

1994

# Development of a High Pressure, Oil Free, Rolling Piston Compressor

S. J. Delmotte  
*Dresser-Rand*

Follow this and additional works at: <https://docs.lib.purdue.edu/icec>

---

Delmotte, S. J., "Development of a High Pressure, Oil Free, Rolling Piston Compressor" (1994). *International Compressor Engineering Conference*. Paper 1033.

<https://docs.lib.purdue.edu/icec/1033>

This document has been made available through Purdue e-Pubs, a service of the Purdue University Libraries. Please contact [epubs@purdue.edu](mailto:epubs@purdue.edu) for additional information.

Complete proceedings may be acquired in print and on CD-ROM directly from the Ray W. Herrick Laboratories at <https://engineering.purdue.edu/Herrick/Events/orderlit.html>

## **DEVELOPMENT OF A HIGH PRESSURE , OIL FREE, ROLLING PISTON COMPRESSOR**

Scott J. Delmotte  
Dresser-Rand Co.  
Painted Post, NY 14870

### **ABSTRACT**

In shipboard environments, maintainability and high reliability coupled with low noise, size and weight are of paramount importance. Dresser-Rand has investigated an alternate oil free compressor for high pressure Naval compression service offering improvement in these areas of design. Research efforts have focused on the rolling piston compressor concept utilizing water for lubrication, sealing, and cooling. This compressor is currently in the development stage with a prototype unit being evaluated. This paper presents a qualitative introduction to the Dresser-Rand design and development efforts for this new application of the rolling piston compressor.

### **INTRODUCTION**

The rolling piston compressor has proven to be a successful design in the refrigeration industry, demonstrating high reliability and good performance. The simplicity of the design lends itself to be a viable candidate in applications that may be thought of as the traditional realm of other compressor varieties. One such application is the supply of high pressure air on board Naval vessels. Traditionally, this role has been filled by reciprocating compressors utilizing lubricated crankcases, distance pieces, and non-lube air end components. These designs have inherent reliability limitations and the everpresent danger of oil contamination of the airstream. Certainly, a compressor capable of eliminating any oil from its mechanism and exhibiting improved reliability characteristics would be beneficial; a water lubricated rolling piston compressor could do this. Such a compressor could also be advantageous in other applications prohibiting the presence of oil.

### **DESIGN CRITERIA**

Design criteria commensurate with existing shipboard high pressure air compressors requires oil free air delivery of 60-70 SCFM, 3000 psig discharge pressure. A service life of 2000-6000 hours is considered acceptable for most air end wearing components. Compressors require militarized hardware accessories, and the complete package must be robust enough to withstand the full compliment of high impact shock and vibration testing.

A new compressor design was investigated to meet these criteria and excel in eliminating the shortcomings experienced with existing machines. The high pressures required for such service severely limit the compressor selection process, certainly defining a window of current technology applicable only to reciprocating machinery. Investigation involving previously compiled data on alternate compressor designs and drawing upon a pool of available expertise, the rolling piston design was chosen as a most viable selection for development of a unit capable of such pressures.

### DESIGN FEATURES

The rolling piston design offers many features which would be advantageous for shipboard service, as well as other applications. Some immediate advantages are:

- fewer wearing and total parts than a reciprocating unit
- inlet valves are not required
- smaller size and weight attainable utilizing high speed operation
- modular running gear and cylinder
- ease of machinability due to simple part geometries
- oil free compression
- interstage condensate removal not required.
- higher compression ratios attainable yielding fewer stages

### Lubrication

A totally oil-free compressor for both the cylinders and the running gear prevents any possibility of system oil contamination. While dry operation is not feasible, water is an acceptable lubricating fluid from an air system standpoint. A design was chosen utilizing a journal bearing approach with force feed water lubrication. Nonmetallic bearings suitable for water and compatible with limited dry operation are used.

Water is also injected into the compressor inlet to act as internal lubrication to the machine. Some bearing lubrication will migrate into the compression pocket, especially at the low pressures. Similarly, leakage of process stream water around the piston faces will occur and mix with the bearing discharge. This fluid commonality eliminates the potential need for internal sealing devices found in other water injected compressor designs. In addition to acting as a lubricant, the injected water's purpose is two-fold. First, it assists in sealing the compressor's leak paths, both internally from discharge to suction chambers and externally from compression chambers to bearing outlets, and second it cools the gas stream.

Compression occurs in four stages, as listed in table 1. In the multistaging, lubricant is injected into the first stage and carried through the successive cylinders. In this system,

interstage cooling is not utilized and condensate removal is not required. This configuration allows reduced system complexity and reduces both cost and overall package weight. Water and air are cooled after the final stage and the gas and liquid stream are separated. Cooled water is then recirculated to cylinder bearings and to the 1st stage inlet(fig. 1).

### Construction

Large quantities of water circulating through the cylinders necessitates special considerations with respect to the compressor valves. Reed valves are utilized in the first, third, and fourth stages while the second stage operates with a plate type valve. In conjunction, the maximum number of valves have been introduced to the gas passage to permit the least obstruction to water flow.

A major advantage of the rolling piston over the reciprocating compressor is the lack of piston rings. For non-lube applications, piston rings are generally the items with the lowest expected life. This reliability gain is a weighted advantage however. When operating at the higher pressures without piston rings, the cylinder efficiencies will lag those of a reciprocating unit. In the absence of rings, as with other rotary units, minimizing clearance is crucial to achieving higher pressures. In all cases, clearances in each cylinder have been reduced to the realistic minimum and cylinder parameters have been designed to yield the greatest volumetric efficiency advantage. Also, the water in the system assists in minimizing gas leakage by obstructing the gas paths. Higher operating speeds also contribute to increased system performance. Cylinder speeds of 3600 for the lower stages and 7000 RPM for the upper stages are selected to balance the opportunities of increased efficiency with the mechanical constraints of the rest of the package.

The third and fourth stage designs are similar, while other stages are distinct and different to accommodate both the physical and pressure disparities of successive stages(fig 2-4). A unique split cylinder employed in the first stage allows more accurate vane slot machining and also reduces stresses in the slot area. The clinch cylinder design of the second stage permits adjustable axial piston clearance. Vane slot stress concentration is eliminated and a positive external seal is maintained with this assembly. The high pressure cylinders utilize 2 vanes per cylinder in order to achieve a more favorable bearing load profile. A pressure containing outer ring is assembled independent of the inner cylinder sections in order to contain the higher working pressures.

### **PROTOTYPE TESTING**

Manufacture and testing of four cylinder sizes has been performed in the Dresser-Rand Panted Post, N.Y. research facility. Reliability, efficiency, and maintainability aspects of each

alternate design continue to be evaluated at the inception of this paper. Short term operation of the unit at 3000 PSIG and stable operation at 2000 PSIG has been achieved. Sustained testing of the lower pressure stages of the compressor verify the viability of these designs for the compressor package as well as in stand alone applications. Future development efforts will continue to focus on reliability improvements of the high pressure cylinders.

Much of the testing has centered upon enhancing the tribological activities of the wearing components in the water lubricated environment. Vane/cylinder and vane/piston couples have required the most extensive experimentation, as might be expected. Composites, metallics, and ceramics are now utilized throughout the unit. Future testing will concentrate upon optimizing operating variables such as water flows and injection pressures to the bearings and airstream to reach an equitable balance of efficiency and reliability. The best features of each of the different cylinder designs are now evident and can be included in any future applications.

#### CLOSING REMARKS

The concept of high pressure 3000 PSIG air delivery utilizing a totally water lubricated compressor has been demonstrated. The feasibility of such a high pressure oil free rolling piston compressor for shipboard and other nonlubricated applications appears promising.

STAGE NUMBER	DISCHARGE PRESSURE (PSIG)	SPEED (RPM)	CYLINDER DIAMETER (IN)	STROKE (IN)
1	100	3600	6.75	.50
2	500	3600	3.75	.20
3	1500	7000	2.00	.09
4	3000	7000	2.00	.09

TABLE 1. OPERATING SPECIFICATIONS

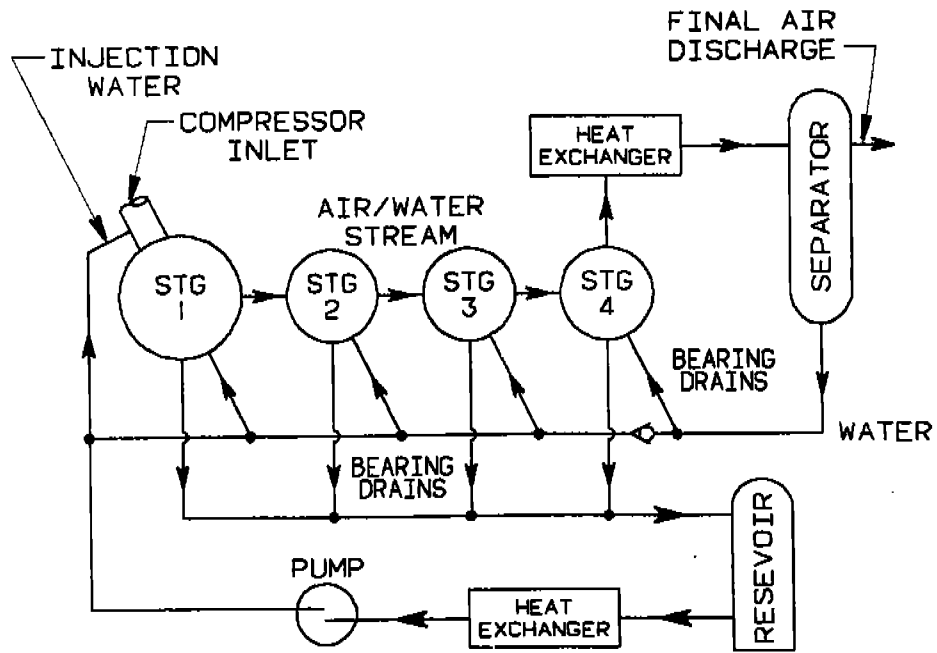


FIGURE 1 - SYSTEM FLOW DIAGRAM

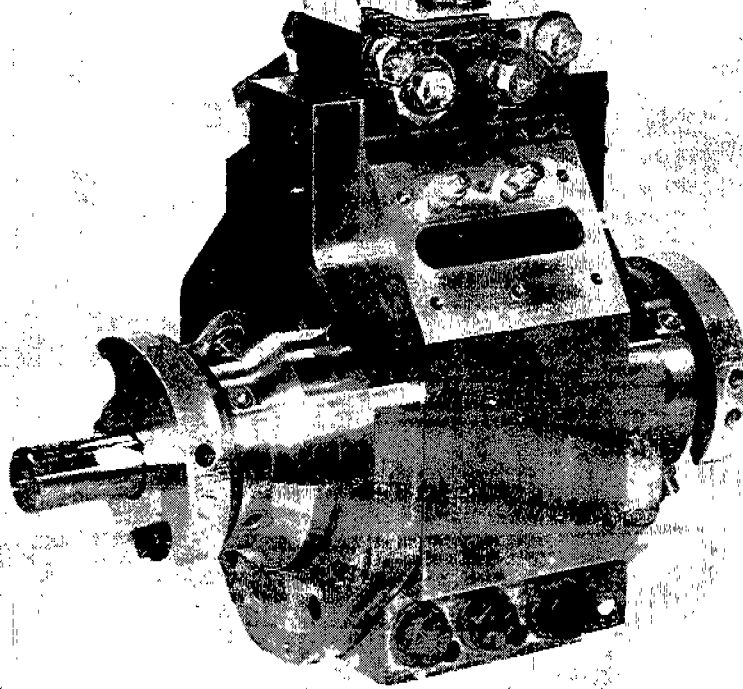


FIGURE 2: FIRST STAGE CYLINDER

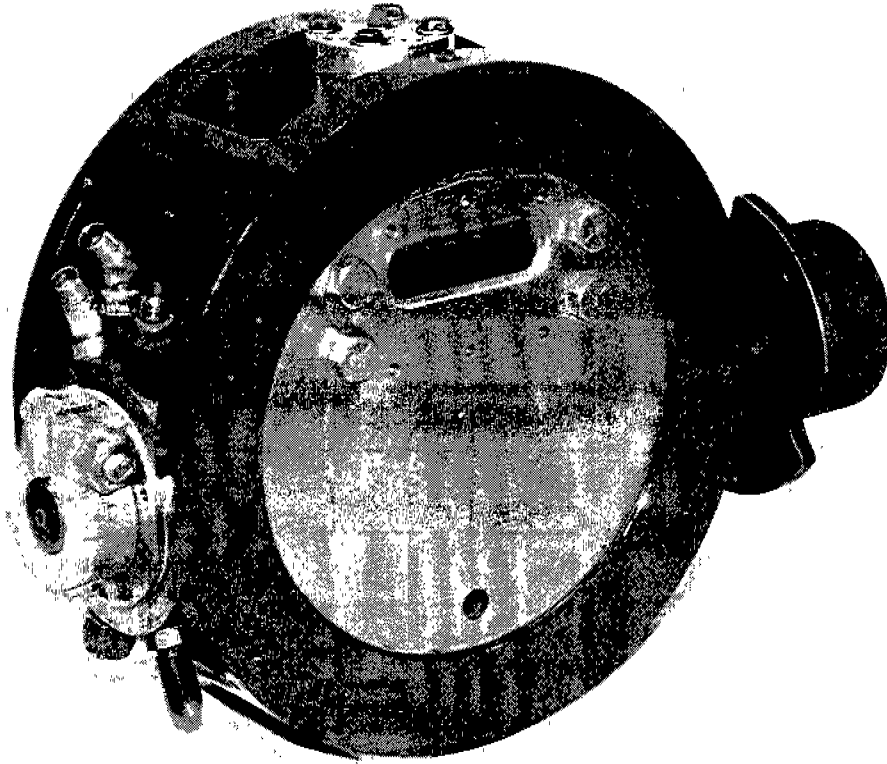


FIGURE 3: SECOND STAGE CYLINDER

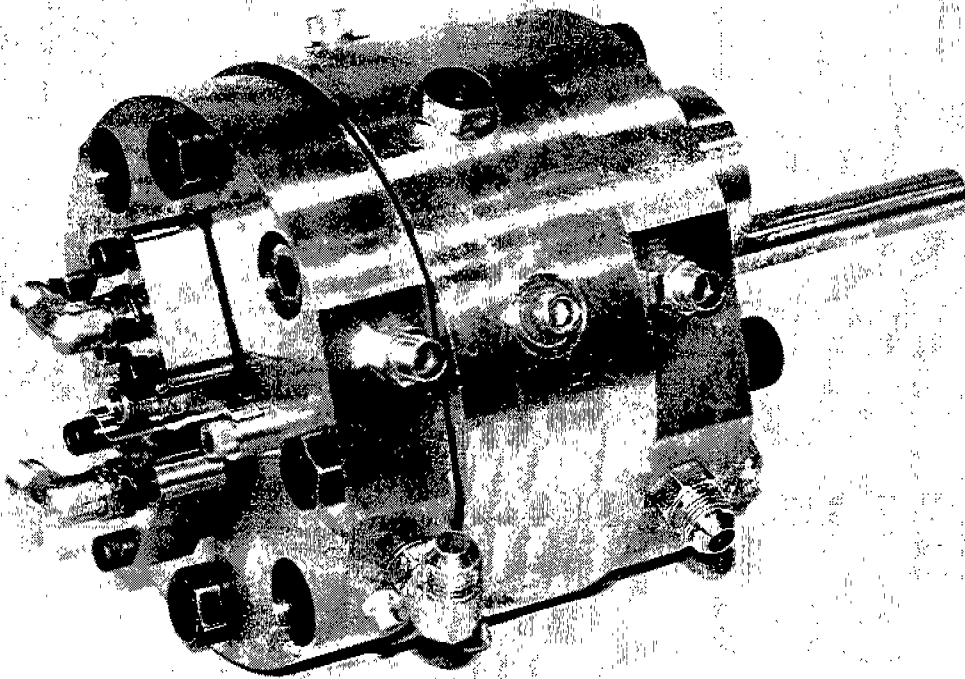


FIGURE 4: 3RD/4TH STAGE CYLINDER