Straight Talk on WOB-L® Piston Pumps

Whether for Pressure or Vacuum, These Versatile Pumps May Be Just What You Need.

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If you work with pressurized air or vacuum systems, chances are you've either specified or considered a pump that uses WOB-L piston technology. It's no wonder. You'll find WOB-L pumps so small that they fit in the palm of your hand, with lots of room to spare. You'll also find double-cylinder versions that require both arms and a strong back to lift. And all sizes in between.

WOB-L piston pumps represent what is arguably the most versatile pressure and vacuum technology available today. Despite this versatility, however, selecting the appropriate WOB-L piston pump is not a job for the uninformed; even more basic, WOB-L technology is not necessarily the best choice for every application.

STEP 1: ASSESS THE UNIVERSE OF TECHNOLOGIES

No single air pressure or vacuum technology is best across the board, as Figures 1 and 2 on the next page demonstrate. Flow, pressure and vacuum charts, commonly available in pump manufacturers' literature, will help get you in the ballpark. In addition, here are chief characteristics of the most common pump technologies used by equipment designers:

WOB-L piston: High pressure and vacuum capabilities relative to the compact size and light weight of the unit. Moderate to high air flows, depending on the design. Very efficient, especially compared with similarly sized diaphragm pumps. Relatively quiet. Easily serviceable. Dry-running (oil-less) design for very clean output. Modern seal materials and simple design contribute to long, service-free

Characteristics Comparison
For Standard Designs

Pump Technology	Compression Ratio	Price/Power Ratio	Size/Power Ratio	Noise/Power Ratio	Vibration/Power Ratio	Operating Efficiency	Operating Life	Tightness (lack of leakage)	Tolerance of Aggressive Media
WOB-L Piston	Good	Excellent	Excellent	Good	Fair	Excellent	Excellent	Good	Fair
Rotary Vane	Fair	Fair	Excellent	Fair	Excellent	Good	Good	Good	Fair
Articulated Piston	Excellent	Fair	Good	Poor	Fair	Fair	Good	Fair	Fair
Diaphragm	Fair	Excellent	Good	Good	Good	Good	Good	Excellent	Excellent
Linear	Fair	Excellent	Good	Fair	Fair	Excellent	Good	Excellent	Excellent

EXCELLENT GOOD FAIR POOR

Figure 1

Comparison of Common Working Points
For Standard Designs

Pump Technology	Maximum Flow (cfm)	Maximum Pressure (psi)	Maximum Vacuum (" Hg)
WOB-L Piston	7	430	29.5
Rotary Vane	21	15	29.6
Articulated Piston	15	175	27.0
Diaphragm	3	45	29.0
Linear	8	6	24.0

Figure 2

life, especially at lower pressures. Intake air must be filtered and should be generally dry. Not suitable for full-pressure restarts.

Rotary vane: Highest air flow relative to physical size, but not applicable to high-pressure applications. Can be oil-lubricated or oil-less. Smoothest air flow,free of pulsation. Simple design contributes to long life. Less efficient than piston or diaphragm pumps. Characteristic "whine," especially in smaller sizes. Vane debris can contaminate output air. Not suitable for full-pressure restarts.

Articulated piston: Generally chosen for heavy industrial applications requiring longest life, especially where full-pressure restart is required. High pressure and vacuum with high flows. Can be oil-lubricated or oil-less. Noise can be an issue. Relatively heavy and higher priced. Intake air must be filtered and dry.

Diaphragm: Best for lower pressure or moderate vacuum at lower air flows. Tolerant of aggressive media, including liquids. Quiet operation. May have lower pulsation than some piston pumps. Many sizes and price points for application flexibility. Generally oil-less design for clean air flow. Can be designed to allow full-pressure restarts.

Linear: Fits applications requiring moderate flow with low pressure or vacuum. Long life and efficient with extremely low power consumption. Low pulsation on pumps with large integral exhaust volumes. Some types have liquid-pumping capability.

STEP 2: THOROUGHLY UNDERSTAND THE WOB-L

If all signs point toward a WOB-L piston pump for your application, now's the time to get up close and personal.

A Bit of History: The patent for the original WOB-L piston pump was filed in 1974 and granted in 1976, meaning that the technology is both relatively modern and time-proven. In the patent application, inventors Arthur Droege Sr. and Richard Bell, of Thomas Industries (now Thomas Products Division),

Key Components of a Wobble Piston Pump

Dual Cylinder Design Shown

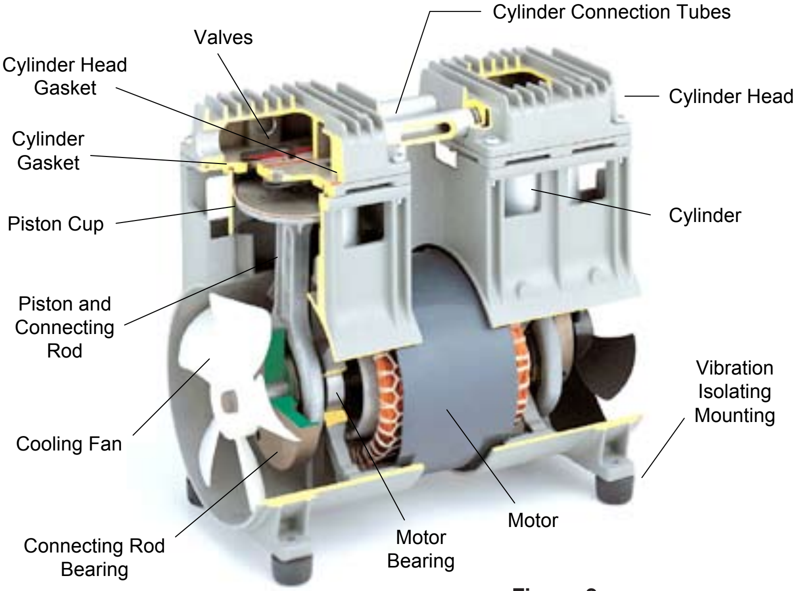

Figure 3.

described a basic design that survives almost intact to today – with, of course, improvements over the years in materials and manufacturing processes. The patent also contains this precise statement of purpose: "The chief object of the invention is to provide a low cost compressor of high efficiency and long life and requiring a minimum of service. A further object is to produce an efficient long life compressor that requires no lubrication."

How It Works: The key components of a WOB-L piston pump are depicted in **Figure 3**, above. In the simplest possible terms, a WOB-L pump is mechanically a cross between a diaphragm pump and an articulating piston (or reciprocating piston) pump – the shared mechanical element being an eccentric connecting rod. Applying this design to a piston pump eliminates the need for a connecting wrist pin, which significantly reduces the size, weight and mechanical complexity of the pump.

As its name implies, the approach of direct coupling a unitary piston rod to the crank without a wrist pin introduces a characteristic wobbling motion to the piston, as shown in **Figure 4**, at right. At the bottom of its stroke, the piston is precisely perpendicular to the cylinder wall; as it moves upward, the piston tilts proportional to the ratio of the stroke to the overall rod length, and reaches perfect alignment

Figure 4. Composite photo shows the characteristic tilt of a wobble pump's piston at mid-stroke, compared with the piston's perpendicular orientation at the top and bottom of the stroke.

again at the stroke's top. The downstroke, of course, produces the reverse motion.

In order both to guide the piston in the cylinder bore and to provide a seal (similar to piston rings) between the wobbling piston and the stationary cylinder walls, the piston rides within a flanged polymer cup. Air pressure on the upward stroke of a pressure pump or the downward stroke of a vacuum pump expands the cup against the cylinder wall, increasing its sealing properties while compensating for the wobble action. Made of a composite containing polytetrafluoroethylene (PTFE for short and most commonly known by the brand name Teflon), this cup produces a minimum of friction, requires no lubrication and generates relatively little heat.

What Makes WOB-L So Popular: A WOB-L pump combines key features of a conventional piston pump (pressure, vacuum and flow performance) with key features of a diaphragm pump (compact size, quiet operation, clean airflow), and beats them both in efficiency and manufacturability. This combination has allowed WOB-L technology to capture a large – in some application areas, dominant – share of the pressure and vacuum market since its introduction just 30 years ago.

Ongoing engineering enhancements have further opened applications to WOB-L pumps. These enhancements include:

- Long-life sintered PTFE composite cups
- Thin-wall aluminum housings for greater heat transfer
- Anti-corrosion treatments to wetted pump parts for moisture tolerance
- Stainless steel valves
- Improved overall valve designs
- Two-cylinder design, including a one-piece head version that provides fewer parts and reduced leak paths
- Automated assembly processes for more consistent and quieter operation
- Magnesium components for applications where extremely low weight is required
- Variable-speed motors, including brushless DC for long life and, with the addition of closed-loop control, extremely precise speed regulation

Where You'll Find WOB-L Piston Pumps: The original WOB-L pump patent referred to the need to supply compressed air for applications "which are more or less mobile such as trucks, buses, mobile homes, etc." While WOB-L pumps are certainly used in these applications, today's application universe is, as one might expect, exponentially larger. Here's a sample:

Medical devices: Nebulizers, aspirators, oxygen concentrators, blood analyzers, blood pressure instruments, pneumatic hospital beds, emergency vehicle suction carts, dental carts, autoclaves and other sterilizers.

Laboratory devices: Water aspirators, vacuum filters, dryers, mass spectrometers, electron microscopes, gas analyzers and samplers.

Vehicles: Air-operated suspensions, seats, horns, clutches and doors.

Vending machines for foods, drinks and compressed air.

Business machines: Copy machines, mail sorters, vacuum frames.

Environmental and safety devices: Air dryers, particle counters, ozone generators, dry fire sprinkler systems, floor cleaners.

Telecommunications: Waveguide and other cable pressurization.

Art and decoration: Airbrushes.

Agriculture: Foam marking, air seats.

Industry: Plasma cutters, plastic welders.

Printing: Sheet transfer and separating, stitching and stapling.

STEP 3: DOCUMENT THE APPLICATION PARAMETERS

When coming up with a list of all the factors that might go in to specifying a WOB-L piston pump, it can be hard to know when to stop. The following "Top Ten List" should cover 90-plus percent of the information a pump manufacturer will need to know to recommend or design the best pump for your application:

1. Working Range

Define the maximum pressure or maximum vacuum required by the application. When determining this, be sure to take into account the maximum allowable pressure or vacuum tolerated by all devices in the system. In this case, look especially at connecting lines and hoses to be sure they are specified properly. Define the airflow requirement at the maximum working point. It is very important that the airflow requirement be tied to the highest pressure or vacuum required, as standard airflow ratings for pumps are usually “wide open” or “full flow” – meaning at zero pressure and zero vacuum. Manufacturers usually have performance curves showing pressures or vacuum that can be delivered at various flows.

Most applications do not require the maximum flow, pressure or vacuum at all times, so also define a typical working point and provide some idea of how frequently and for how long peak or maximum performance is required. This information can help prevent pump over-sizing and potentially reduce cost.

If stop and restart under pressure or vacuum is a requirement, be sure to state this.

2. Motor Requirements

Define your power source. If direct current (DC), specify the voltage and the source – for example, rectified AC, battery, solar, DC generator. If alternating current (AC) define the voltage as well as the frequency (generally 60 Hz in North America and 50 Hz in Europe and many other places in the world). List any power consumption and current draw limitations, and whether thermal overload protection is required. If the motor is to run at a constant speed, define how precisely must this speed be maintained. If variable flow through an adjustable-speed motor and controller is required, be sure to state that.

Finally, determine the duty cycle of the application. Define as either “continuous” or, if intermittent, indicate a pattern of “minutes on, minutes off.”

3. Unit Envelope

List height, width and length maximums that can be accommodated. Also, determine how much free air space will exist around the unit. Knowing this will help the pump manufacturer to know whether there is sufficient cooling air, or whether additional fans or other cooling mechanisms will be required.

Pump mounting must also be considered. Mounting systems can be as simple or complex as needed to meet the specific needs of an application. When noise and vibration are important considerations, careful attention must be paid to both the mounting system and piping or hose connections to ensure that vibrations are not transmitted to surrounding structure inadvertently.

There is inherent vibration in all types of reciprocating pumps due to torque pulsations that result from the motor speeding up and slowing down on each revolution in response to the build up of pressure in each cylinder and the subsequent intake of air at atmospheric pressure. Care has to be taken to isolate the compressor so that minimal vibration is transmitted to the surrounding structures and enclosures to minimize noise and vibration of the device or system in which a WOB-L pump is used.

In larger pumps, an isolation system will typically involve elastomeric members. These provide some damping and snubbing capability to prevent impacting of metal parts during shipping and handling or under startup and shutdown conditions. In smaller pumps, standard elastomeric mounts are often used to provide a measure of isolation and to withstand shock loads. Often overlooked are vibration transmission paths created by piping or hose connections to the pump. These need to be flexible enough to provide isolation, just as the mounting system does.

In small OEM pumps where cost is critical, isolation systems may consist of simply an elastomer squeezed between recesses on each side of the pump housing and the inner surfaces of the enclosure in which the pump is mounted, thus avoiding the need for fasteners. The elastomeric members must be carefully designed so that they are soft enough to provide adequate isolation and yet strong and stiff enough to withstand shock loading from handling and

dropping the product.
Because WOB-L pumps do not use liquid lubricants, they can run in any orientation.
This gives the product designer leeway in placing the pump inside a product. Low-cost mounting and isolation can be achieved by capturing the pump inside an enclosure with elastomer components and/or springs.
This works well when pumps are ordered in a high enough volume to allow the tooling of custom mounting features. For lower production volumes, standard, off-the-shelf isolators are available that can be threaded into mounting feet for most pumps.

4. Operating Life
Be straightforward about your expectations for a pump's service-free life. Because of their application versatility, WOB-L piston pumps may be designed for anywhere from 500 to more than 30,000 hours of service-free life, depending on the ambient temperature, operating speed, type of motor used, and a variety of other factors.
Many times, larger WOB-L units are serviceable to further extend unit life. Piston cups and stationary seals are the major wear parts. Be sure to let your pump manufacturer know if serviceability is required so that the pump can be chosen or designed accordingly.

5. Environment
Typical ambient temperatures for WOB-L piston pumps are from 50º F to 104º F (10º C to 40º C). However, special designs can operate in temperatures as low as minus 40º F or as high as 212º F (minus 40º C to 100º C). Describe the air surrounding the pump: clean, dusty, gaseous, etc. Also determine the relative humidity. This information will help determine the type of filters required, as well as recommended seal materials.

6. Media to Be Pumped
Chemicals, volatile gases and moisture in the air, as well as the media temperature will affect pump sizing and construction, especially of the piston cups, the primary wear component in a WOB-L pump. The cups are compression molded and may include a variety of materials depending on the application. For example, if the application requires exposure to condensed moisture, piston cup materials used for general purpose applications will rapidly disintegrate. Pump manufacturers have conducted extensive life testing under various combinations of temperatures, pressures, strokes and humidity conditions with hundreds of different composite blends, resulting in development of specialized materials for each type of application. Make sure that these environmental factors are communicated to the application specialists when selecting a WOB-L pump to ensure that the appropriate piston cup material is selected for your application.

7. Sound and Vibration
Sound and vibration can be a significant challenge when applying a pump. When operating alone, with intake and exhaust piped away, WOB-L pumps in fractional horsepower sizes will typically range in noise level from about 40 dBA to about 60 dBA. Proper application of inlet mufflers and isolation mountings will help limit the noise in the end use application.
Noise and vibration transmission through a device can be complex. It often requires specialized skills and tools to determine the best ways to prevent transmission of unwanted vibrations and acoustic noise that can result from gas pulsations, valve action, rolling element bearings, and various flow-path restrictions encountered downstream of the pump.

Your WOB-L pump supplier should have the knowledge, skills and tools to provide this service and reduce noise to the low 30 dBA range. Factors as simple as stiff hose connections can transmit vibration that results in noise being emitted from the hoses and components to which they are connected. System resonances can greatly amplify the vibrations and resulting noise level of a device even with a well-balanced compressor. Take advantage of the compressor supplier's noise and vibration reduction services to ensure that noise and vibration levels are reduced to satisfactory levels.

8. Agency Requirements
UL, CSA, TUV, FDA, ISO and other regulatory agencies require that pumps and the motors used with them meet rigorous safety standards. Suppliers with certified labs can test and evaluate their products

quickly and work closely with these agencies to ensure that their products comply and are properly labeled to demonstrate compliance with the appropriate standards.

For custom-designed products, make sure that the compressor supplier is aware of all the agency requirements for your application so that regulatory issues can be addressed in parallel with the development of the product.

9. Altitude

Altitude above sea level, barometric pressure and temperature all affect air density – which is a major variable in sizing vacuum and pressure pumps to meet flow requirements. Temperature will have been defined in Point 5. Day-to-day changes in barometric pressure can affect pump performance, but generally these are within tolerance ranges. Altitude, or more specifically its constant effect on diminishing the atmospheric pressure, is therefore the most critical factor.

As Figures 5 and 6, at right, indicate the effect of altitude on pump flow is magnified at higher pressures or vacuums. A compressor at free flow (high cfm) isn't affected much at all, while a compressor operating closer to its full, deadhead pressure can lose virtually all of its flow at a very high altitude. Altitude affects vacuum applications even more than it does pressure applications. As the pump gets closer to maximum vacuum, the flow drops off steeply. In

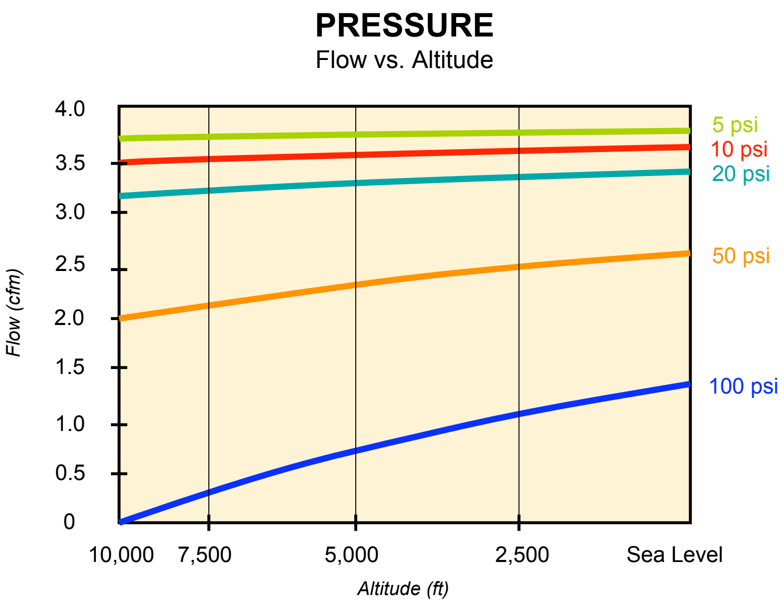

Figure 5

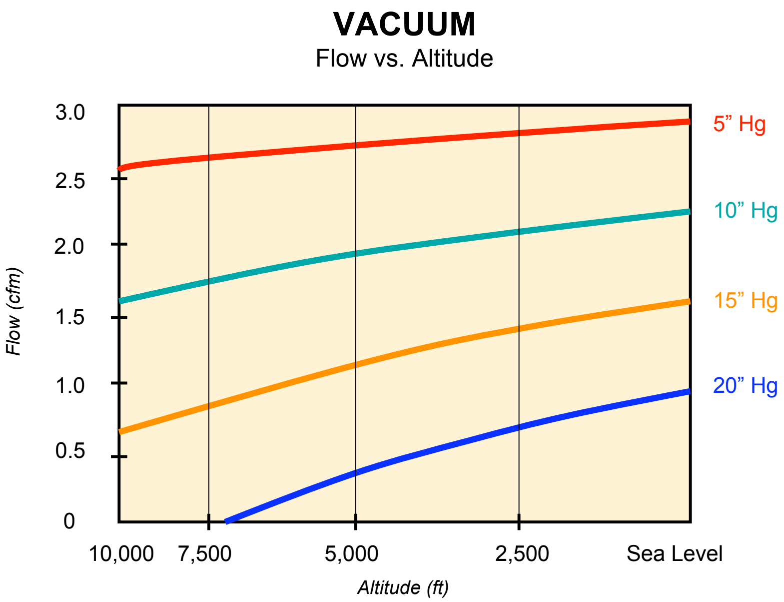

Figure 6

general, the clearance volume to total volume ratio or compression ratio will determine how sensitive the pump or compressor will be to altitude effects. Make sure that the application specialist is aware of any requirement to work at varying altitudes so that the pump can be properly selected or designed to meet the application requirements.

10. Cost Considerations
It's just a fact of life. Cost plays a role in determining what kind of pump to buy, and who to buy it from. Sometimes the role of cost is secondary, sometimes primary – but it's always present and should be one of the key factors considered. When analyzing cost, consider all elements of it – including first-cost, lifecycle operating and maintenance cost, cost of a unit failure, and so on. Let your manufacturer know which of these elements is your top priority.

STEP 4: INVOLVE YOUR PUMP SUPPLIER EARLY ON

No matter how much an equipment designer might know about vacuum and pressure technology, it's a good bet that the engineers at pump manufacturers know even more. Don't underutilize this resource. While the manufacturer probably offers a wide array of standard pumps, modified or even all-new designs specific to the application requirements are also possible – given sufficient time for design, prototyping, testing and manufacturing.

Point is, don't put yourself or the pump supplier in a box that can lead to a pump that's either over-designed and too expensive, or under-designed and a recipe for failure. Consider all technologies and all application factors, as a team. Then share your data, thoughts and concerns with your supplier, and ask their advice. The result is likely to be the perfect pump at the lowest possible cost.