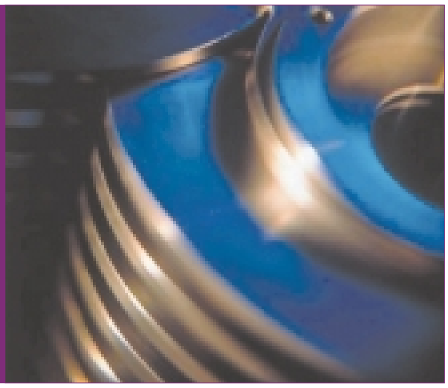
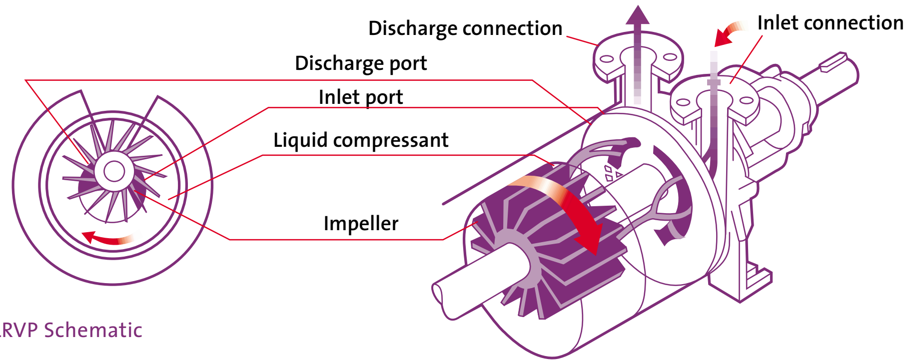
save water, money and the environment

Sydney WATER

The use of vacuum pressure is common across many industries, however the cost of operating vacuum systems often goes unnoticed. There is significant opportunity to optimise these systems, thereby providing cost, operational and environmental benefits for businesses.



The Liquid Ring Vacuum Pump



LRVP Schematic

There are a number of pumps using different design principles to produce a vacuum. The most common is the liquid ring vacuum pump (LRVP). This design uses a liquid seal to achieve a vacuum, and the most commonly used liquid is water – typically used once through and dumped to drain. It is this once-through use that presents an opportunity to save significant amounts of water.

Before making changes to your site's vacuum system it is important to understand why and how a vacuum may be used, and to evaluate current running costs and potential savings. The following is a guide to evaluate your vacuum system and identify ways to minimise or eliminate water usage and effluent discharge.

Vacuum applications

Vacuum pumps are widely used in the petrochemical, pharmaceutical, food manufacturing and health sectors. Typical process applications for vacuum pumps include use in dryers, distillation columns, evaporative coolers, degassifiers, chemical reactors, freeze dryers, medical suction, laboratory analysis and extruders.

Vacuum uses

- Reducing process temperatures
- Increasing drying rates
- Transferring of materials
- Optimising filtration rates
- Inert blanketing (removal of oxygen).

Defining a vacuum

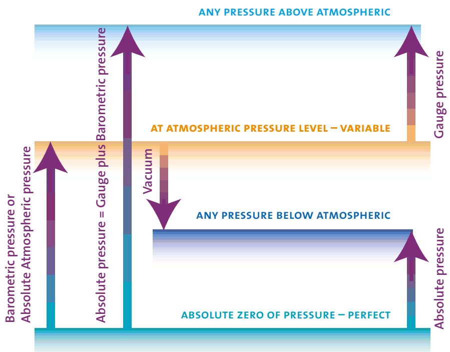
The pressure the earth's atmosphere exerts upon us is known as atmospheric pressure, which can be measured in a number of ways. At sea level the standard pressure is 14.7 pounds per square inch (psi), 29.9 inches of mercury (Hg), 760 mm of mercury (Torr) or 101.3 kPa.

The term 'vacuum' is used to describe the zone of pressure below atmospheric and the operating pressure of a vacuum system can be defined in one of two ways.

Vacuum can be expressed as 'below atmospheric pressure' or as 'absolute pressure' as shown in the adjacent figure. Absolute pressure always refers to perfect vacuum as a reference point. Barometric pressure is the level of the atmospheric pressure above perfect vacuum.

A typical vacuum level encountered in many applications is 50 Torr absolute (710 Torr or 94.6 kPa below atmosphere).

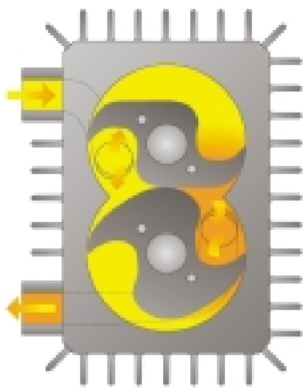
Relationship between Gauge and Absolute pressures



Controlling the level of vacuum

It is usually desirable to control the level of vacuum. One such example includes maintaining the temperature of a drying process, thereby preventing product degradation due to overheating. It may also be critical to maintain the vacuum level in a chemical reactor to optimise reaction rates. The various methods employed to control the level of vacuum are:

- Installing variable speed drives (VSDs) on the vacuum pump(s) to match variable production capacity. One major benefit is that energy costs will reduce.
- Installing a throttling valve between the process and the vacuum pump (not recommended for LRVPs as the valve may act as a restriction and make the vacuum unstable).
- Injecting air or gas into the suction side of the pump (although pump efficiency will reduce).



Rotary Claw-type Vacuum Pump

Evaluating vacuum running costs

The running costs of vacuum systems are usually much more significant than the initial capital cost to install the equipment. This should be taken into consideration when selecting the preferred vacuum system. The first step in this evaluation is an understanding of why a vacuum is used. Changes in the process environment may no longer require the use of vacuum or perhaps the duration of operation and the vacuum pressure could be reduced. It is also useful to determine the checks and controls that are in place to ensure efficient performance, such as operating procedures, automated controls, product quality checks and production throughput.

Other factors that require careful consideration when evaluating running costs are:

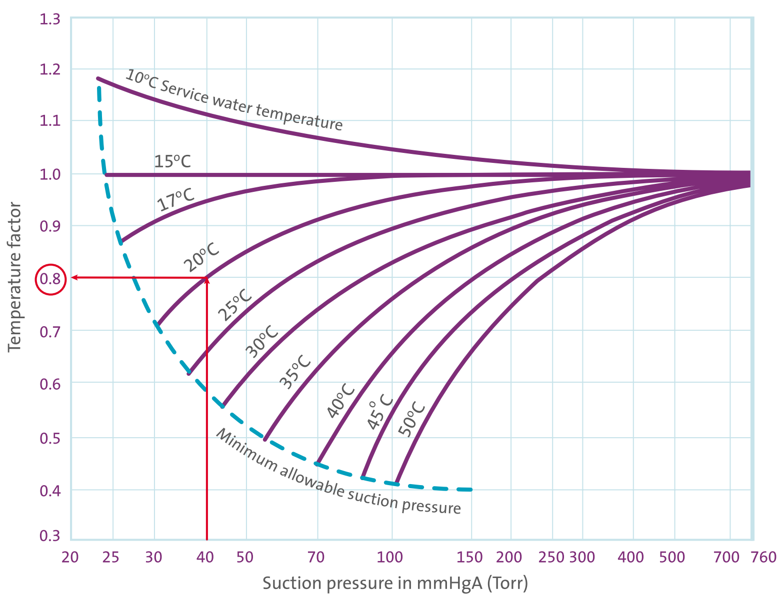
- Required vacuum duty*
- Energy running costs
- Water supply and effluent discharge costs
- Other waste management costs
- Maintenance costs
- Associated ancillary equipment costs (cooling towers, scrubbers, condensers, etc)

*The required vacuum duty can be calculated using suction pressure, pumping capacity and pull-down time. Pull-down time is the time taken to achieve the operating vacuum from atmospheric pressure.

Improving your LRVP system

Before replacing your LRVP with a more efficient vacuum system, there may be a number of low cost alternatives to reduce operating costs and improve vacuum performance. Improvements in efficiency can reduce running costs by over 15 per cent through reduced energy consumption, water usage and effluent discharge. The various measures available to improve your LRVP system are:

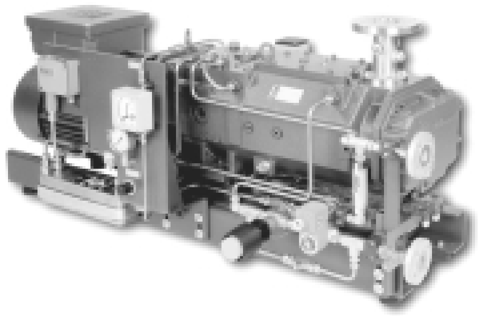
- Installing solenoid valves on seal and cooling water supplies and interlocking these valves with the main power supply to the pump motor. This will prevent water wastage when the equipment is not in use.
- Converting your LRVP from a once-through water seal to a recirculating water seal (the cost of which may be over three times greater than the cost of the LRVP). The feasibility of this option will depend on the degree of contamination picked up on each pass of the liquid seal. This problem can be negated in a number of ways, including liquid bleed off and make-up with fresh water or the removal of solids and immiscible liquids from the liquid seal.
- Using alternative liquid seals, which can eliminate wastewater generation and also improve vacuum performance. Make sure the new liquid seal has a suitable vapour pressure for your process and is compatible with the suction gases and materials of construction of the pump.
- Ensuring the liquid seal temperature is minimised. The liquid seal temperature is critical to the performance of the liquid ring pumps. An increase of a few degrees can reduce pump capacity by 30 per cent or more and lower the maximum suction pressure the pump can deliver, as shown in this diagram.



Single Stage Liquid Ring Vacuum Pumps

Note: The adjacent graph displays the importance of minimising liquid seal temperature. A small rise of 5°C at 40 Torr will reduce the pump capacity by 20%!

To overcome this problem LRVPs are commonly oversized to compensate for this effect – this compensation further increases energy consumption. Controlling liquid seal temperature will avoid the need to oversize LRVPs.



Dry vacuum pump (screw type)

- Installing VSDs on motors to reduce electricity costs and wear and tear on the pump. This is especially beneficial when vacuum requirements vary and running hours are long. Care should be taken to ensure that the liquid seal is not compromised at lower pump speeds.
- Switching off vacuum pumps when not required (either using standard operating procedures or interlocking controls to other processes within the plant).
- Interlocking cooling utilities to the operation of the vacuum pump. The cost of running a closed loop recirculating water circuit can be significant (cooling towers require fan and pump electricity, water make-up and water treatment chemicals).
- Incorporating a leak detection program into your vacuum system operating procedures. Leakage of air into systems is the most common reason for waste and inefficiency.
- Avoiding pump cavitation, which occurs when the seal fluid vapour pressure is near the operating inlet pressure of the vacuum pump, leading to the rapid boiling of the seal liquid. This results in a noisy pump during operation and leads to extensive erosion or pitting of the pump internals.*

*Methods employed to avoid cavitation can create other problems. The use of a colder seal fluid will lower the vapour pressure of the seal fluid and keep it from boiling. However, this may require increased capital and operational costs associated with a closed loop chilled water system.

Replacing your LRVP system

Inherent problems with LRVPs have lead to the development of alternative vacuum systems. These new systems are designed to overcome difficulties with solvent recovery, the requirement of costly ancillary equipment and the oversizing of pumps.

The alternatives to LRVPs include steam ejectors, rotary vane and dry vacuum pumps. Recent improvements in dry pump technology have made their use more attractive, with many businesses now looking to replace LRVPs with dry vacuum pumps.

These pumps should be given consideration especially when installing a new vacuum system or upgrading an existing system. Cost savings of more than 50 per cent can be realised by eliminating water usage and minimising energy consumption.

Unlike steam ejectors and LRVPs, dry vacuum pumps do not require working fluids to create a vacuum. These pumps are machined with extremely close clearances between the rotating elements and the pump walls and are energy efficient.

Dry vacuum pumps are designed to operate at elevated temperatures to avoid condensation of suction vapours, which can cause erosion of the sealing surfaces. If condensation is likely then the use of condensers in the gas suction stream is recommended.

Gas ballasting is another technique that can be employed. This method can prevent condensation by introducing gas (typically air) into the vacuum pump, which dilutes the condensable vapour and reduces the suction vapour pressure below saturation.

Catchpots can be installed to prevent slugs of process liquid entering the vacuum pump, while filters, screens and wet scrubbers can be utilised to remove solid particles from the suction stream if necessary.

case studies

Operating costs, product recovery issues plus environmental factors tend to be the most important aspects when determining the economic feasibility of vacuum systems and in many cases payback periods of less than two years can be obtained.

A recent study to replace four LRVPs with dry vacuum pumps in a Sydney hospital is a good example:

Total replacement cost:	$100,000
Water savings:	100kL/d
Cost savings:	$78,000 p.a*
Payback:	1.3 years

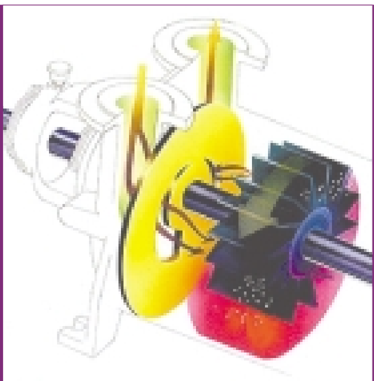
*The costs savings above are water and sewer usage charges only. Chemical costs and tradewaste charges are excluded.

Another case study includes the replacement of two LRVPs with four dry rotary claw dry vacuum pumps at a major food manufacturing facility:

Total replacement cost:	$100,000
Water savings:	$18,000/yr
Power savings:	$6,000 p.a
Payback:	1.5 years*

*One of the main benefits for the project was an improvement in Clean-In-Place (CIP) effectiveness, as the dry pumps run at much greater temperatures.

every drop counts



Consider this…

If your process uses a LRVP or there is a requirement to install a vacuum system within your plant, install a dry vacuum pump to conserve water and reduce wastewater costs. If replacing a LRVP with a dry vacuum pump is not an option, try closing the loop through use of a fully recirculated liquid seal system with a liquid-to-liquid, or liquid-to-air heat exchanger. (This option may not be possible where there is product carry over or where the liquid circuit would become acidic and cause corrosion.)

Relative performance of LRVPs and dry vacuum pumps

- Proven technology, robust construction, tolerant of product carryover
- Easy maintenance
- One moving part, no metal-to-metal contact in the compression chamber, no internal lubrication required
- Low internal operating temperatures in saturated applications allow vapours to condense, improving operating efficiency

LRVPs DISADVANTAGES

- Vacuum will be vapour pressure limited at deeper vacuum levels
- Environmental concerns with disposal of condensed liquid waste
- Relatively high power consumption
- Pumps are oversized to compensate for high liquid seal temperatures
- Changes in liquid seal temperature makes vacuum system unstable
- Once-through use of the liquid seal is necessary with corrosive gases
- Temperature limits for the liquid seal can inhibit CIP effectiveness
- At deep vacuum levels the pump will cavitate and extensive erosion or pitting of the pump internals may occur
- Contamination of the seal liquid may increase the seal vapour pressure, with a corresponding decrease in pump performance
- Maximum vacuum possible is -98 kPa (25 Torr) under ideal conditions

DRY VACUUM PUMPS ADVANTAGES

- Operate with no liquid in the compression chamber
- Minimal maintenance requirements – fine tolerances result in non-contacting mechanical parts and no wear
- No handling of contaminated lubricating oil waste
- Non-polluting, (with the exception of nitrogen or air purge)
- No water usage or wastewater generated
- Can handle most corrosive vapours even though construction material is typically iron
- Energy efficient (the motor size for a claw type dry pump is about 50 per cent the size of equivalent an LRVP)
- Can handle process flow variations and product carry over
- Quiet operation

DRY VACUUM PUMPS DISADVANTAGES

- Capital cost is marginally greater than LRVPs
- Risk of explosion if flammable vapours present (dry pumps generally run hot to prevent condensing). Can be mitigated with flame arrestors and the control of oxygen levels
- Temperature control may be required by using a water jacket or by injecting cooled process gas or nitrogen into the pump
- Cost of gas purge can be prohibitive
- Maintenance costs can be expensive.

Photos courtesy of Busch Australia

For more information please visit: **www.sydneywater.com.au**

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