

# Choose the Right Type of Vacuum Pump



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This article has been compiled after years of experience in the Vacuum Industry. The primary focus of this article is on Vacuum Pumps used in Chemical, Pharmaceutical and other related process Industries. This article has been compiled in April - 2017

The need to operate under Vacuum is wide spread throughout the Chemical Process Industries (CPI). Distillation, Drying, Flash Cooling and Evaporation, Stripping, Freeze Drying, Impregnation etc. are some among the unit operations processes that frequently take place at less than atmospheric pressure.

## What is Vacuum?

Vacuum is any system of reduced pressure, relative to local (typically atmospheric) pressure, achieved through a Vacuum System which are commonly used to:

- | Remove excess air and its constituents.
- | Remove excess reactants or unwanted by products.
- | Reduce the boiling point.
- | Dry solute material.
- | Create a pressure differential for initiating transport of material.

In many process industries the overriding concern is the amount of vacuum (degree of evacuation) required. In the below article we will talk about the 6 (six) major types of vacuum producing devices namely:

- | Steam Ejectors.
- | Water Ring Vacuum Pumps.
- | Piston Vacuum Pumps (Rotary and Reciprocating).
- | Rotary Vane (Oil type – Semi Dry) Vacuum Pumps.
- | Dry Screw Vacuum Pumps.
- | Mechanical Vacuum Boosters.

All the above type of pumps have uses in different and specific processes with varied levels of vacuum and displacement requirements. Each of them has its own set of attractions and drawbacks.

## Steam Jet Ejector Systems:

These have been considered as work horses and have been the most widely used vacuum producers over the last few decades. This works on the principle of converting the energy of Motive fluid (which may be the same as or different from process fluid) into velocity (kinetic energy) as it flows through a relatively small converging – diverging nozzle. This lowered pressure of the motive fluid creates suction in a mixing chamber, into which the process fluid is drawn. The process fluid thus mixes and becomes entrained in the motive fluid stream. This mixed fluid then passes through a converging – diverging diffuser, where the velocity is converted back to kinetic energy. Hence, the resultant pressure is higher than the suction pressure of the ejectors.

Depending on the degree of vacuum required, Ejectors usually come in a series configuration with various stages attached (called a multi stage unit). Usually the backing work is done by Water Ejectors/Steam Ejectors and front end stages are known as Steam Boosters. Barometric leg (Direct contact type) condensers are installed in the intermediate stages.

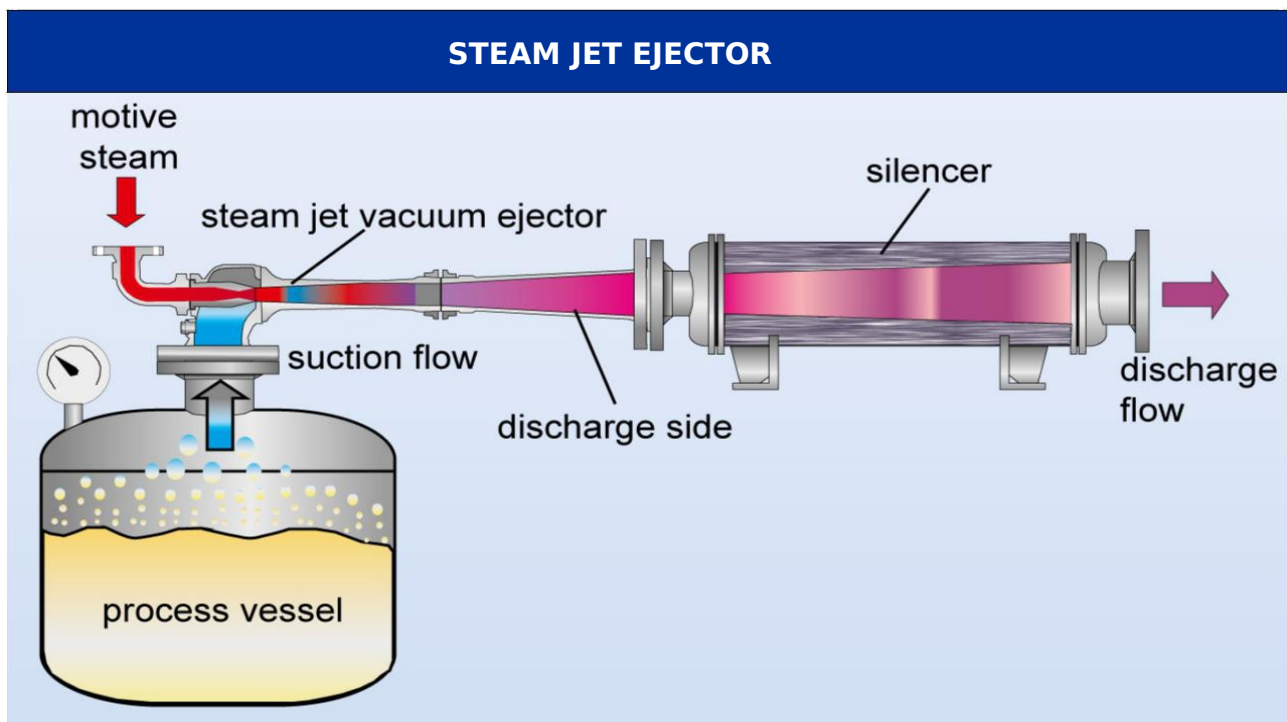
Steam ejector technology however is a conventional/old technology now and has many dis-credits attached to it as per the present day scenario.

#### Advantages:

- 1) Low investment cost.
- 2) No moving parts, hence less maintenance. However, the nozzle needs to be replaced periodically for optimum performance.
- 3) High Vacuum Capability at high suction loads. This is obtained by increasing the flow of steam into ejectors.

#### Disadvantages:

- 1) The biggest drawback is that it requires a steam source to operate. Steam generation requires boiler installations/ enhanced capacity of boilers.
- 2) Cost of Steam generation due to increased cost of fuel makes it economically unviable.
- 3) Unlike the Rotary Vacuum Pumps, Steam Ejectors require longer start-up time.
- 4) In case of Power failure (very common in developing countries) the vacuum consistency cannot be maintained.
- 5) Leads to increased loads on ETP's. Any low boiling media mixes with the steam/water of ejector/condenser and enhances the load.
- 6) Continuous problems with the Pollution Control Boards.
- 7) Recovery of solvents cannot be obtained leading to monetary loss at most of the operating units.
- 8) High Operating cost due to many allied equipment's being involved.



## Water / Liquid Ring Vacuum Pumps:

LRP's are cool. In the cylindrical body of the pump, a sealant fluid under centrifugal force forms a ring against the inside of the casing. The source of that force is a multi-blade impeller whose shaft is mounted eccentric to the ring of liquid. Because of this eccentricity, the pockets bounded by adjacent impeller blades (also called buckets) and the ring increase in size on the inlet side of the pump, and the resulting suction continually draws gas out of the vessel being evacuated. As the blades rotate toward the discharge side of the pump, the pockets decrease in size, and the evacuated gas is compressed, enabling its discharge.

A continuous flow of fresh sealing liquid is supplied to the pump via the sealing-liquid inlet.

In the case of the two-stage liquid ring pump, the discharge from the first stage does not discharge to atmosphere. Instead, the first stage discharges through the manifold leading to the second stage as well as through a discharge port located in the intermediate plate between the first and second stage impellers. The process repeats itself allowing deeper vacuum and finally discharges into the atmosphere.

The ring of liquid not only acts as a seal; it also absorbs the heat of compression, friction and condensation. Popular liquid choices include water, ethylene glycol, mineral oil and organic solvents.

### Advantages:

- 1) Can perform as both Vacuum Pump as well as direct contact condenser.
- 2) Low purchase price as compared to dry type Vacuum Pumps/Systems
- 3) Has high Vapour handling capacity. All process carry overs mix with the sealing water and are pumped out of the discharge.
- 4) Assembly, Disassembly and Maintenance is easy due to robust structure.
- 5) Very useful in specific applications .
- 6) With minor modifications Everest Team has also used Oil as sealing fluid instead of Water for specific process applications. This is known as "OIL- SYST" pump.
- 7) High reliability for long term sturdy operation.

### Disadvantages:

- 1) Efficiency is low. Around 30% at vacuum level of 70-80 Torr. Around 50% for a good pump.
- 2) With usual liquid media as CT water, ultimate vacuum is restricted to 100 torr in a double stage configuration and around 60 torr in a single stage configuration.
- 3) Relatively higher operating cost as compared to other Rotary Vane or Dry Vacuum pumps.
- 4) Operations normally result in high amount of Effluent/Hazardous waste being generated which has high treatment cost as well as issues with the pollution boards.
- 5) Solvent recovery for low boilers is not possible as it mixes with the sealing fluid leading to monetary loss at some places.

**Everest also offers Complete Skid mounted vacuum systems with Water Ring Vacuum Pumps as backing units. These skids are coupled with Mechanical Vacuum Boosters for obtaining the desired process results.**

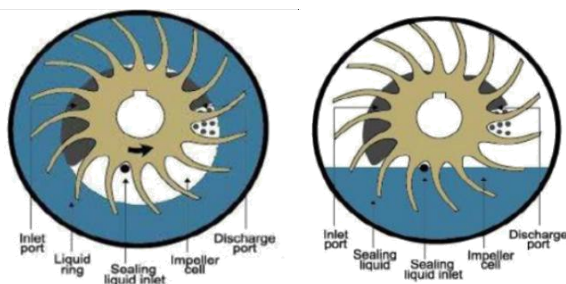


Figure: Water/Liquid Ring Vacuum Pump



Figure: Water Ring Vacuum Pump+Vacuum Booster

## Piston Type Vacuum Pumps (Rotary and Reciprocating):

### Rotary Piston:

A rugged type of vacuum producing device is the Rotary Piston Vacuum Pump. Its piston is attached to a cam that is mounted eccentrically to the main bore of the vacuum pump cylinder.

At the start of the cycle, the volume between the piston and the cylinder increases as the shaft rotates the piston cam assembly. Gas is drawn in through a channel in the piston, until volume is at its maximum. At that point, the pocket becomes sealed from the inlet as the inlet channel in the piston closes off. Lubricating oil helps seal the clearances. The shaft then further rotates the piston and cam assembly, in a way that compresses sealed off gas against the pump cylinder and the discharge valve. The discharge valve opens when the gas pressure is slightly above atmospheric. The gas and lubricating oil is then forced out and cycle repeats itself.

This technology has also been around for ages and finds use in applications when the process load is Dry and contains only NC (Non-Condensable) gases. Contamination of the process cannot be avoided with this design. Furthermore, even liquid carryover can lead to damage of the pump internals.

### Reciprocating:

Operation of reciprocating motion is done by the power source (i.e. electric motor). Power source gives rotary motion to crank; with the help of connecting rod we translate reciprocating motion to piston in the cylinder (i.e. intermediate link between connecting rod and piston). When crank moves from inner dead centre to outer dead centre vacuum is generated in the cylinder.

Everest has been manufacturing and supplying various vacuum systems with Reciprocating piston vacuum pumps in combination with Vacuum Boosters. These systems find major applications in speciality processes like: \*Waste Oil Re-Refining; \*Menthol and Aromatic Industries; \* some volatile applications.

### Advantages:

- 1) Minimum vibrations, due to balanced designs.
- 2) Rugged Design, fostering long life.
- 3) Option of cheaper pumps as compared to other types of sophisticated pumps available.

### Disadvantages:

- 1) Cannot handle liquid carryovers. Even minimum quantity can lead to contamination of sealing oil.
- 2) Discharge gas is usually contaminated with oil.
- 3) Solvent Recovery is not possible, due to oil contamination.
- 4) Some of the designs of such pumps are noisy.
- 5) Reciprocating pumps require frequent maintenance.
- 6) Ultimate vacuum achieved is course. Have to couple for series with boosters in fine vacuum applications.



Figure: Reciprocating Piston Ring Vacuum Pump

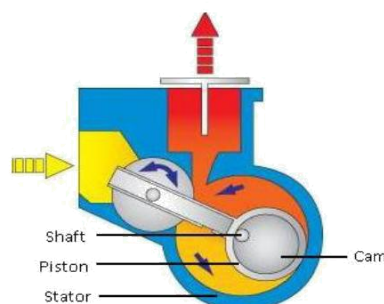


Figure: Rotary Piston Vacuum Pump



Figure: Reciprocating Piston Pump + Booster Vacuum Pumping Systems



## Rotary Vane Vacuum Pumps :

The standard lubricated rotary vane pump is a single-stage pump with an integral, closed-loop oil-circulation system. The construction is heavy-duty and compact. Typical vane life is 50,000 hours. The pump rotor is mounted eccentrically in the pump cylinder. As the pump rotor turns, inlet air is trapped between the rotor and vane segments (see #1 in the diagram below). This creates increasing cell volume on the inlet port side, creating vacuum. Since the rotor is located eccentric to the pumping chamber, the volume between the rotor, vanes and housing decreases and increases as rotor spins. Air is compressed and discharged into the exhaust box as rotation continues. See #3 in the diagram below.

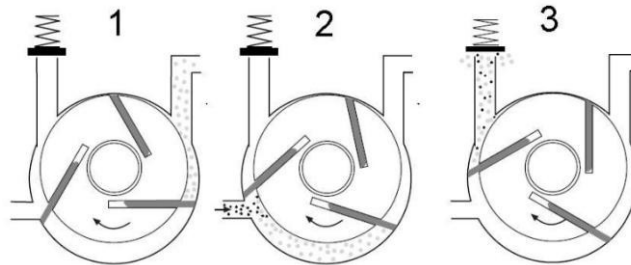
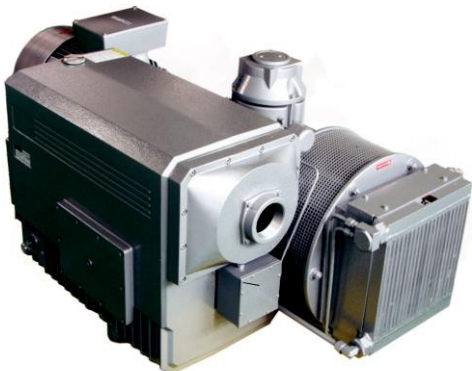


Figure: Rotary Piston Vacuum Pump

Air passes through several stages of internal oil-and-mist eliminators to remove 99.9% of the lubricating oil from the exhaust. Oil is then returned to the oil reservoir.

Features of the EVEREST Rotary Vane Vacuum Pumps:

- | an automotive spin-on oil filter (for large size pumps)
- | a built-in inlet anti-suckback valve that prevents the pump from rotating backwards when shut down with vacuum remaining in the process and prevents the rotor housing from flooding with oil
- | a built-in gas ballast valve
- | Vanes are of Carbon Fibre.
- | Everest Offers complete skid mounted Rotary Vane Pump+Vacuum Booster combination Systems "Super Vane" series.
- | It is available in Both configurations (Single and Double Stage)



### Advantages:

- 1) Can attain high vacuum levels. EMVO series of EVEREST pumps can go up to 0.5 mbar for the industrial range.
- 2) Reasonable price when compared to Dry counterparts.
- 3) Available in different capacities (ranging from 6 m<sup>3</sup>/hr – 630 m<sup>3</sup>/hr).
- 4) Wide acceptance across various applications in the industry.

### Dis-advantages:

- 1) Cannot handle liquid carryover.

- 2) Frequent contamination of oil, when low boiling solvents are present.
- 3) Solvent Recovery is not possible hence not much recommended in applications related to chemical and pharmaceutical process.
- 4) Has wide application in clean processes (Packaging, Pick n Place Applications etc.) Not too widely accepted in dirty applications.

Some companies are now referring this technology as SEMI DRY vacuum Pumps. The fact remains that vapour does come in contact with the lubricating oil and hence increases the chances of contamination.

### **Dry Screw Vacuum Pumps :**

Two parallel bearing-supported, intermeshing screw rotors having opposite threads synchronously and contact less counter-rotate in a cylindrical housing that tightly encloses them, and together form a multi-stage Dry Screw Vacuum pump. Due to of the counter-mesh of the two rotors (screws), the volumes sealed in each thread are advanced along the rotors to the outlet. When a displacement volume reaches the outlet opening, the pressure is equalized with the atmosphere. This means that atmospheric air flows into the displacement volume and is then discharged again as the rotor turns. This pulsing gas flow generates a high level of dissipated energy and heats the pump. The dissipated energy can be minimized by means of internal compression. Everest Screw Vacuum pumps are such designed to ensure that the differential temperature remains in-tact and is optimized for operation. This internal compression is achieved by reducing the thread pitch in the direction of the outlet. The gaps between the housing and the rotors, as well as between the rotors relative to one another, determine the ultimate pressure which a screw pump can attain. The geometry and the gap configuration which results when the rotors engage with each other also significantly influence the ultimate pressure.

The dissipated energy that is generated by the pulsating gas flow heats the pump on the outlet side hence, cooling is required at precisely this location. The gap between housing and rotors is a function of the temperature differential between the warmer rotors and the cooled housing. The amount of heat produced and the temperature are a function of the inlet pressure range. Temperatures are lowest at high inlet pressures (nearly atmospheric), as virtually no compression work is performed here and the displaced air transports sufficient heat out of the pump. In addition, the high gas flow also prevents oscillation of the gas in the last stage. During operation at ultimate pressure ( $p < 1$  hPa), the oscillation of the atmospheric air produces higher temperatures at the outlet area, since no gas is passing through the pump and therefore no heat is being transported out of the pump.

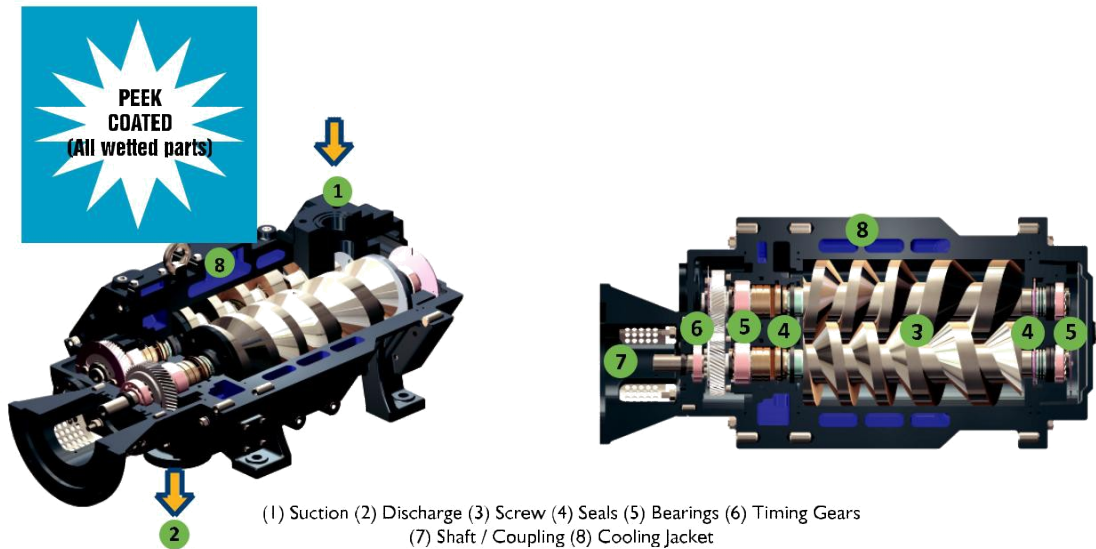
**SuperScrew (Everest) pumps are Dry Screw Pumps with internal compression. The screw rotors have a symmetrical geometry with Hybrid Combined Variable Pitch. This is the 3<sup>rd</sup> and latest generation of Dry Screw Vacuum Pumps.** These Pumps are such designed that a slit is made in the discharge end to ensure the temperature does not rise beyond a certain level. The FEP plate has cooling water along with a provision of "Thermostatic Water Temperature Control Valve" for optimum functionality.

This results in lower power consumption, quiet operation, uniform temperature distribution within the pump and low cooling water consumption. This makes these pumps extremely cost-effective, in spite of their robust design and suitability to run operator free by following simple operating procedures.

These pumps have been the best technology available in field of Vacuum Pumps especially for process industries but did not gain much popularity owing to the high capital cost as well as that of consumables and spares.

Everest, being the First and only indigenous manufacturer of this technology with state of the art machinery, as well as developing a strong vendor base both from within and outside the country has managed to bring down the price and improve quality through value engineering and strict process controls.

## SECTIONAL VIEW OF EVEREST SUPERSCREW SERIES DRY SCREW VACUUM PUMP



### Advantages:

- 1) Hybrid combined variable pitch design. 3<sup>rd</sup> generation of Screw Pumps.
- 2) Can attain high ultimate vacuum levels ( $7.5 \times 10^{-3}$  Torr).
- 3) Top Suction and Bottom discharge, leading to easy gravitational flow of process vapours and solvents out of the pump.
- 4) Internals are PEEK coated. Peek has great chemical compatibility and high adhesive strength with the base metal.
- 5) Effective gas purge system is supplied along with Everest range of Dry Screw Vacuum Pumps.
- 7) Special and advanced design of Mechanical Seals. Extremely Robust with minimum failure rate.
- 8) Both sides (Suction and Discharge) end of the pump are Oil Lubricated. This ensures effective performance even at high temperatures.
- 9) Temperature control valves are given along with the vacuum pump for maintaining the cooling water flow inside the pump.
- 10) Capability of substantial amount of Solvent recovery.
- 11) High Efficiency. Screw pumps usually provide 95-100 % volumetric flow rate even at vacuum levels of 1 torr.
- 12) Trouble free performance.

### Disadvantage:

- 1) Relatively High Capital cost.
- 2) Utilities are required for smooth operation (like water and N<sub>2</sub>).

Everest offers special series of Anti-Corrosive Dry Screw Vacuum Pumps. This range has Ni-Peek coating and comes with Hast Alloy Mechanical Seals along with PTFE coated Pipelines and valves.

This is meant for harsh and corrosive solvent/vapours and keeps running where all others stop.



Figure: Anti Corrosive Dry Screw Vacuum Pumping Systems

## Mechanical Vacuum Boosters:

Vacuum Boosters manufactured by EVEREST, are being extensively used in chemical and process industry to boost the performance of the backing pumps, in low-pressure range, where conventional vacuum pumps have poor volumetric efficiency. Everest Vacuum Boosters are capable of moving large quantity of gas at low pressures, with far smaller power consumption than for any other equipment now available. The internals of a Booster are totally free of any sealant fluid, and therefore the pumping is dry. Also because of the vapour compression action by the booster, the pressure at the inlet of the backing pump is relatively high, resulting in higher volumetric efficiency & low back streaming of sealing fluid. They act as dynamic one way valve and are used in series with a variety of backing pumps to achieve higher speeds and lower ultimate pressures. Since the rotors in a Booster rotate within the casing with finite clearances, no lubrication of the internals is required and the pumping is totally oil free.

Everest Twin Lobe Mechanical Vacuum Booster pumps offer very desirable characteristics, which make them the most cost effective and power efficient option.

Vacuum Boosters have two basic advantageous characteristics:

- 1) Boosting the Vacuum of any backing pump, there by resulting in reduction of process temperature.
- 2) Boosting up the displacement of the backing pumps, there by resulting in reduction of process time.

These are driven with a directly flanged electric motor of high efficiency (FLP or NFLP type) and is supplied without a mechanical bypass. Usually a VFD is recommended along with the boosters for various advantageous features.

Vacuum Boosters are considered to be the most energy efficient pumps in their range as once coupled with any backing pump they result in increasing process efficiency drastically.

### Advantages:

- 1) Dry Vacuum Pump, does not use any process fluid.
- 2) Can pump vapour and gas with equal ease.
- 3) Results in reducing power consumption.
- 4) High pumping capacities, even at low pressures.
- 5) Can be used for high range of working vacuum (from 100 torr down to 0.001 torr).
- 6) Very low frictional losses, resulting in lower power consumption.
- 7) **Everest has two series of boosters running at 1500 and 3000 rpm respectively.**
- 8) Discharge pressure is higher than at suction, resulting in low back streaming of prime pump fluid and effective condensation at high discharge temperature.
- 9) Low capital and maintenance costs.
- 10) Robust process performance. (Average life is 15 years).



### Disadvantages:

- 1) Requires special clearance in case of sticky fluids.
- 2) Metallurgy (MOC) available is CI / SG Iron.

*For further technical information on any of our specific Vacuum Pumps, you may visit our website or call any of our sales representatives.*



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