Vacuum Booster for Distillation Process

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EVEREST

PRESSURE & VACUUM SYSTEMS

1.00 Introduction:

Distillation at reduced pressures is a widely used process in the chemical industry, specially used in extraction / purification of essential oils, deodorisation of Vanaspati / Vegetable Oils and purification & drying of chemicals. The advantages of low-pressure distillation process over Atmospheric pressure distillation are as under:

1.01 Use of lower process temperatures. Under vacuum, there is a reduction in boiling points. Hence thermally sensitive substances can be processed easily.

1.02 Shorter time of thermal exposure of the distillant. The reduction in thermal exposure time enables the processing of thermally sensitive items such as vitamin & harmones, whose properties are adversely affected by extensive exposure to heat.

1.03 Increase in relative volatility. Materials become more volatile under vacuum and therefore more evaporation takes place, resulting in higher production rates.

1.04 Fractional distillation under vacuum leads to easier separation of components of a mixture.

1.05 Change in position of the azeotropic point at reduced pressure. This enables separation under reduced pressure / vacuum of hard to separate materials.

1.06 Reduction of energy consumption by lowering of the boiling point under vacuum.

1.07 Oxidation losses of the feed stock are reduced under good vacuum conditions.

1.08 Reduction in stripping steam requirements for de-odourisation process of oil due to increased specific volumes (of steam) at low pressures and enhanced agitation & stirring of the oil.

2.00 Ideal Vacuum Pump :

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

2.01 Low energy input for a given volumetric pumping capacity.

2.02 The pump should be 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.

2.03 The ideal pump should have minimum number of stages to achieve the desired vacuum levels.

2.04 No environmental pollution should be caused by pump operation. Hence there should be no material pollution due to stripping or disposal of pump fluids. Noise pollution should be at the minimum.

2.05 The pump should have high volumetric pumping capacity at low pressures.

2.06 The pump should have low maintenance requirements.

2.07 The condensation of the vapors within the pump should be minimum so as not to effect its performance.

2.08 The pump should have high vapor handling capacity.

2.09 Should be able to pump out little amount of liquids, in case condensation occurs inside the pump.

3.00 Pump Choice :

No single Vacuum Pump can meet all the above criteria completely. Some of the widely used pumps for distillation are described below along with their limitations.

3.01 Ring Type Pumps (eg. 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 vapor 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 30 Torr abs.(730 mm Hg), since vapor pressure of water at 300C 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 & speeds 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.

3.02. 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 IBAR 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.

3.03 Rotary Vane and piston pumps :

These type of pumps have high power to capacity ratios and are therefore, not available in large volumetric capacities. They are effective for pumping noncondensable loads but have a limitations of not being able to pump large & regular quantities of water vapor (and other vapors) 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 vapors.

4.00 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 / oil ring/ rotating vane / 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 pump offer very desirable characteristics, making them the most cost effective & power efficient alternative. The major advantages are :

4.01 The vacuum booster is Dry Pump. It does not use any pumping fluid. Hence it pumps vapor or gases with equal ease. Small amounts of condensed fluid can also be pumped.

4.02 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.

4.03 The vacuum Booster can be used to generate vacuum in range of 0.001 Torr and yet have high volumetric speeds at such low pressures. At these pressures the rotary oil and water ring pumps are not effective, as their pumping speed falls drastically when approaching the ultimate levels.

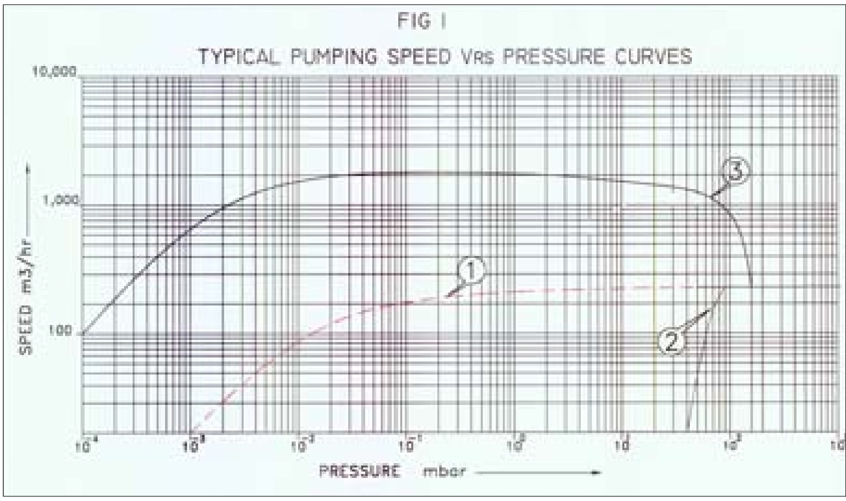
4.04 The vacuum Booster can be used over a wide pressure range, from atmospheric pressure down to 0.001 Torr (mm of mercury), with suitable arrangement of backup pumps.

4.05 Use of electronic control devices such as Variable Frequency Drive allows to modify vacuum boosters operating characteristics to confirm with the operational requirements of the prime vacuum pumps. Hence they can be easily integrated into all existing pumping set up to boost their performance.

4.06 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)

4.07 Vacuum booster has long M.T.B.F. (Mean time between failure) and the service life is in excess of 7 to 10 years (assuring preventive maintenance is done) Vacuum boosters don't have any valves, rings, stuffing box etc., which demand regular maintenance due to constant wear & tear.

4.08 Due to vapor 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 & prime pump inlet would trap all the escaped vapors thus keeping the prime pump free of any vapor load, thereby increasing its life, efficiency and minimizing frequent oil change.



(1) Two Stage Rotary Vane Oil\ Pump (RP)
(2) Water Ring Pump
(3) Booster RP Combination

In order to illustrate the benefits of using Vacuum Booster the following actual case studies are given.

Case # 1 :

Vacuum Boosters used in Menthol Distillation.

An existing menthol distillation unit used 2 x 10 HP Piston Type Vacuum Pumps (Ingersoll Rand make) and was having problem in achieving & 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 & production rates could not be achieved, since inadequate vacuum levels were achieved. (ref. Fig. 2)

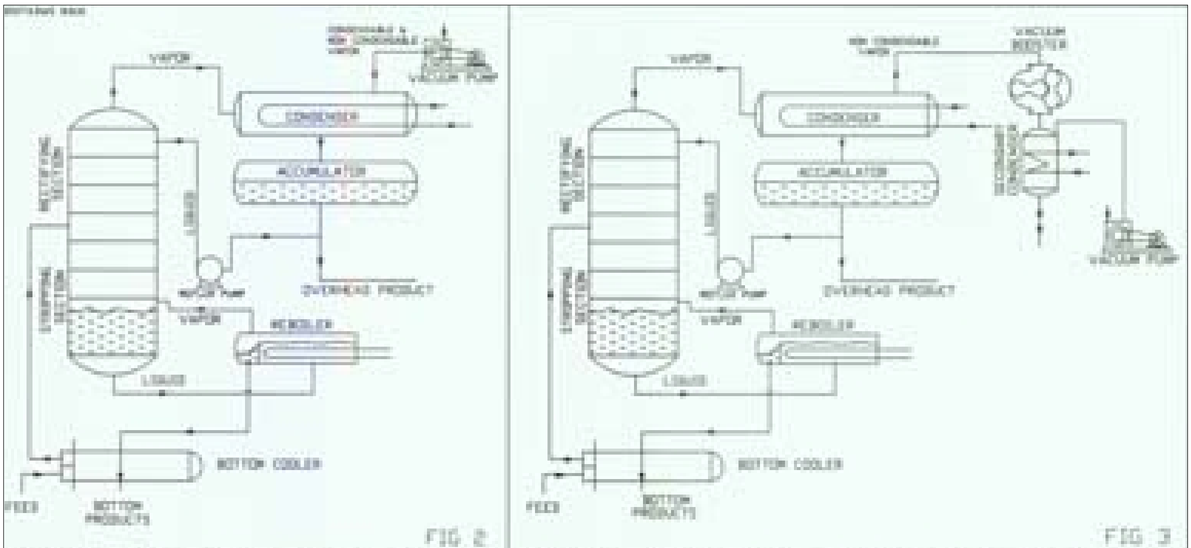


FIG 2
MENTHOL DISTILLATION WITHOUT BOOSTER

FIG 3
MENTHOL DISTILLATION WITH BOOSTER INSTALLATION

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) below to boost the system performance. The following remarkable results were obtained:

a) improvement in plant system vacuum, thereby the plant manager could easily regulate the column, D.P. (differential pressure) to desired limits so as to get high purity product

b) Rate of production increased substantially due to high rate of evaporation & low reflux feed back.

c) Improved vacuum in the system prevented oxidation of residue product resulting in lower bottom product losses.

d) Substantial saving in running cost was observed since the primary piston pump capacity requirement was reduced by 50%, as major pumping at low pressures was done by the vacuum booster.

e) Practically zero vapor loss since at the outlet of vacuum booster vapor compression took place and all the residual vapor could be condensed in the secondary condenser, which would earlier enter into the primary pump and affects its performance.

f) Practically 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 major modification was required.

Case # 2 :

Booster installed for De-odourisation of Vegetable Oil

In one of the existing vanaspati unit of batch capacity 10 MT was not getting the required product quality since due to inadequate levels of vacuum the total process of deodourisation could not take 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 surplus steam was available to install a steam ejector (ref. fig. 4).

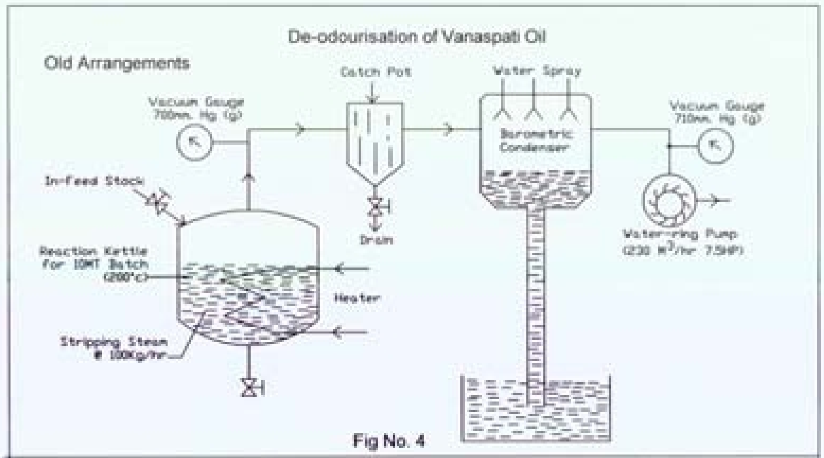


Fig No. 4

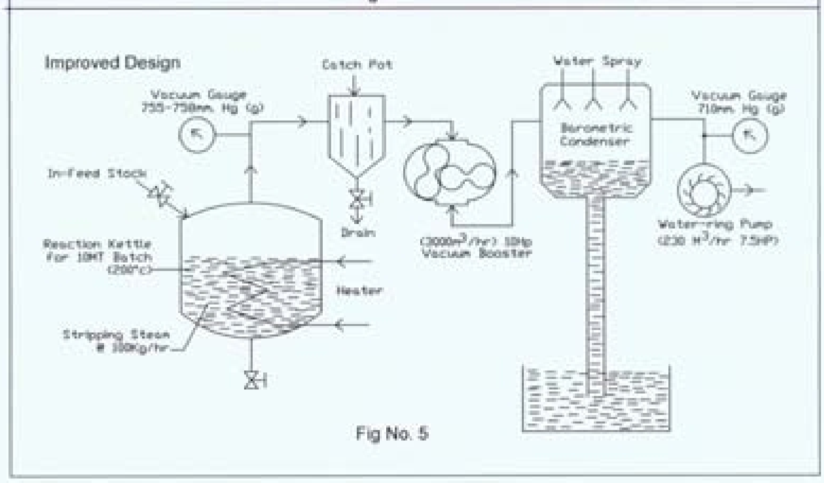


Fig No. 5

To get the required product quality higher vacuums to the level of 740 mm Hg were essential against the levels of 680-700 achieved. The available option was to install a steam ejector for which additional Boiler & 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 bigger condenser, demanding heavy capital investment

To meet the process demand Vacuum Boosters of capacity 3000 m3/hr was installed between the vessel and the condenser. As per the case-II figure (Fig. 5) given below. The booster was designed to handle super heated steam at 2000 C. The installation of booster was a simple operation not demanding additional piping or auxillary equipment. Quick installation of booster resulted in minimum down time. System was put in operation and following results were obtained :

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

CONCLUDING REMARKS :

*I*nstallation of Boosters would, in most of the vacuum distillation *appl*ications, yield tremendous success in achieving higher vacuums and *p*umping speeds thereby increasing product quality and production rates at *n*ominal additional power.

Thank you

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