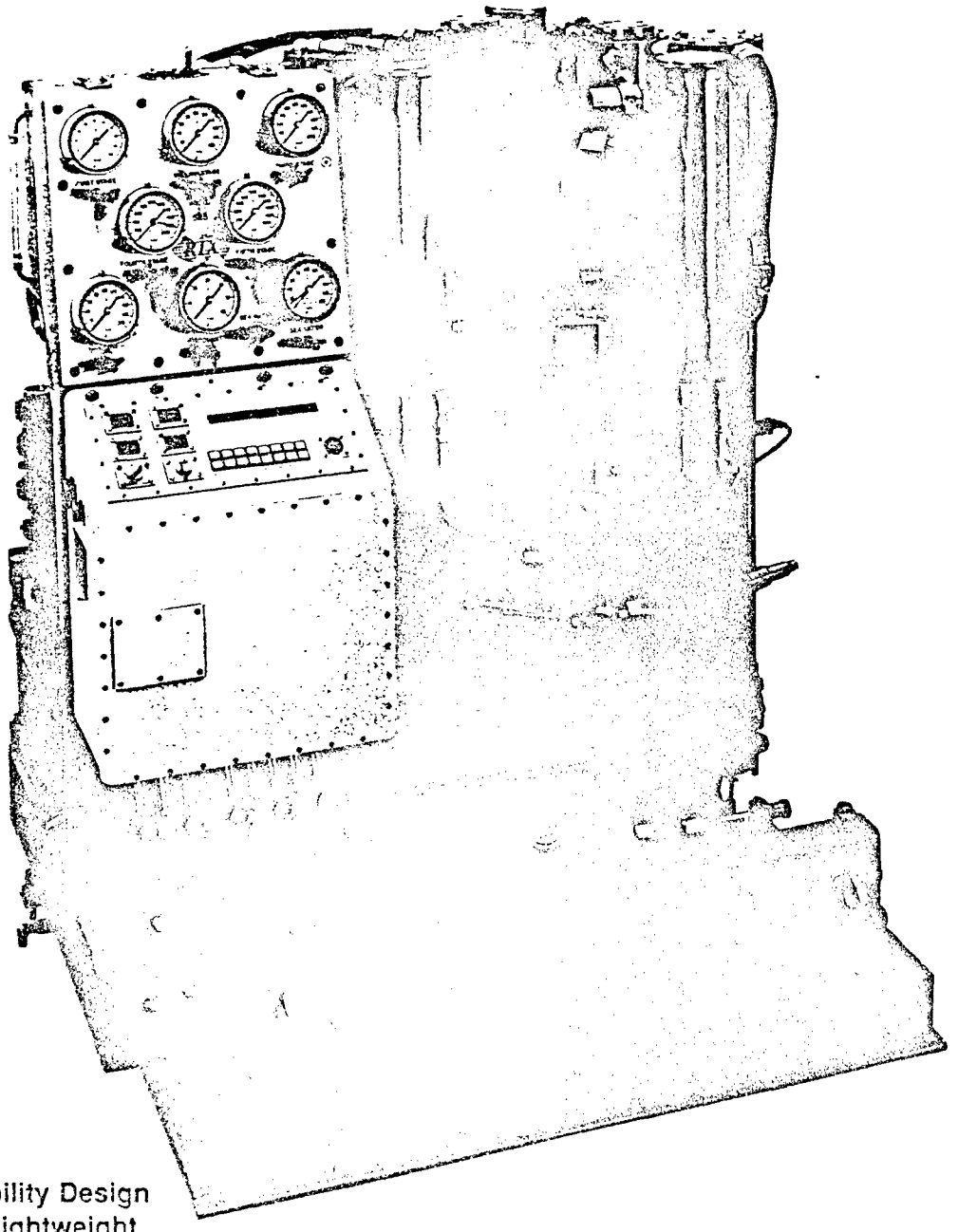
COMMENT ON RIX: The RIX organization is preceived as well-organized, efficient, and capable of responding to Navy needs. Also impressive is the apparent compentence of the organization as a whole and the organized, clear thinking of Bert Otterson in particular. It is felt that RIX makes a superior compressor, whether HP or LP. It should be noted that many parts are used in common with the HP and LP models built with the J crankcase style. A most outstanding quality of the RIX compressors is that they are so easy to work on.

4. Various land-based locations - a) such as submarine charging system with dryer package - 7 locations - 17 compressors (100 SCFM @ 5,000 psi), commencing 1976; b) other locations are land-based breathing air operation such as Coronado - 2 units in 1976, 2 in 1982.

RIX Industries 5R5

High Pressure • Oil Free

AIR COMPRESSORS



- Oil Free
- High-Reliability Design
- Compact, Lightweight
- Low Structural and Airborne Noise
- Exceeds US Navy Specifications for
  Surface Ships, Submarines, and Aircraft Carriers

Now in production for the USN

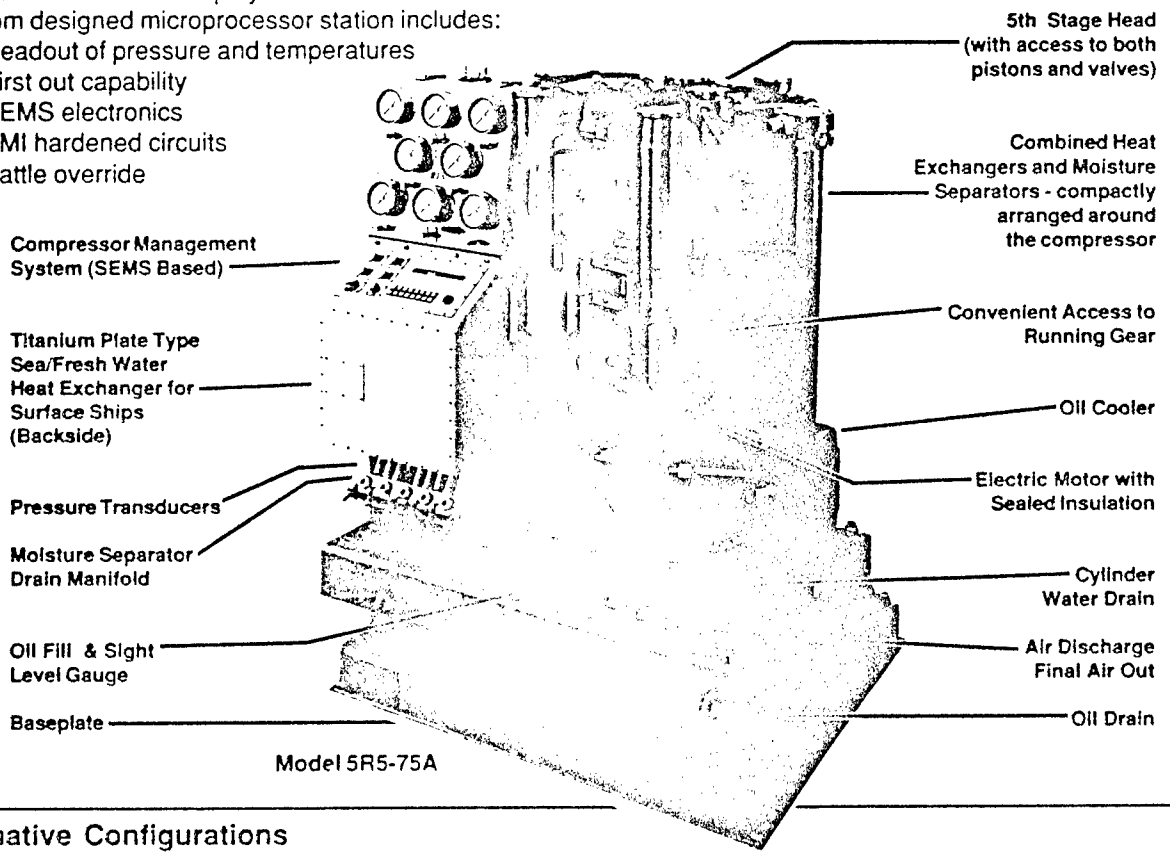
5R5 High Pressure Air Compressors

Key Design Characteristics for Reliability and Maintainability

- Oil free 5-stage unit.
- Swash-plate direct drive design provides easy access to major components for maintenance.
- RIX floating piston design facilitates easy change-out.
- All five stages are single acting - no packing required.
- Efficient moisture separation and a demand type drain system.
- Valves are all on top and accessible without piping removal.
- Deflection valves are employed for maximum life.
- Custom designed microprocessor station includes:
  - Readout of pressure and temperatures
  - First out capability
  - SEMS electronics
  - EMI hardened circuits
  - Battle override

NOISE LEVELS (typical)
- Airborne: 78 dba (a weighted broadband)
- Structureborne (@ 15 hertz): < 95 db

US NAVY QUALIFIED for -
- High Shock
- Vibration
- EMI
- Software Support



Model 5R5-75A

Alternative Configurations

Model	5R5-75A	5R5-75B	5R5-75S*	5R5-75C
Pressure	3000 psig	4500 psig	4500 psig	4500 psig
Capacity	70-75 scfm (22CFH)	70-75 scfm (14CFH)	70-75 scfm (14CFH)	85 scfm (17CFH)
Weight	3900 Lbs.	3900 Lbs.	3300 Lbs.	4100 Lbs.
Space	51L x 34W x 59H	51L x 34W x 59H	34L x 34W x 52H	51L x 34W x 59H

Design features subject to change without notice

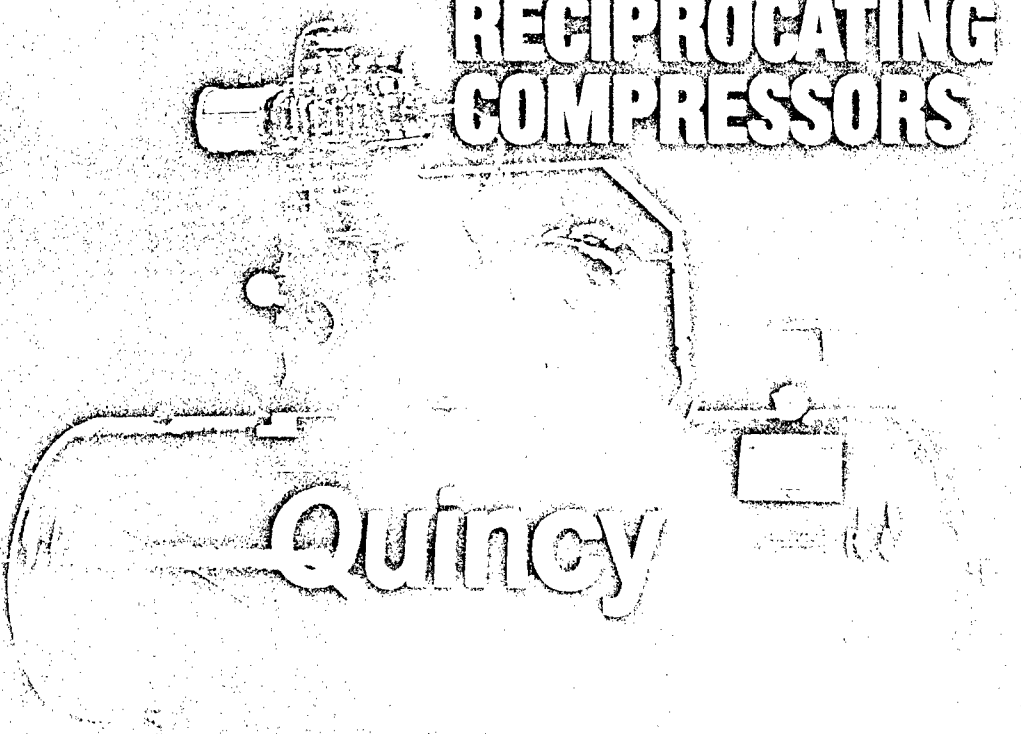
** Hatchable on submarines*

manufactured by RIX INDUSTRIES
6460 Hollis Street • Oakland, CA 94608 USA
• Phone 415-658-5275
• FAX 415-428-9102
• Telex 33-7724
On San Francisco Bay since 1878

5R5 09 P3

QUINCY COMPRESSOR

QUINCY QR-25 SERIES RECIPROCATING COMPRESSORS



QR-25 ... the BEST a

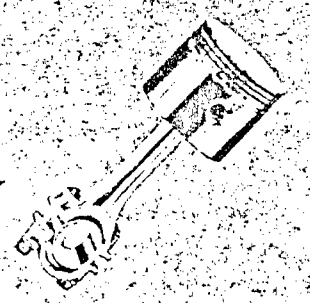
The QR-25 Performance Story...

QR-25 is uniquely qualified to be the best. With continuous duty capa
standard for reciprocating compressors

What Makes It Better?

In a reciprocating compressor, three areas are critical to performance. They are:

1. *Cylinder and Pistons*
2. *Valve design*
3. *Running gear design*

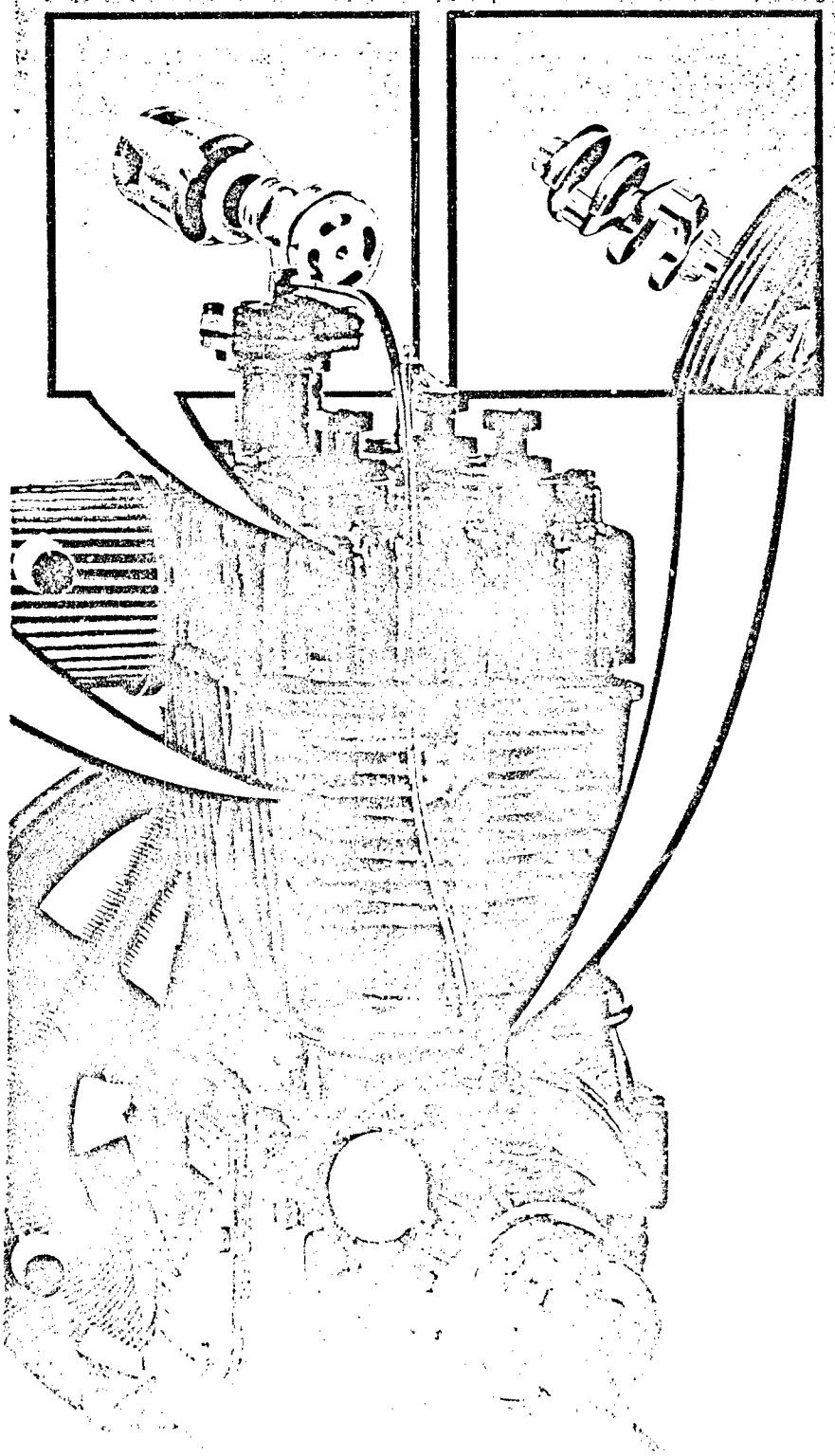


Cast Iron Cylinders...
Balanced Pistons...
Efficiency and Easy Maintenance

Valves...Disc type for
Efficiency and Life

compressor you can buy!

high efficiency, high pressure capability, and longest life. Quincy sets the



Higher Pressure?
QR-25's distinguish themselves from the rest of the reciprocating competitors with the high pressure capability. All of the two stage basic compressors are capable of continuous operation at 200 PSIG and intermittent duty up to 250 PSIG. Several of the QR-25 compressors can be rated to perform at pressures up to 500 PSIG. This is due to the heavy duty design of the QR-25.

Running Gear... Low Vibration, Long Life

The [illegible] of the reciprocating compressor [illegible] life [illegible]

The rest of the story... Safe-Q-Lube!

Pressure Lubrication

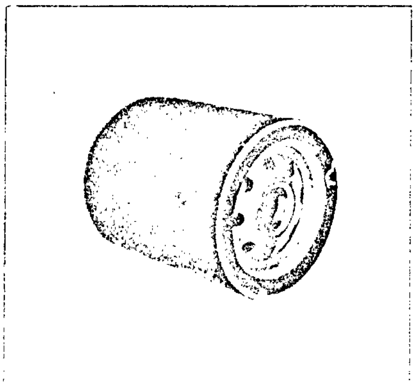
The most common cause of major failure for a reciprocating compressor is friction created by poor lubrication. QR-25 compressors use a positive displacement oil pump to constantly lubricate all critical areas. The wrist pins, crank pins, and bearings all receive a full flow of lubrication through oil-flow passages. They don't simply rely on the chance that some oil will "splash" onto the right area.

Loadless starting

The Quincy patented loadless starting system employs oil pressure and air pressure from the receiver to keep the compressor unloaded during startup. [illegible]

Oil Filter - maximum protection

[illegible]



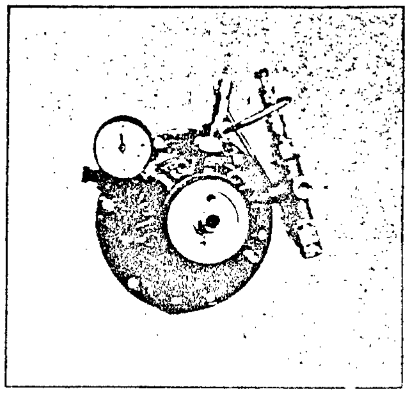
Head unloaders

"Energy Saving" Optional Dual Control operation

The compressors can be run in standard stop-start modes or continuous run. The dual control option gives you the ability to select either mode, depending upon the demand for air. If demand is less than 50% of the capacity, start - stop should be used. Usage greater than 50% would be better suited for the continuous run mode. This enables you to match the compressor operation to your air system.

Reversible oil pump

The oil pumps can be manually reversed so that the compressor can be run with alternate power sources which may require opposite rotation.



QR-25 ... it gives you more!

QR-25 Series Basic Single Stage Compressors

Specifications
Splash
Lubricated

MODEL	MOTOR OR ENG. H.P.	CFM F.A.D.	OPER. PRESS. PSI	OPER. SPEED R.P.M.	APPROX SHIPPING WT.-LBS
X2-8	⅓ ½	.90 1.80	100 100	503 897	17 17
X2-10	⅓ ½	1.10 1.80	100 100	570 897	17 17
X-3	½ ¾	1.70 2.60	100 100	538 808	25 25
X8	1 1½	3.30 5.20	100 100	508 799	38 38
~~A4~~	½ ¾	1.56 2.70	100 100	400 692	65 65
~~106~~	½ ¾	1.50 2.30	100 100	410 628	95 95
103	1 1½	3.00 4.60	100 100	526 821	105 105

Obsolete

Specifications
Pressure
Lubricated

MODEL	MOTOR OR ENG. H.P.	CFM F.A.D.	OPER. PRESS. PSI	OPER. SPEED R.P.M.	APPROX SHIPPING WT.-LBS
206	½ ¾	1.30 1.80	100 100	421 586	17 63
210	1 1½	2.90 4.50	100 100	451 691	63 63
~~214~~	2	6.60	100	766	70
216	2 3	7.40 10.63	100 100	628 900	145 145
~~220~~	3 5	12.50 18.00	100 100	626 900	235 235
240	5	19.30	100	760	235
~~245~~	7½	28.60	100	786	375
4125	15 20	61.80 81.40	100 100	711 937	800 800

QR-25 Series Basic Two-Stage Compressors

Specifications
Pressure
Lubricated

		PRESSURE P.S.I.G.								
		100		150		200		250		
MODEL	MOTOR H.P.	OPER. SPEED R.P.M.	CFM F.A.D.	OPER. SPEED R.P.M.	CFM F.A.D.	OPER. SPEED R.P.M.	CFM F.A.D.	OPER. SPEED R.P.M.	CFM F.A.D.	APPROX SHIPPING WT.-LBS
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.60 6.03	[illegible]	3.84 5.30	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10.90	[illegible]	9.90	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

QUINCY COMPRESSOR

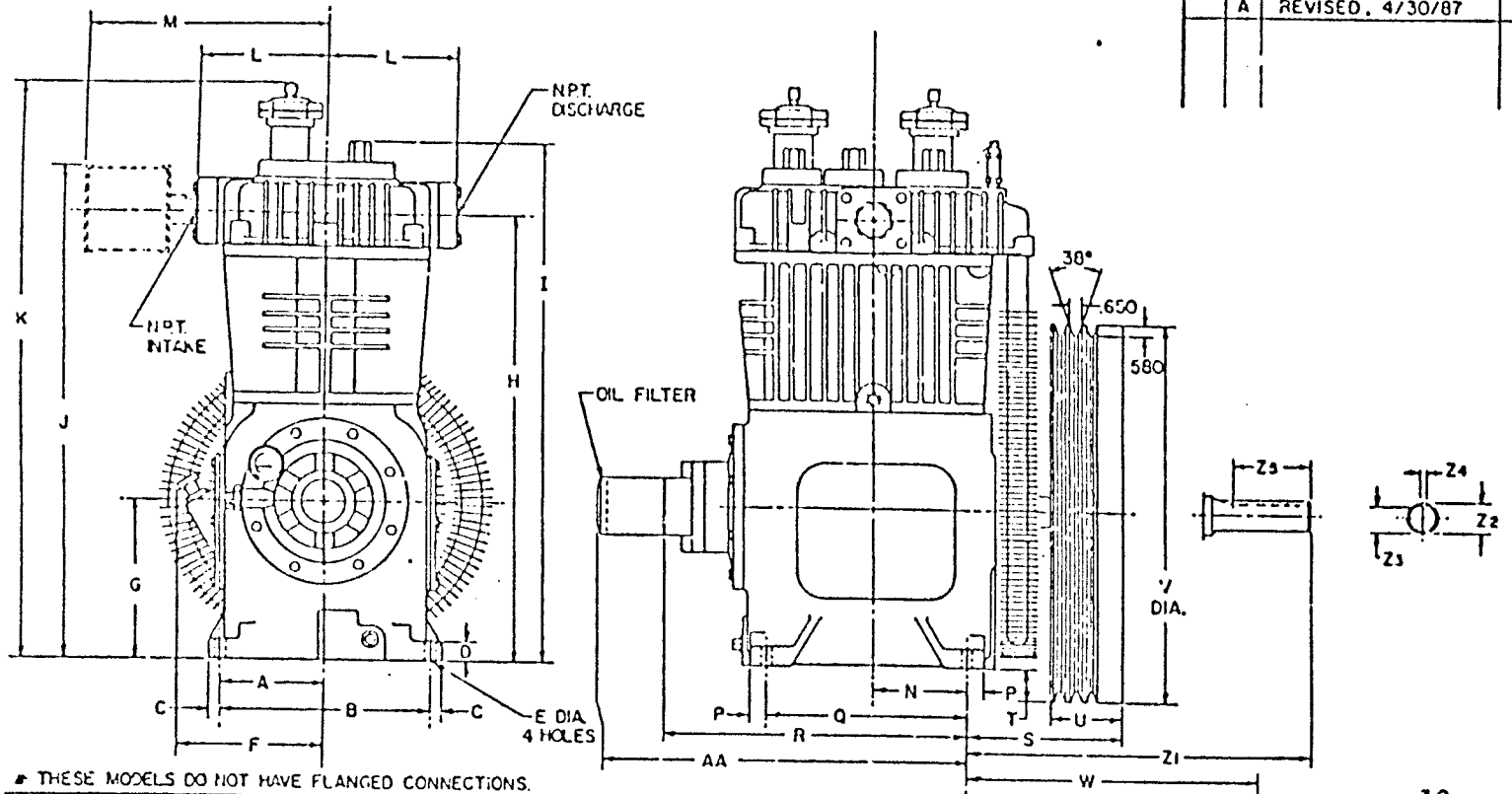
Manufacturing the World's Finest Air Compressor

The Mechanic's Story

Quincy

Colt Industries

	A	REVISED, 4/30/87



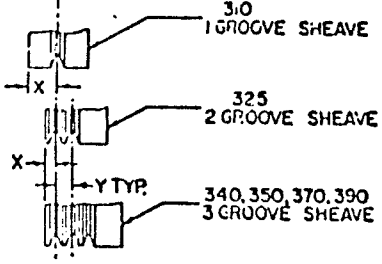
* THESE MODELS DO NOT HAVE FLANGED CONNECTIONS.

LEGEND

	MODEL	SIZE	N.P.T. INTAKE	N.P.T. DISCHARGE	A	B	C	D	E	F	G	H	I	J	K	L	M
*	310	3½ Ø 2 x 2½	3/4	3/4	3.69	7.38	.56	.62	.41	5.19	5.38	15.07	18.46	17.92	21.00	3.00	6.44
*	325	4½ Ø 2½ x 3	1	3/4	4.69	9.38	.50	.69	.50	6.12	5.88	18.12	21.53	20.38	24.44	4.12	9.94
	340	5¼ Ø 3 x 3½	1½	1¼	5.38	10.75	.62	1.00	.56	7.94	8.25	23.31	26.97	25.56	29.84	6.53	12.34
	350	6.8 3¼ x 3½	2	1¼	5.38	10.75	.62	1.00	.56	7.94	8.25	23.94	27.62	26.94	30.50	7.16	13.66
	370	6.8 3¼ x 4	2	1¼	5.38	10.75	.62	1.00	.56	7.94	8.25	24.19	27.83	27.19	30.75	7.16	13.66
	390	7½ Ø 4 x 3	2½	1½	6.38	12.75	.75	1.00	.69	8.06	9.00	26.53	30.62	29.53	33.75	7.59	13.91

LEGEND

MODEL	N	P	Q	R	S	T	U	V	W	X	Y	Z1	Z2	Z3	Z4	Z5	AA
310	3.38	.56	7.50	11.96	5.75	1.62	3.00	14.00	4.25	1.50	N/A	5.62	1.44	1.06	2.59	2.00	15.03
325	4.12	.62	9.12	13.69	6.81	2.12	3.00	16.00	4.31	.50	.75	5.81	1.69	1.31	3.19	2.98	17.03
340	4.75	.88	10.25	15.21	7.88	1.50	3.75	19.50	4.62	.50	.75	6.88	2.00	1.56	3.81	3.88	18.55
350	4.75	.88	10.25	15.21	9.25	1.50	3.75	19.50	6.00	.50	.75	8.25	2.00	1.56	3.81	3.00	18.55
370	4.75	.88	10.25	15.21	9.25	1.50	3.75	19.50	6.00	.50	.75	8.25	2.00	1.56	3.81	3.00	18.55
390	5.12	1.00	11.00	17.34	12.50	2.75	5.00	23.50	8.00	.50	.75	12.00	2.00	1.56	3.81	4.00	20.64



Y BLACK	M-B	DIMENSIONS OF AIR COOLED STAND ARD TWO STAGE COMPRESSORS
		EDA1268

APPENDIX (D)

Miscellaneous Calculations

Contains Calculations for Emergency Air supply requirements, capacity of standard high pressure flasks and the minimum number of flasks needed to pressurize the recompression chamber and minimum number needed to bring divers back up safely from several mission scenarios.

Emergency Air Requirements:

General equation used for determining air needed to bring divers to the surface safely (SCF of air). From Navy Diving Manual.

D = depth
V = Cubic feet per minute per man
N = number of divers
T = time at depth

$$SCF = \frac{D + 33}{33} * V * N * T$$

Assumed scenario #1.

Three divers down for maximum time covered in Navy Air decompression tables at 250 FSW when compressor fails. (240 Minutes) (this is an extreme exposure dive)

Divers need 4.5 ACFM during decompression.

Accent rate is 60 FPM (feet per minute)

Depth (FSW)	Time (minutes) (decomp. table)	SCF (standard cubic feet)
160	9	710.6
150	14	1048.1
140	21	1486.2
130	22	1467.0
120	22	1377.0
110	40	2340.0
100	40	2176.4
90	42	2113.4
80	56	2588.7
70	76	3202.3
60	98	3728.5
50	100	3395.5
40	114	3404.5
30	122	3144.3
20	142	3078.8
10	187	3289.5
	total	38,550.8 SCF
	accent	269.3 SCF

Air necessary for transit from 250 to zero.

250 f = 4.17 minutes, Average depth 125 FSW
60 f/min

SCF = 269.3 TOTAL 38,820.1 SCF

Emergency Air Requirements Cont.:

Assumed scenario #2

Three divers down for maximum time that is not considered an extreme exposure dive at 190 FSW when compressor fails. (40 minutes)

Divers need 4.5 ACFM during accent

Accent rate is 60 FPM

Depth (FSW)	Time (minutes) (decomp. table)	SCF (standard cubic feet)
40	8	238.9
30	14	360.8
20	23	498.7
10	55	967.5
	Total	2,065.9 SCF
	Accent	165.8 SCF

Air necessary for transit from 190 to zero.

190 f = 3.17 minutes, Average depth 95 FSW
60 f/min

SCF = 165.8 TOTAL 2,231.7 SCF

Emergency Air Requirements cont.:

Number of SCF needed to pressurize decompression chamber from one atmosphere. (14.7 psia)

General Equation:

$$P1 * V1 = P2 * V2$$

P1 = 14.7 psia
V1 = ?
P2 = 88.4 psia
V2 = 236 cubic feet

From 0 psia it takes 1,419 SCF to reach 88.4 psia or 165 FSW in recompression chamber.

From 1 atmosphere it takes 1,419 - 236 = 1183 SCF

Air available in DOT 6000 high pressure flask.

Equation used for this calculation is from the Navy Diving Manual.

Pf = flask pressure (psig), 5000 from Army Hp compressors
Pmf = minimum flask pressure (psig), 350 assumed
MMP = minimum manifold pressure (psig), 250 from 250FSW + 135 psig overpressure for MK Mod 0
V = volume of the flask CFFV (cubic feet floodable volume), 1.528

$$\text{SCF available} = \frac{Pf - Pmf - MMP}{14.7} * V$$

SCF available per flask is 457 SCF.

This section covers the calculations that yield the minimum number of DOT 6000 air flasks necessary for emergency purposes.

1. For the RECOMPRESSION CHAMBER - 3 bottles

$$\frac{1183}{457} = 2.6$$

2. Other Cases
   A. 250 FSW, No compressor (hp)
   B. 190 FSW, No compressor (hp)
   C. 250 FSW, 1 compressor (hp)
   D. 190 FSW, 1 compressor (hp)
   E. 250 FSW, 2 compressor (hp)
   F. 190 FSW, 2 compressor (hp)

The high pressure compressors in question are 5000 psig, 20 CFM FAD units.

Case (A):

$$\frac{38{,}820 \text{ SCF}}{457 \text{ SCF/bottle}} = 85 \text{ bottles}$$

Case (B):

$$\frac{2{,}232 \text{ SCF}}{457 \text{ SCF/bottle}} = 5 \text{ bottles}$$

Cases C through F are more complicated than the first two cases. Air is being put back into bottles from the high pressure compressors at the same time cylinders are being drained by the divers. The rate the divers use the air varies with the depth while the refill rate is constant. It is a step function and the problem of minimum flasks was solved with a table. These solutions do not take into account the temperature variations at different depths and the final numbers do not take into account transit time between depths. Transit time air consumption is a small part of the total. Finally, all rates are based on the emergency conditions described earlier in this appendix.

The table presented has several columns. Here, we will explain what each column represents and how the numbers in that column were generated.

Column #1: This is simply the depth in FSW.

Column #2: This is the time spent at that depth.

Column #3: This is the number of bottle used at this depth. It is the number of SCF used divided by the number of SCF of air in a standard bottle

Column #4: This is the number of flasks filled by two (2) 20 CFM FAD 5000 PSIG compressors in the time spent at that depth.

Column #5: This is the difference between the number of flasks filled and the number of flasks used. (Column #4 - Column #3)

Column #6: This number is the summation of column #4 up to that depth. This is the important number. The largest negative number that appears in this column is the minimum number of full flasks that are necessary, before the dive begins, for emergency purposes. Positive numbers indicate an excess number of flasks. This column is for two high pressure compressors and flasks as the emergency air supply. (Case (E))

Column #7: This is the number of bottles filled by one (1) 20 CFM FAD 5000 PSIG compressor in the time spent at that depth.

Column #8: This is the difference between the number of flasks filled and the number of flasks used. (Column #7 - Column #3)

Column #9: This number is the summation of column #8 up to that depth. This is the important number. The largest negative number that appears in this column is the minimum number of full flasks that are necessary, before the dive begins, for emergency purposes. Positive numbers indicate an excess number of flasks. This column is for one high pressure compressor and flasks as the emergency air supply. (Case (C))

This table is for Case (C) and Case (E).

#1 DEPTH (fsw)	#2 TIME (min)	#3 USED (bot's)	#4 FILL (bot's)	#5 DIF. (bot's)	#6 TOTAL (bot's)	#7 FILL (bot's)	#8 DIF. (bot's)	#9 TOTAL (bot's)
160	9	1.56	0.79	-0.77	-0.77	0.39	-1.16	-1.16
150	14	2.29	1.23	-1.07	-1.84	0.61	-1.68	-2.84
140	21	3.25	1.84	-1.41	-3.25	0.92	-2.33	-5.18
130	22	3.21	1.93	-1.28	-4.53	0.96	-2.25	-7.42
120	22	3.01	1.93	-1.09	-5.62	0.96	-2.05	-9.47
110	40	5.12	3.50	-1.62	-7.24	1.75	-3.37	-12.84
100	40	4.76	3.50	-1.26	-8.45	1.75	-3.01	-15.85
90	42	4.62	3.68	-0.95	-9.40	1.84	-2.79	-18.64
80	56	5.66	4.90	-0.76	-10.17	2.45	-3.21	-21.85
70	76	7.01	6.65	-0.36	-10.52	3.33	-3.68	-25.54
60	98	8.16	8.58	+0.42	-10.10	4.29	-3.87	-29.41
50	100	7.43	8.75	+1.32	-8.78	4.38	-3.05	-32.46
40	114	7.45	9.98	+2.53	-6.25	4.99	-2.46	-34.92
30	122	6.88	10.68	+3.80	-2.45	5.34	-1.54	-36.46
20	142	6.74	12.43	+5.69	+3.24	6.21	-0.52	-36.98
10	187	7.20	16.37	+9.17	+12.41	8.18	+0.99	-36.00

For Case (C), 250 FSW, one compressor, 37 bottles + one for transit are needed for an emergency supply. 38 Bottles.

For Case (E), 250 FSW, two compressors, 11 bottles + one for transit are needed for an emergency supply. 12 Bottles.

This table is for Case (D) and Case (F).

Column #6 is for Case (F) and Column #9 is for Case (D)

#1 DEPTH (fsw)	#2 TIME (min)	#3 USED (bot's)	#4 FILL (bot's)	#5 DIF. (bot's)	#6 TOTAL (bot's)	#7 FILL (bot's)	#8 DIF. (bot's)	#9 TOTAL (bot's)
40	8	0.52	0.70	+1.77	+0.18	0.35	-0.17	-0.17
30	14	0.79	1.23	+0.44	+0.61	0.61	-0.18	-0.35
20	23	1.10	2.01	+0.92	+1.54	1.01	-0.08	-0.43
10	55	2.12	4.81	+2.70	+4.23	2.41	+0.29	-0.14

For Case (D), 190 FSW, one compressor, 1 Bottle

For Case (F), 190 FSW, two compressors, will have an excess of 4.23 Bottles