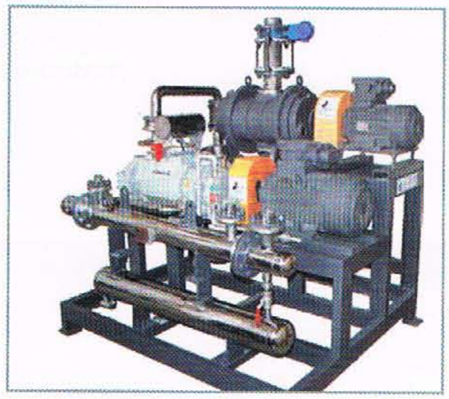
Efficient vacuum distillation

Vacuum booster pumps are the most cost effective and power efficient devices

In many cases of vacuum distillation applications, where the desired vacuum level is not achieved because of system inefficiency, it ultimately affects the product quality. Installation of booster pumps, which is comparatively a cheap proposition, often helps in improving the vacuum level under such circumstances.





Source: Everest Blowers

Diverse range of vacuum packages from standard compact units to complex purpose-built systems with integrated instrumentation and control panels are available nowadays for various industrial applications. A good vendor can offer services from initial engineering design to final commissioning.

Distillation at reduced pressures is a widely used process in the chemical industry, specially used in extraction or purification of essential oils, deodourisation of 'vanaspati' or vegetable oils and purification and drying of chemicals.

Let us take a look at the advantages of low-pressure distillation process over atmospheric pressure distillation.

- Use of lower process temperatures: Under vacuum, there is a reduction in boiling points. Hence, thermally sensitive substances can be processed easily.
- Shorter time of thermal exposure of the distillant: The reduction in thermal exposure time enables the processing of thermally sensitive items – such as vitamins and hormones, whose properties are adversely affected by extensive exposure to heat.
- Increase in relative volatility: Materials become more volatile under vacuum, and therefore more evaporation takes place, resulting in higher production rates.
- Fractional distillation under vacuum leads to easier separation of components of a mixture.
- Change in position of the azeotropic point at reduced pressure: This enables separation, under reduced pressure or vacuum, of hard to separate materials.
- Reduction of energy consumption by lowering of the boiling point under vacuum.
- Oxidation losses of the feed stock are reduced under good vacuum conditions.
- Reduction in stripping steam requirements for de-odourisation process of oil due to increased specific volumes (of steam) at low pressures and enhanced agitation and stirring of the oil.

Ideal vacuum pump

In order to ensure satisfactory operation of the distillation process, it is essential that suitable vacuum pumps are used. Although, there is no single perfect pump, the ideal characteristics of the vacuum pump required for distillation process are described hereafter.

- Low energy input for a given volumetric pumping capacity.
- The pump should be of dry type, i.e., it should not use any pumping fluid such as water, oil, steam etc., these fluids interfere with the purity of the product and limit ultimate vacuum level.
- The ideal pump should have minimum number of stages to achieve the desired vacuum levels.
- No environmental pollution should be caused by the pump's operation. Hence, there should be no material pollution due to stripping or disposal of pump fluids. Noise pollution should be at the minimum level.
- The pump should have high volumetric pumping capacity at low pressures.
- The pump should have low maintenance requirements.
- The condensation of the vapours within the pump should be minimum, so as not to affect its performance.

The article has been compiled on basis of actual field trials conducted by the technical cell of Everest Blowers.
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Source: Everest Blowers

FIG 1: **TYPICAL PUMPING VRS PRESSURE CURVES**

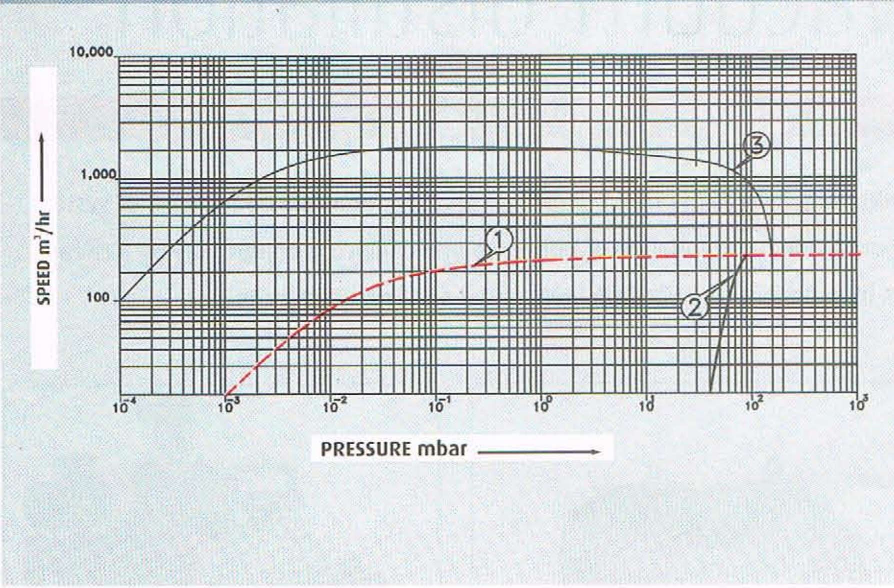

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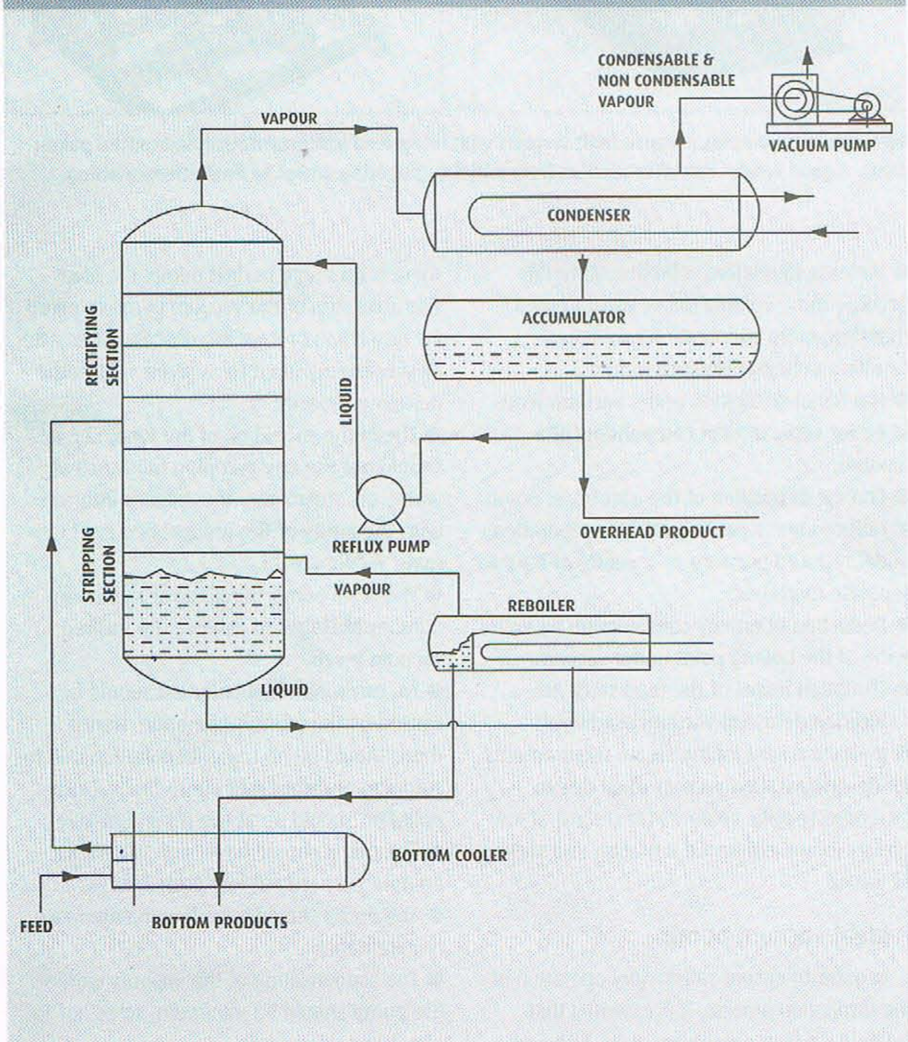
FIG 2: **MENTHOL DISTILLATION WITHOUT MECHANICAL VACUUM BOOSTER**



- The pump should have high vapour handling capacity.
- It should be able to pump out little amount of liquids, in case condensation occurs inside the pump.

Pump selection

No single vacuum pump can meet all the above criteria completely. Let us now see some of the widely used pumps for distillation along with their limitations.

Ring type pumps (e.g., water ring pump, oil ring pump)

These pumps use water and sometimes oil as the pumping medium. For this reason, with ring type pumps, the ultimate vacuum achieved gets limited to the vapour pressure of the pump fluid at the working temperature. Owing to the above, even an efficient double stage water ring pump would stall at around 50 torr abs. (710 mm Hg), since vapour pressure of water at 30°C is about 30 torr.

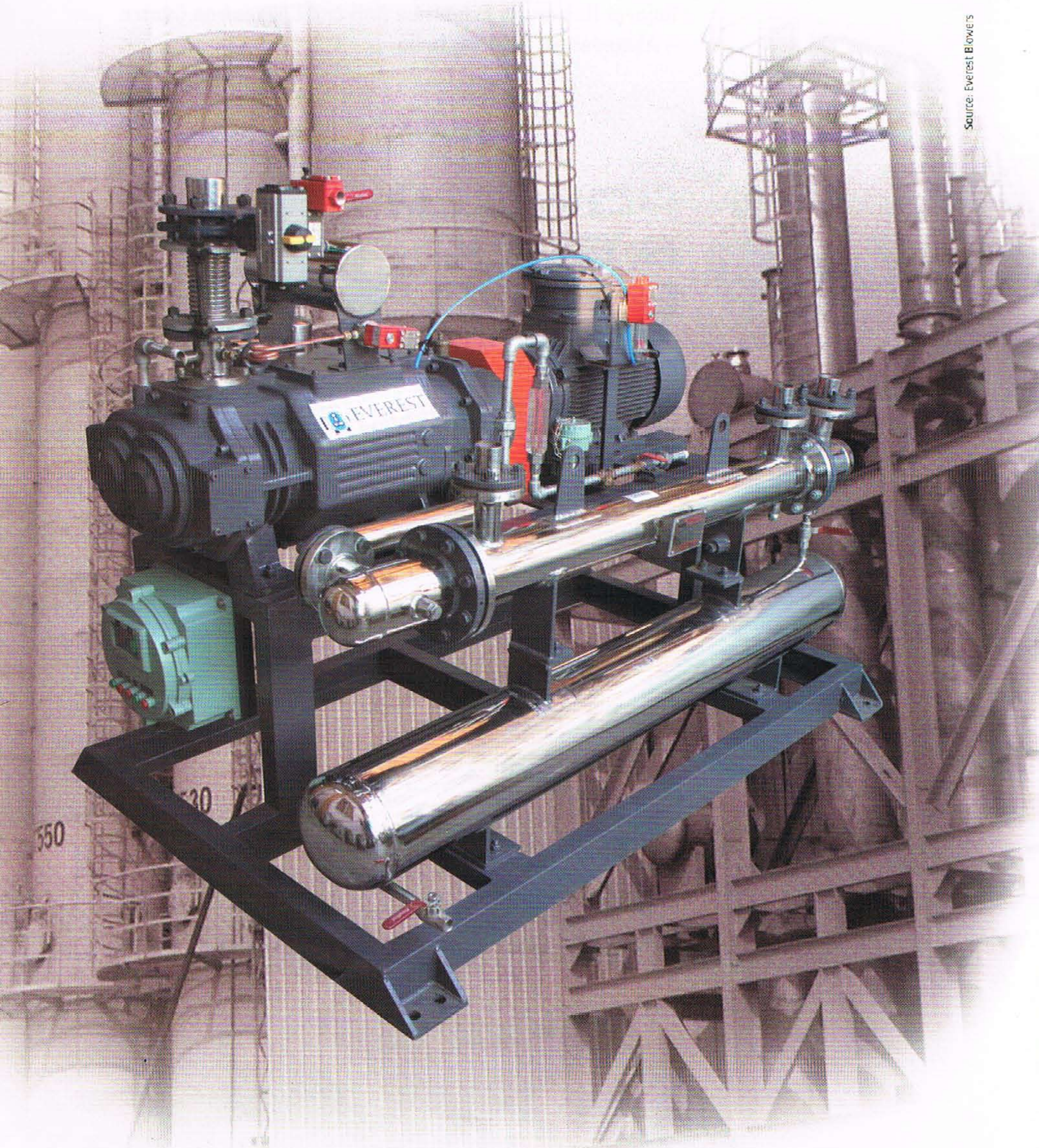
They have further disadvantage of being highly energy inefficient, because most of the power is lost in friction losses of moving the pump fluid inside the pump. This restricts the water ring (or oil ring) pump to relatively modest volumetric pumping capacities. Water ring pumps are widely used in food processing and pharmaceutical industry, since any other fluid contamination is not acceptable. This restricts the process capabilities – as working vacuum and speed get restricted. Another disadvantage of ring pumps is that the working fluid often has to be treated before it can be discharged or reused – as it contains the carry-over of condensed product.

Steam ejectors

Steam ejectors can produce low pressures (when used in multiple stages with suitable condensers) and have very high volumetric speeds. However, they require the maintenance of a complete steam generation facility confirming to IBRA regulations and inspection. They are generally not available as stand-alone installations – but can be found where process steam is easily available. Relatively large barometric condensers are required to handle the ejector steam. For the obvious reason, large amount of soft-demineralised water is required, which is an additional recurring expense.

Rotary vane and piston pumps

These types of pumps have high power to capacity ratios, and are therefore, not avail-

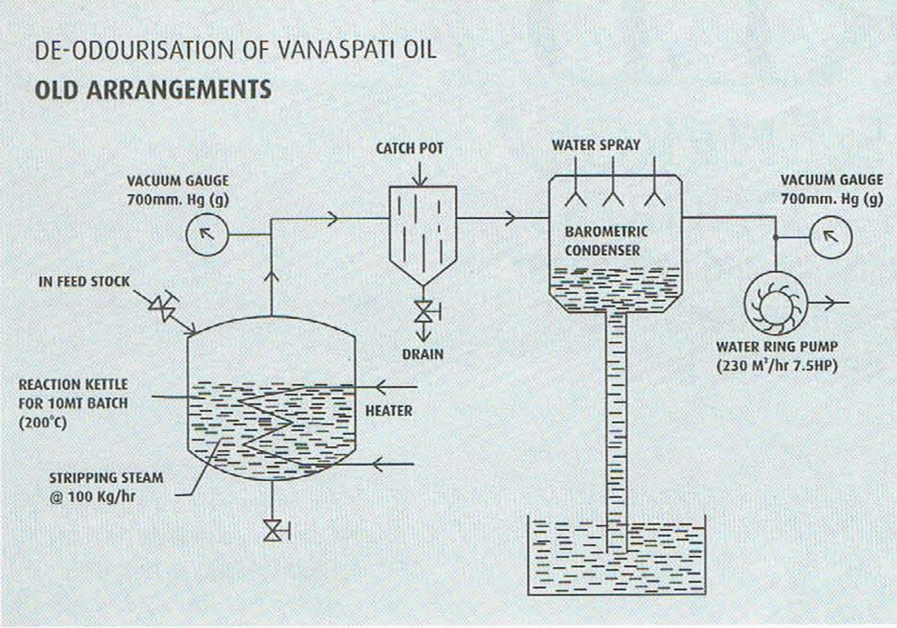


Source: Everest Blowers

Industrial vacuum system for vacuum distillation and solvent recovery applications

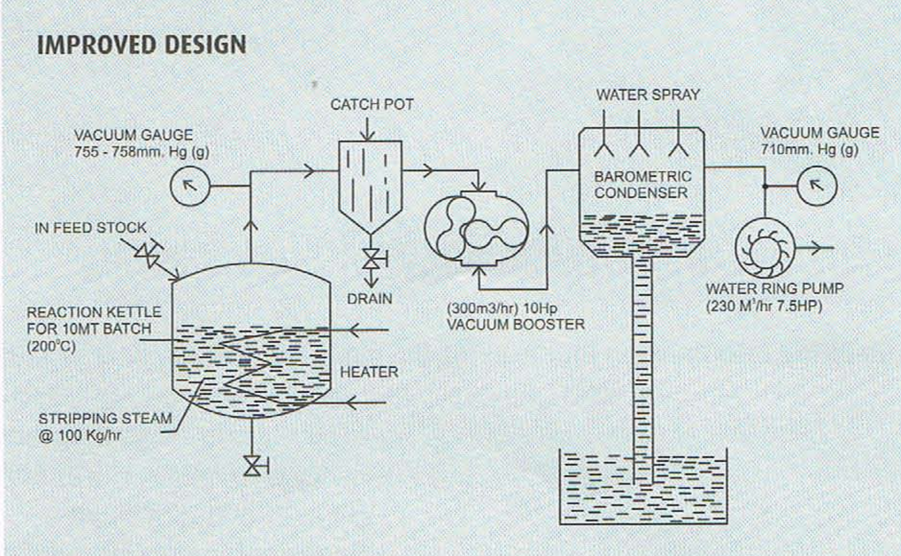
Source: Everest Blowers

FIG 4: **WITHOUT MECHANICAL VACUUM BOOSTER DE-ODOURISATION OF VEGETABLE OIL**



Source: Everest Blowers

FIG 5: **BOOSTER INSTALLED FOR DE-ODOURISATION OF VEGETABLE OIL**



- Practically zero vapour loss was achieved - since at the outlet of vacuum booster pump, vapour compression took place, and all the residual vapour could be condensed in the secondary condenser, which would earlier enter into the primary pump and affected its working performance.
- Practically there was no contamination of primary pump oil demanding less frequent oil changes. This also resulted in savings of pump oil.

The above advantages were made possible by merely introducing a booster in the existing system as no other major modification was required.

Case study:

Booster installed for de-odourisation of vegetable oil

In one of the existing *vanaspati* (Food & Beverage) units of batch capacity 10 MT, the plant was not getting the required product quality. Due to inadequate levels of vacuum, the total process of deodourisation was not taking place. A water ring pump of 7.5 HP was being used in the system with condenser to handle 100 Kg/hr of stripping steam load. The available steam was just sufficient for stripping, and no extra or surplus steam was available for installing additional steam ejector *(ref. Fig. 4)*.

To get the required product quality, higher vacuum to the level of 740 mm of Hg was essential against the levels of 680-700 mm of Hg achieved. The available option was to install a steam ejector for which additional boiler and accessories were also required – since additional steam to the tune of 250-300 kg/hr was required.

Also, additional steam would add to the condenser loading and hence need for a bigger condenser, cooling tower etc., were demanding a heavy capital investment.

To meet the process demand vacuum boosters of capacity 3000 m/hr were installed between the vessel and the condenser, as shown in figure *(ref. Fig. 5)*. The booster was designed to handle super- heated steam at 200°C. The installation of booster was a simple operation, not demanding additional piping or auxiliary equipment. Quick installation of the booster resulted in minimum down time. The system was put in operation and the following results were obtained:

- Desired vacuum levels to the range of 755-758 mm of Hg was achieved.
- Due to the vapour compression at the discharge, condenser efficiency increased allowing less stringent control on inlet water temperature.
- Requirement of stripping stream was reduced substantially, since at lower vacuum levels higher specific volumes of steam were available for effective stripping.
- With installation of vacuum booster between the vessel and the condenser, the cycle time was reduced thus it increased the plant capacity.

Concluding remarks

Installation of boosters would, in most of the vacuum distillation applications, yield tremendous success in achieving higher vacuums and pumping speeds, thereby increasing product quality and production rates at nominal additional power.

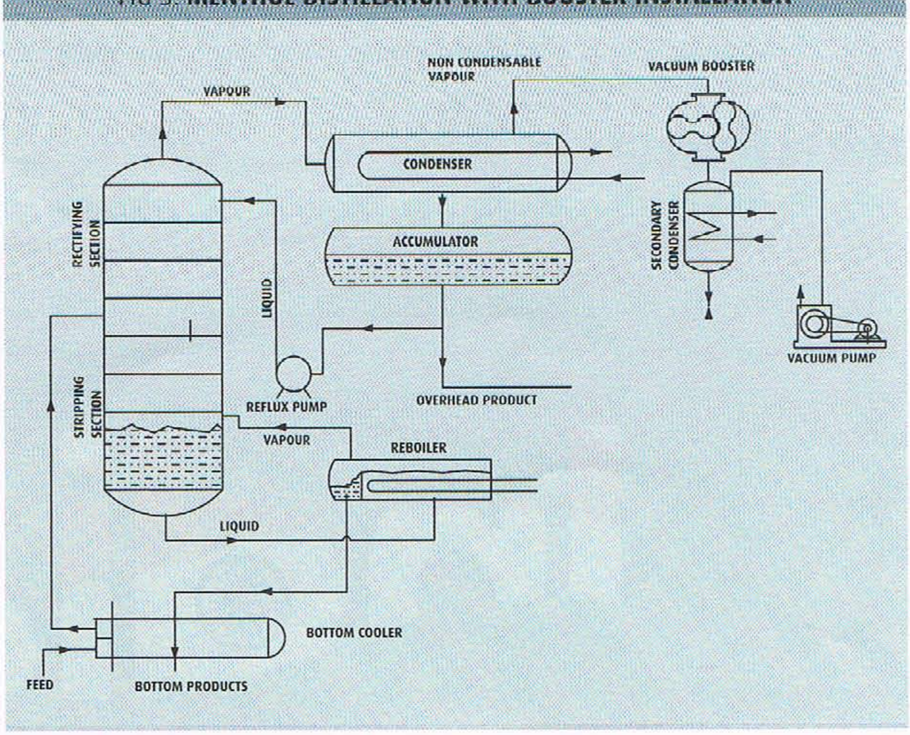
able in large volumetric capacities. They are effective for pumping non-condensable loads but have a limitation of not being able to pump large and regular quantities of water vapour (and other vapours) released in low-pressure vacuum processes. Various precautions have to be taken – if they are used for food grade applications to avoid contamination of process material by the pump oil or back streaming of oil vapours.

Vacuum booster

Vacuum booster is a dry pump that meets most of the ideal pump requirements. It works on positive displacement principle. As its name suggests, it is used to boost the performance of water ring or oil ring or rotating vane or piston, and in some cases even steam ejector pumps. It is used in conjunction with any one of the above mentioned pumps, to overcome their limitations. Vacuum booster pumps offer very desirable characteristics, making them the most cost effective and power efficient alternatives. Their major advantages are listed hereafter.

- The vacuum booster is a dry pump. It does not use any pumping fluid. Hence, it pumps vapours or gases with equal ease. Small amounts of condensed fluid can also be pumped through it.
- It has a very low pump friction losses, hence requires relatively low power for high volumetric speeds. Typically, their speeds, at low pressure are 20-30 times higher than corresponding vane pumps or ring pumps of equivalent rating.
- A vacuum booster can be used to generate vacuum in range of 0.001 torr, and maintain high volumetric speeds at such low pressure. At this pressure, the rotary oil and water ring pumps are not effective, as their pumping speed falls drastically when approaching the ultimate levels.
- A vacuum booster can be used over a wide pressure range, from atmospheric pressure down to 0.001 torr (mm of mercury), with suitable arrangement of backup pumps.
- Use of electronic control devices, such as Variable Frequency Drive (VFD), allows to modify the vacuum booster's operating characteristics to conform with the operational requirements of the prime vacuum pumps. Hence, they can be easily integrated to all existing pumping setups to boost their performance.

FIG 3: **MENTHOL DISTILLATION WITH BOOSTER INSTALLATION**



Source: Everest Blowers

- Vacuum boosters are power efficient. Very often the combination of vacuum booster and primary pump result in reduced power consumption per unit of pumping speed. They provide high pumping speeds at low pressures *(ref. Fig. 1)*.
- A vacuum booster has long M.T.B.F. (Mean Time Between Failures) and the normal service life is in excess of 7 to 10 years. Vacuum boosters don't have any valves, rings, stuffing boxes etc., also they do not demand regular maintenance arising due to constant wear and tear.
- Due to vapour compression action by the booster, the pressure at the discharge of booster (or inlet of prime pump) is maintained high, resulting in low back streaming of prime pump fluid. A suitable secondary condenser installed between the booster outlet and prime pump inlet would trap all the escaped vapours, thus keeping the prime pump free of any vapour load, thereby increasing its life, efficiency and minimising frequent oil change.

Benefits of using vacuum boosters

Case study: Vacuum boosters used in menthol distillation

An existing menthol distillation unit used 2 x 10 HP reciprocating piston vacuum pumps and was having problem in achieving and maintaining adequate vacuum. This resulted in poor quality product and low production rates. The distillation column had imported packing material, yet the desired final product quality and production rates could not be achieved, because of inadequate vacuum levels *(ref. Fig. 2)*.

Vacuum booster of capacity 800 m³/hr with 3 HP motor power was installed in series with the existing vacuum piston pump *(ref. Fig. 3)* to boost the system performance. Remarkable results that were obtained – have been listed in the next few lines.

- The booster pump improved the plant system vacuum, thereby the plant manager could easily regulate the column D.P. (Differential Pressure) to the desired limits – so as to get high purity product.
- Rate of production increased substantially due to the high rate of evaporation and low reflux feed back.
- The improved vacuum in the system prevented oxidation of residual products resulting in lower bottom product losses.
- Substantial saving in running cost was observed since the primary piston pump capacity requirement was reduced by 50 per cent, as major pumping at low pressures was done by the vacuum booster.