# Case Studies confirm that Mechanical Vacuum Boosters are Inevitable for Chemical Process Industries.

Mechanical vacuum boosters are dry pumps that meet most of the ideal vacuum pump requirements. They work on positive displacement principle and are used to boost the performance of water ring / oil ring / rotating vane / piston pumps and steam or water ejectors. They are used in combination with any one of the above mentioned pumps, to overcome their limitations. Vacuum boosters pumps offer very desirable characteristics, which make them the most cost effective and power efficient option.

The major advantages are:

- Can be integrated with any installed vacuum systems such as steam ejectors, water ring pumps, oil sealed pumps, and water ejectors etc
- The vacuum booster is a dry pump as it does not use any pumping fluid. It pumps vapour or gases with equal ease. Small amounts of condensed fluid can also be pumped
- Vacuum boosters are power efficient. Very often a combination of vacuum booster and suitable backup pump result in reduced power consumption per unit of pumping speed. They provide high pumping speeds even at low pressures
- Boosters increase the working vacuum of the process, in most cases very essential for process performance and efficiency. Vacuum booster can be used over a wide working pressure range, from 100 Torr down to 0.001 Torr (mm of mercury), with suitable arrangement of backup pumps
- It has very low pump friction losses, hence requires relatively low power for high volumetric speeds. Typically, their speeds, at low vacuums are 20-30 times higher than corresponding vane pumps/ring pumps of equivalent power
- Use of electronic control devices such as variable frequency control drive allows modifying vacuum boosters operating characteristics to conform to the operational requirements of the prime vacuum pumps. Hence they can be easily integrated into all existing pumping set up to boost their performance
- Vacuum boosters don't have any valves, rings, stuffing box etc, therefore, do not demand regular maintenance
- Due to vapour compression action by the booster, the pressure at the discharge of booster (or inlet of backup pump) is maintained high, resulting in advantages such as low back streaming of prime pump fluid, effective condensation even at higher condenser temperatures and improvement of the backup pump efficiency

The table below gives a rough estimate of how the boosters enhance the working vacuums of the processes when installed in combination with various types of industrial vacuum pumps, conventionally used in the industry. They can effectively replace multistage steam ejectors, resulting in considerable steam savings and reduced loads on cooling towers. Mechanical vacuum boosters are versatile machines and their characteristics depend largely on backing pump.

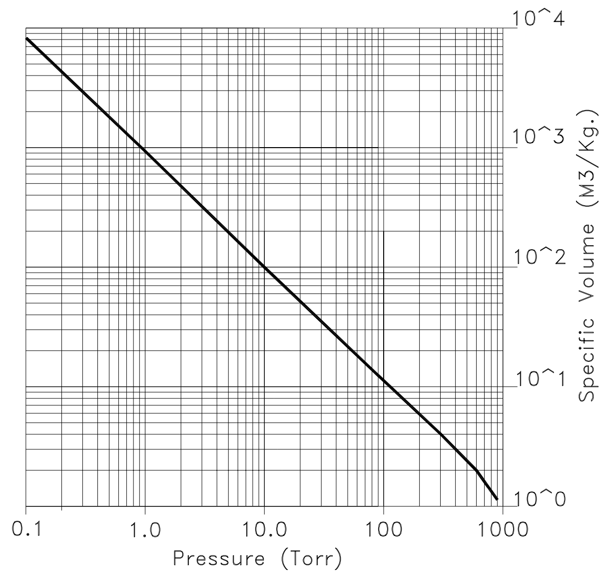
Various types of backing pump can be used, depending upon the system requirement and ultimate vacuum needs. However, the final vacuum is governed by the suitable selection of the backing pump and booster arrangement. The table below gives a broad range of vacuum achieved with various backing pumps combinations.

| VACUUM PUMP | VACUUM RANGE | VACUUM ON INSTALLATION OF BOOSTER |
|---|---|---|
| Single Stage Ejector | 150 Torr | 15 – 30 Torr |
| Water Ejector | 100 Torr | 10 – 20 Torr |
| Water Ring Pump | 40 – 60 Torr | 5 – 10 Torr |
| Liquid Ring Pump | 20 – 30 Torr | 2 – 5 Torr |
| Piston Pumps | 20 – 30 Torr | 2 – 5 Torr |
| Rotary Piston Pumps | 0.1 Torr | 0.01 Torr |
| Rotary Vane Oil Pump | 0.01 – 0.001 Torr | 0.001-0.0001 Torr |

***Table: Enhanced System Performance with Booster & Conventional Backup Vacuum Pumps.***

For example, if a process is using water ring pump, the estimated working vacuums would be of the order of about 670-10 mm Hg gauge (90-50 mmHg abs), largely dependent on the water temperature and pump design. When a booster is installed backed by water ring pump, vacuum levels of the order of 5-10 Torr can easily be expected. For higher vacuums a series of boosters can be used to bring down vacuum down to 0.01 Torr. Mechanical boosters offer a completely dry pumping solution and do not add to any vapor load, unlike steam ejectors, and therefore, do not require large inter stage condenser.

At low vacuums, higher pumping speeds are required to maintain the through-put (mass flow rates), since the specific volume increases with the increase in vacuum. Vacuum boosters enhance the pumping speeds by about 3-10 times depending upon the selection, by virtue of which one can expect higher through-puts and considerable reduction in process time. The drawbacks of steam ejector system such as sensitivity to motive fluid pressures and discharge pressure are overcome easily by the mechanical boosters, since the volumetric displacements/pumping speeds are relatively insensitive to the inlet and outlet working pressures.




***Graph: Specific volume of water vapour at various pressures***


***Fig: Typical Direct Mounted Mechanical Vacuum Booster Assembly***

Vacuum boosters being very versatile vacuum machines are used in a wide range of processes, some of them being:

**Rough vacuum applications (Typically in range 1- 100 Torr)**

- Vacuum drying application
- Vacuum distillation processes
- Solvent recovery
- Vanaspathi oil deodorization
- Replacement of steam ejectors
- Enhancing the performance of water ring pumps /water ejectors
- Vacuum flash cooling

**Medium Vacuum applications (Typically in range 0.001-1 Torr)**

- Efficient backup for diffusion pump systems
- Thin film deposition /coating
- Short path/ molecular distillation
- CFL, tube light and general lighting industry
- Object & roll metallizers
- Vacuum heat treatment and degassing / vacuum furnaces
- Semi-conductor processing
- Transformer oil de-humidification
- Chemical laser applications
- Freeze drying
- Vacuum impregnation

## Case studies on industrial installation of boosters

Everest's technical team is fully geared to undertake design, supply and commissioning of these boosters for chemical processes. Since process parameters vary considerably in chemical plants a careful study of process and installation of suitable Booster arrangement is essential to get the desired objectives. Some of the case studies carried out by the technical team of Everest are briefly described here.

**1) Objective: Replacement of steam jet ejector – Energy saving**

A large industrial unit at Barnala, Punjab manufacturing acetic acid anhydride was using steam ejectors for maintaining process vacuum of 720 mm HG for which the average steam consumption per day was 15 tonnes. The client was keen to eliminate steam from the process due to high-energy cost, huge load on cooling tower, and total process dependency on steam availability. Everest's technical team worked on the project. The estimated non-condensable load of the process was 100 Kg/hr apart from the steam load. Everest vacuum booster with a 15 HP drive backed by water ring pump with a 30HP drive was suggested and successfully installed, replacing the steam ejector.

**Major Advantages achieved**

- **Huge energy saving** – 15 Tonnes of steam was totally eliminated by electrical energy of 45HP. Net saving of Rs 7200/day on energy (taking steam generation cost @ Rs 0.70/Kg and Electrical unit @ Rs 4/-unit.

**2) Objective: To reduce load on cooling towers**

A multinational company in Aligarh, manufacturing milk powder, was forced to reduce its production during the monsoon season due to drop in cooling tower efficiency. The company was using number of multi stage steam ejectors and the total heat load of condensing steam was taken care by the cooling tower. The technical team of Everest advised installation of vacuum booster replacing the steam ejectors, with an idea of reducing heat load on the cooling tower. On trials a steam ejector consuming 100 – 125 Kg steam was replaced with a 5HP vacuum booster reducing heat load of about 25 Tonnes.

In case of multistage steam ejector systems the steam consumption is high for the initial stages. Inter-stage condensers are generally installed to condense the steam before the subsequent stage. For every 100 Kg of steam condensed there is heat load added to water equivalent to about 20 tonnes, and this heat load is to be dissipated to atmosphere which is generally done through cooling towers. During monsoons or in areas where relative humidity levels are high, cooling tower efficiency drops affecting the available water temperature. Most of the processes and vacuum pumps are adversely affected by the rise in water temperature reducing the plant/process efficiency. Vacuum boosters offer an ideal replacement overcoming steam ejector limitations as they do not add any heat load to the system. No inter-stage condensing is required as they run dry.

**3) Objective: Removal of steam boiler:** A South India based company manufacturing cardanom oil, from cashew nut shell extract, had installed a mini boiler only to run the steam ejectors backed by water jet ejector to get a process vacuum of 759 mm Hg in their distillation columns. Frequent production loss was a regular phenomenon due to boiler associated holdups such as drop in steam pressure, shortage of dry fuel, availability of cheap fuel, DM water, scaling etc. Everest's technical team proposed installation of a 10HP and 5HP booster, in series, backed by water jet ejector for the required vacuum of 759mm Hg and capable of handling the total plant load. The installation today runs on Everest boosters and boiler has been dismantled from the site. Massive energy saving have been reported with better product quality and process reliability. Associated problem with the boiler such as availability of fuel, DM plant, scaling etc, have totally been eliminated since there is no steam requirement by plant after installation of Everest boosters. The unit has installed three parallel systems for their three columns with independent control.

**Major advantages achieved**

- Total elimination of steam, making the plant boiler free
- Saving in the energy consumption
- All distillation columns can now be independently operated. With single boiler operations the entire plant was sensitive to boiler performance
- Quick start and stop possible since no initial heating period is required
- No need for inter-stage condensers, cooling water, cooling tower and allied accessories such as pumps, valves etc

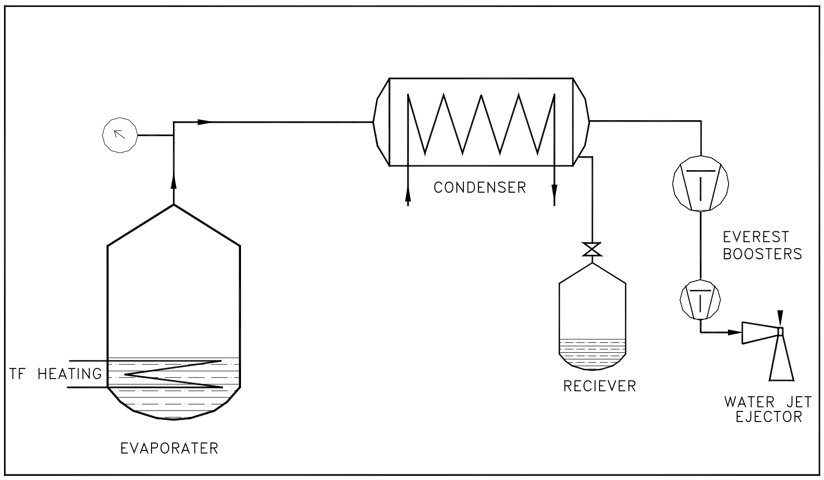



***Fig: Distillation process with Two Stage Booster backed by Water Jet Ejector to get Vacuum of 1 torr.***

4) **Objective: Spice solvent extraction – increase in purity:** A South India based industrial unit engaged in manufacture of spices was using water ring pump to extract solvent (ethylene di-chloride, hexane, methanol, acetone, ethyl acetate) from the product. The concentration level of purity required was over 99% and in order to achieve the same with the water ring pump alone; the batch time was 15-17 hours. On the recommendation of Everest's technical team, 5 HP vacuum booster was installed backed by the water ring pump and the overall process time was reduced to 7-8 hours with higher purity levels. Better vacuum created by the boosters not only reduced the process time but also reduced the residual solvent concentration levels down to 10 – 12 ppm.

According to Raoult's law, "In a solution, vapour pressure of a component (at given temperature) is equal to the whole fraction of that component in the solution multiplied by the vapor pressure of that component in the pure state". Accordingly, as the concentration levels of the solvent drops, higher vacuums are essential to remove the final traces of the solvent. For all applications of solvent extraction where the residual levels of solvent have to be maintained low, Everest boosters are essential.

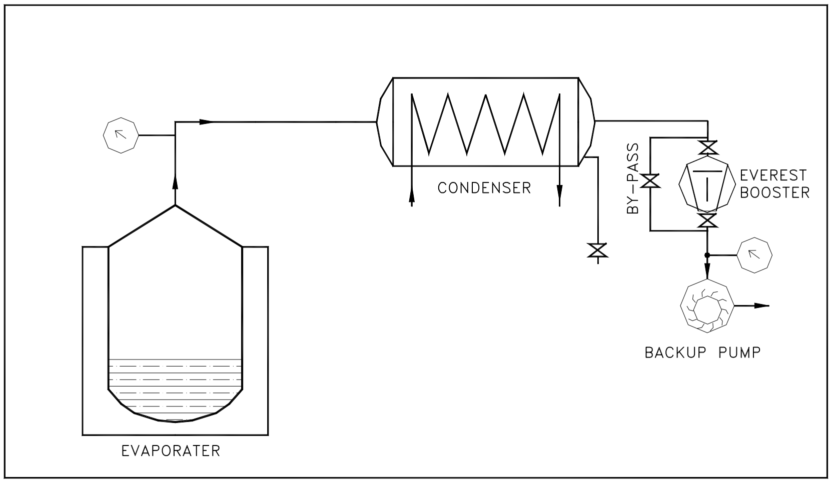



***Fig: Booster arrangement with External Bypass for Solvent Recovery Application requiring high vacuum at final stages.***

**5) Objective: Increase in purity of silicon DM 350:** An industrial unit in Rajasthan manufacturing Silicon DM 350 wanted to increase the final product purity from 99.35% to better than 99.6%. The company was using multiple vacuum systems consisting of water ring pump and various capacities of oil seal rotary pumps, which were switched into system sequentially to get better vacuum levels in the plant for solvent extraction. They were unable to get product purity better than 99.3% in reasonable batch time. Everest's technical team advised installation of a 7.5 HP booster backed by existing 7.5 HP rotary oil seal pump and a 5HP water ring pump. Now, with the modified proposed arrangement client is able to get purity in the range of 99.72% with saving of about 18 HP due to removal of other pumps, previously used.

**Major Advantages achieved**

- Product purity increased to 99.7%
- Reduction in energy requirements by about 18HP
- Frequent change of rotary oil seal oil minimized, saving on cost and process down time

Rotary oil pumps give better vacuums but have relatively low pumping speeds. They are not suitable for handling condensable loads and in many processes oil vapor suck-back can cause serious problems. Vacuum boosters overcome all these problems and therefore offer a perfect substitute for applications requiring high pumping speeds at low pressures.


***Fig: Mechanical Vacuum Booster with post condenser backed by Rotary Oil Pump for Molecular Distillation.***

**6) Objective: Process time reduction – vacuum tray drying:** One of the bulk drug manufacturing units at Panoli, was using vacuum tray drying process for which the cycle time was about 18-20 hours. A 10HP water jet ejector was used for achieving process vacuum of about 690-700 mmHg. A 5HP Everest vacuum booster was installed between the vacuum tray dryer and the water ejector to increase the pumping speed and process vacuum, which resulted in reduction of cycle time to 10-11 hours. The total evaporation (water) from a 150 Kg batch, having initial moisture content of 15 – 20 Kg was made possible in 10-11 hours against the original time taken of 16 – 20 hours.

Principally, in any drying process, the water is evaporated from the product. The specific volume ($m^3$/Kg) of vapour is much higher than liquid and rises sharply with the drop in pressures. Therefore, for effective removal of vapors high pumping speeds, at the low working pressures are essential. Vacuum boosters are the most cost and energy efficient pumps, which meet the desired parameters, and the process time can be considerably reduced.

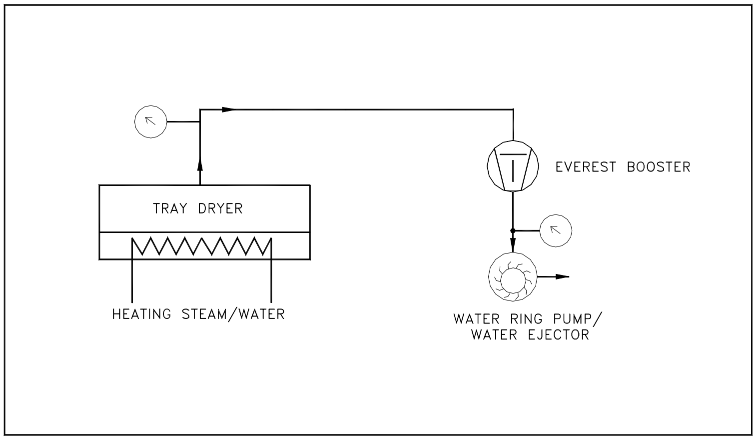



***Fig: Vacuum Tray Dryer installation for Low residual moisture requirement – Ideally used in Pharmaceutical, Food & Chemical Drying.***

Some of the case studies have been presented. Many more areas like freeze drying, oil purification units, vacuum distillation, molecular distillation etc have been covered for booster operation. In fact mechanical vacuum boosters can be used for any application demanding low pressure and high displacements and they offer the most energy efficient solutions.

***Fig: Mechanical Vacuum Booster (Displacement 3000 m3/hr)***


***Fig: Mechanical Vacuum Booster with External Bypass Valve for regulating differential Pressure across the Booster***

***(Article written by technical team of Everest Transmission – The only successful manufacturer of Mechanical Vacuum Boosters in India)***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