DRY MECHANICAL BOOSTERS – REPLACE STEAM EJECTOR

Steam ejectors find wide use in vacuum pumping applications – so called dirty application such as in Vapour extraction, Chemical processing, Evaporative Cooling, Vacuum distillation, Vegetable oil de-odourization, Vacuum Refrigeration, Drying etc. In spite of the fact that steam ejectors have poor overall efficiency and relatively high energy consumption, they are popular in vacuum applications because of their simplicity and ease of operation. Its high time now when the industry should realize the disadvantages associated with it and switch over to efficient alternatives – Dry Mechanical Vacuum Booster being one of them. Mechanical Vacuum Booster offers an efficient replacement to steam ejector, for most of the applications, as they overcome major drawbacks associated with steam ejectors. The major advantages of Mechanical Booster being :-

(a) Mechanical Vacuum Boosters are more energy efficient.

(b) Minimum of auxiliary equipment is needed; unlike for steam ejectors, which need large condensers, cooling towers, re-circulation pumps etc.

(c) Mechanical Vacuum Boosters are dry pumping system and don't give rise to water and atmospheric pollution.

(d) Startup time for mechanical booster is very low making them ideal for Batch process operation where immediate startup and shut down is essential for energy conservation.

Apart from the above, the operating costs for mechanical vacuum systems are low, resulting in extremely short pay back period. For example, when operating in the range of 5-10 Torr the operating cost of mechanical pumping system would be about one tenth of the equivalent steam ejector system.

Steam Ejectors:

Steam ejectors comprise of converging – diverging nozzle through which high-pressure steam (motive fluid) is forced through. (Fig.1). The ejector nozzle converts the high-pressure head of the motive fluid into high velocity stream as it emerges from the nozzle into the suction chamber. Due to increase in velocity head, there is a drop in pressure head causing partial vacuum in the suction chamber. Pumping action occurs as the fluid / vapors present in suction chamber are entrained by the motive fluid and are carried into the diffuser, by viscous drag process.

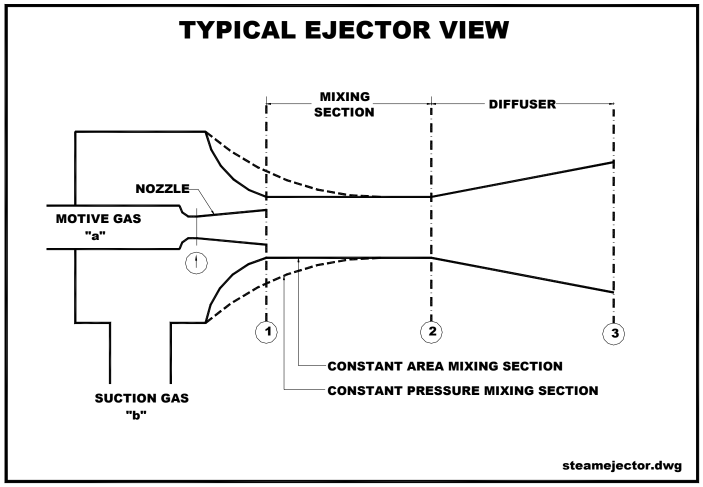


Fig.1

The operating medium for ejectors (motive fluid) can be vapor, gas or liquid under pressure. Generally, high-pressure steam is used and in such cases they are known as steam ejectors. In the diffuser section of the nozzle, the velocity of the mixture is recovered to pressure head greater than suction pressure but much lower than the motive pressure. This pressure (diffuser pressure) must be equal or higher than the backing pressure for stable operation. In order to get low vacuum multiple stages are used which are broadly classified in the, table1 under.

No. of stages	*Operating suction pressure*	*Total steam consumption per kg of air pumped.*
1	200 – 100 Torr	4 – 8 Kg.
2	60 – 400 Torr	15-20 Kg.
3	20 – 5 Torr	18-25 Kg.
4	3 - 0.5 Torr	20-100 Kg.

Table1

The capacity of steam ejector is directly proportional to the weight of the motive fluid. Generally, the ratio of motive fluid to the gas pumped is high, especially under low vacuum and results in excessive demand of steam in multi-stage systems. The overall performance of steam ejector is sensitive to changes in operative parameters such as motive steam pressure and discharge pressure. A slight variation in operating parameters weighs heavily on the system capacity.

Multi steam ejectors require inter-stage condensing as each stage adds to the pumping load for the succeeding stage and for reason of economy, condensation becomes important. The heat gained during condensation i.e. latent heat of vaporization, adds to the need for additional equipment such as re-circulation pumps, cooling towers etc. so that the same can be dissipated. In a steam ejector, steam comes in direct contact with gas/vapour pumped and many a time, this mixture of pumped vapour and water needs elaborate treatment before it can be discharged / re-used. Steam ejectors, especially multistage not only require steam generation facilities but also raise demand for auxiliary equipment such as D.M. plant for boiler feed water, condensing units, re-circulation pumps, cooling towers, effluent treatment plant etc. thereby increasing total energy consumption and maintenance costs. **Steam ejectors are, therefore, no longer popular as they were once because of dramatic increase in cost of steam generation, auxiliary power and effluent treatment problems**. It is for this reason many steam ejector installations have been replaced by mechanical Vacuum Pumps which use far little energy for the same service and require no additional auxiliary power, cooling tower nor give rise to effluent.

MECHANICAL VACUUM BOOSTERS :-

Mechanical Vacuum Boosters are dry pump that meet many of the ideal pump requirements. They work on positive displacement principle. As it's name suggests, it is used to boost the performance of water ring/oil ring/rotating vane/piston and in some cases even steam or water ejectors. It is used in combination 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 alternative.

The major advantages are:-

(a) The Vacuum Booster is a dry pump.

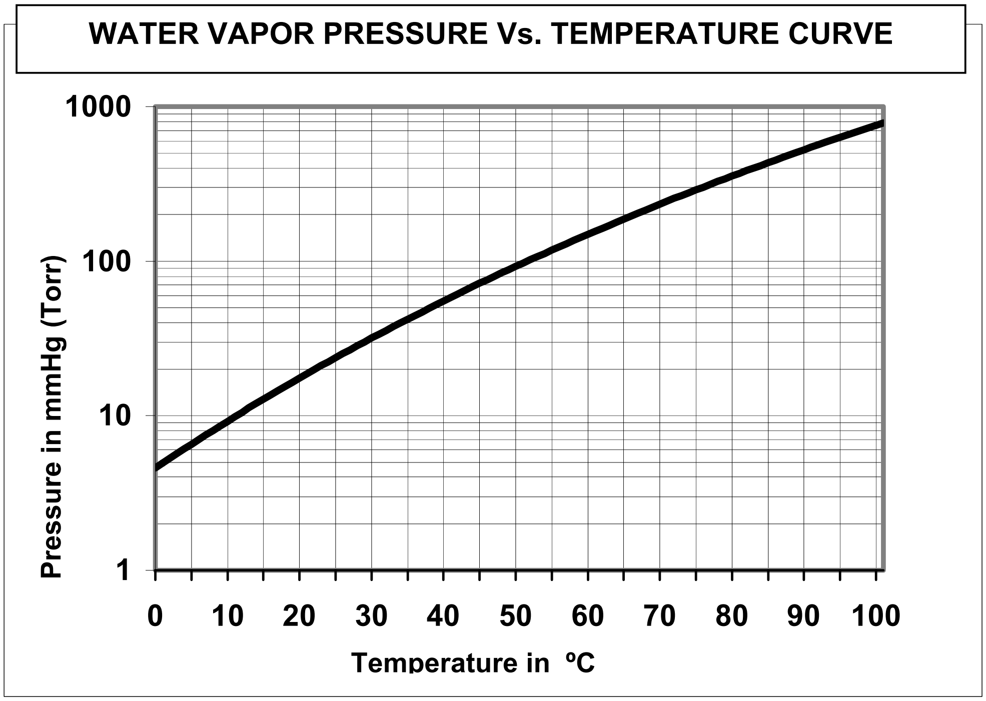
(b) It does not use any pumping fluid. Hence it pumps vapour or gases with equal ease. Small amounts of condensed fluid can also be pumped.

(c) It has very low pump friction losses, hence requires relatively low power for high volumetric speeds.

(d) It can be started instantly. Makes it highly suited for batch processes.

Typically, their speeds at low vacuums are 20-30 times higher than corresponding vane pumps/ring pumps of equivalent power. The vacuum booster can be used to generate vacuum in up to the range of 10^{-4} Torr and yet maintain high volumetric speeds at such low pressure. At these pressures the rotary oil and water ring pumps are not effective, as their pumping speed falls drastically when approaching the ultimate levels. 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 backing pumps. Use of electronic control devices such as variable frequency drive (VFD) allows modifying vacuum boosters operating characteristics to conform with the operational requirements of the backing pumps. Hence, they can be easily integrated into all existing pumping set-up to boost their performance.

Most often the combination of vacuum booster and Backing pump results in reduced power consumption per unit of pumping speed as they effectively provide high pumping speeds at low pressures. During selection of Booster, the pumping speed of booster selected is 3-10 times higher than the backing pump which results in gas/vapour compression at the discharge end of Booster. Due to vapour compression action at the discharge of the booster, the pressure at the discharge of booster (or inlet of backing pump) is maintained high, resulting in low back streaming of backing pump fluid. A suitable secondary condenser installed between the booster outlet and backing pump inlet would trap all the escaped vapours thus keeping the backing pump free of any vapour load.



To illustrate further let us consider a typical case for drying under vacuum. The graph above gives the water vapor pressure at various temperatures. Say for drying at 20°C the vacuum should be better than 20 Torr and for proper condensation of the vapor the condenser temperature should be in the range of 10-12°C, which would require refrigeration plant. In case a vacuum Mechanical Booster is installed between the condenser and the system, then at the inlet to Booster, pressures can be much lower and due to vapor compression at the discharge, the corresponding pressure would be higher. For higher pressures, the corresponding temperatures are higher and, therefore, water at room temperatures may be used instead of chilled water. The Fig.2 shows a typical installation where the Mechanical Booster is installed before the Barometric condenser to achieve higher vacuum at the process end and yet make the condenser effective for use with 25 C cooling water.

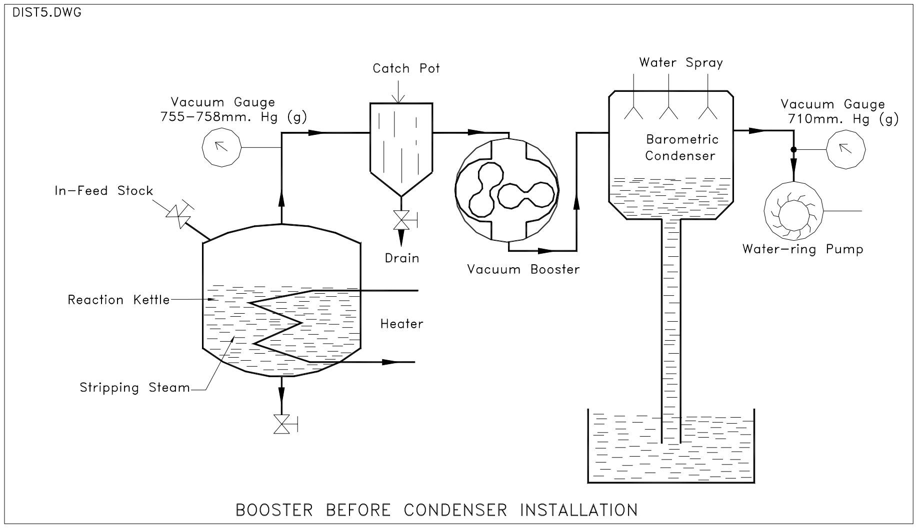


Fig.2

Alternatively the booster can be installed after the condenser, at the Inlet of the backing pump,as shown in Fig.3 This arrangement reduces the pumping load considerably and smaller Booster & backing pump combination can work effectively saving on energy. The best location, however, depends upon the process requirement and needs.

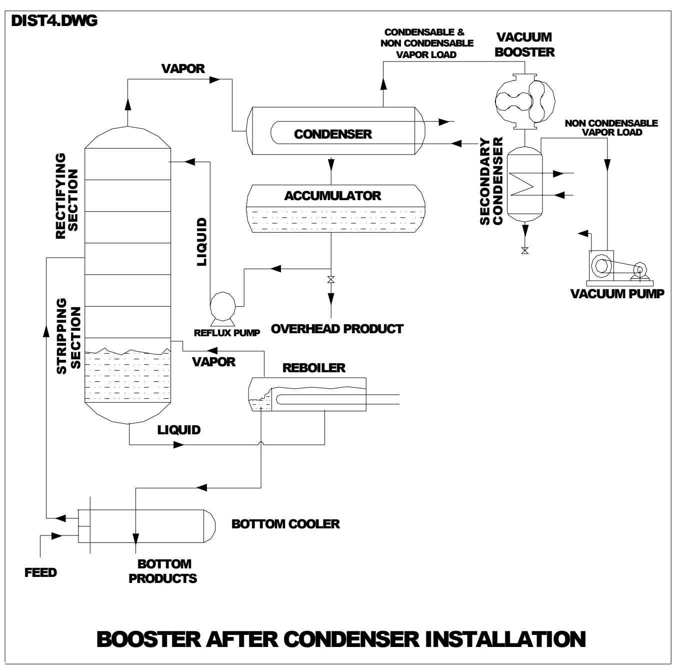


Fig.3

Suitable Backing Pump:-

Mechanical Vacuum Boosters are a versatile machine and their characteristics depend largely on backing pump. Various type 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.

BACKUP PUMP	APPRX. VACUUM ACHIEVED AT INLET OF THE BACKING PUMP	FINAL VACUUM AT THE INLET 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/ Compressor	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.

Table2

Table2 gives a broad indication as to how the Boosters enhance the ultimate vacuum when used with various back up pumps. The increase in pumping speed is manifold (3-10 Times). Better vacuum can be achieved with 2 or more Boosters when used in series. Mechanical Boosters offer a complete dry pumping solution and do not add to any vapour load, unlike steam ejectors, and, therefore, do not require large inter stage condenses. However, inter stage levels there is a vapour compression and in many cases the pumped vapour, which has otherwise escaped the condenser, can be conveniently condensed at the interstage. The mechanical boosters have a pumping capacity 3- 10 times higher than the backup pump which makes the overall pumping capacity of system relatively high. The major drawback of steam ejector system such as sensitively to motive fluid pressures, discharge pressure are overcome easily by the Mechanical Boosters. Mechanical Boosters are most energy efficient in the vacuum range less than 20 Torr and offer a very energy efficient alternative to steam ejectors. The ease of operation, simplicity in maintenance and immediate startup are added advantages that are a generally missing in steam ejectors.

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

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