EVEREST
PRESSURE & VACUUM SYSTEMS

MECHANICAL VAPOUR RECOMPRESSORS

QUALITY SYSTEM CERTIFICATION
DNV·GL
ISO 9001:2015

Engineering
Evaluation
Designing
Manufacturing
Testing
Execution
Post Sales & Service

EVEREST
PRESSURE & VACUUM SYSTEMS

Linked in

www.everestblowers.com | enquiry@everestblowers.com

EVEREST PRODUCT RANGE
Roots Blowers | Mechanical Vacuum Boosters | Dry Screw Vacuum Pumps | Acoustic Hoods | Industrial Vacuum Systems

We don't just offer **Blowers**, **Boosters and Systems** we offer **Solutions !!!**

MECHANICAL VAPOUR RECOMPRESSION – EVEREST HAVE THE SOLUTION!!!

Industrial units are facing multiple problems for survival such as in effluent water discharge. It could be very difficult to get process water abundantly as water sources are limited and it is very essential for industries to recover as much water as possible for recycling. Many industries are considering "**ZERO OR NEAR ZERO LIQUID DISCHARGE.** "Toachieve Zero or Near Zero liquid discharge many existingoperations are required such as: i) Filtration of suspended solids ii) Concentration of soluble minerals &salts and its recovery for concentration and recovery of mineral salts, equipment's such as evaporators are used.

Also increasing energy cost and pressures on improving process efficiency are forcing Process Engineers to minimize wasteful losses. Efforts are continuously being made to minimize all such losses. In almostall-industrial processes steam is used for the purpose of concentration of effluent using single or multi stage evaporators with or without Thermo VapourCompressors/ Re-Compressors (TVR). The Cost of steam rising with the rising cost of fuel, stricter pollution control normsw.r.t. to flue gases emission norms, water discharge and plant capacityexpansion permission is very difficult. Thus,it has become absolutely necessary to minimize the consumption of steam by diverting the steam required for evaporation to other process requirements.

Steam economy i.e. Kg of water evaporated per Kg of steam generated becomes the controlling factor.Alternate to TVR is Mechanical VaporRe-compressor (MVR) where entire vapourgenerated is recompressed and used as steam for heating. Mechanical Vapour re-compressor increases total enthalpy (heat) of steam by compressing it to pressure almost 1.1 - 1.5 times of the inlet steam pressure.

Hence,

Using TVR some percentage of vapor, which goes to condenser &is wasted can be avoided by using MVR.

MVR in single or multiple effects is operated at same temperature & pressure, vapor condensate coming out of the calendria is at the boiling point of the liquid and carries lot of heat which can be utilized to pre-heat feedstock to the evaporator. (Refer Fig-5).

1. VAPOUR RE-COMPRESSION EXPLAINED:

When this compression is performed by a Mechanically Driven Compressor, the Evaporation process is referred to as **MVC** (**Mechanical Vapour Compression**) or **MVR** (**Mechanical Vapour Recompression**) & if the heat of evaporation comes from Thermal Compression of steam in a Thermo-Compressor then it is called TVC (Thermal Vapor Compression) or TVR.

For evaporation design purposes, the capacity is defined as the evaporation rate per hour. However, in some applications such as seasonal fruit juice processors, the equipment is only operated for part of the year. This means that an expensive evaporator is idle for part of the year. The economic calculation has to include annual operating hours.

In many cases, mechanical vapour recompression (MVR) is the most efficient evaporator. However, these systems operate at a low temperature difference, which results in high heat transfer area/ high efficiency of calendria/heat exchanger.

1.1 THERMAL VAPOUR COMPRESSION/ RE-COMPRESSION:

Thermal vapour recompression is the process of evaporating the vapours by utilizing the heat of compressed steam coming from thermal compressor.

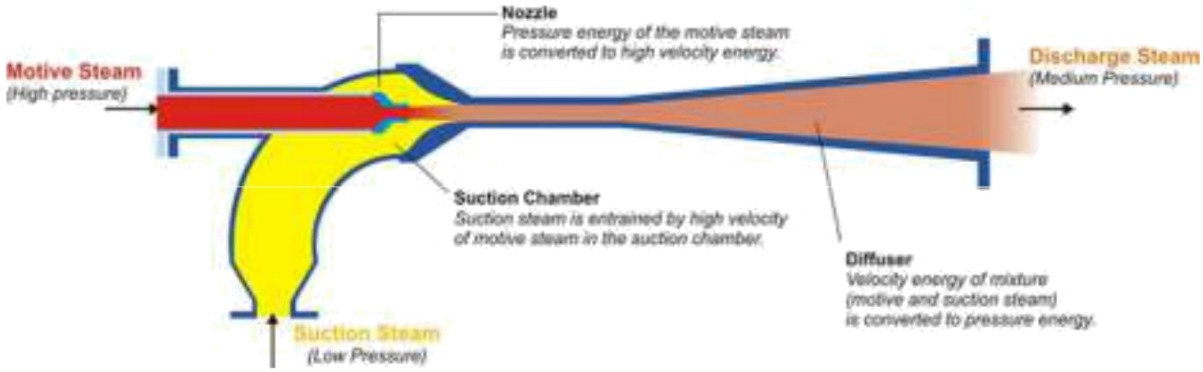


Fig. - (1)

The Main Disadvantages of THERMAL VAPOUR RE-COMPRESSION are:

i) High-pressure steam is required for operation leading to higher operating cost.

ii) Steam consumption is more than is needed for boiling the solution, so that excess steam must be vented out or condensed.

iii) The ratio of steam required to the mass of water evaporated is 0.5 in single effect evaporator.

iv) Very low efficiency of the jets.

v) Lack of flexibility towards changes in operating conditions.

vi) High operating cost and maintenance on boiler and its auxiliary operating equipment's such as pumps, DM plant etc.

vii) Steam recovery systems/condensers required and cooling water consumption is very high.

1.2 MECHANICAL VAPOUR COMPRESSION/RE-COMPRESSION:

Fig.- (2)

During Mechanical Vapour Recompression, the vapor generated from an evaporator is recompressed to a higher pressure by means of a Mechanically Driven Compressor. The re-compressor therefore also operates as heat pump, adding energy to the vapour. Positive displacement compressors are generally used to raise the pressure and temperature of the generated vapours. Since mechanical compressors do not require any motive steam, all vapours can be compressed to elevated pressure and temperature eliminating the need for subsequent recovery systems or condensers.

1.2.1 OPERATING PRINCIPLE OF MVR:

Thermodynamically, the most efficient technique to evaporate water is to use mechanical vapour recompression. This process takes the vapour that has been evaporated from the product, compresses the vapour mechanically and then uses the higher-pressure vapor in the steam chest.

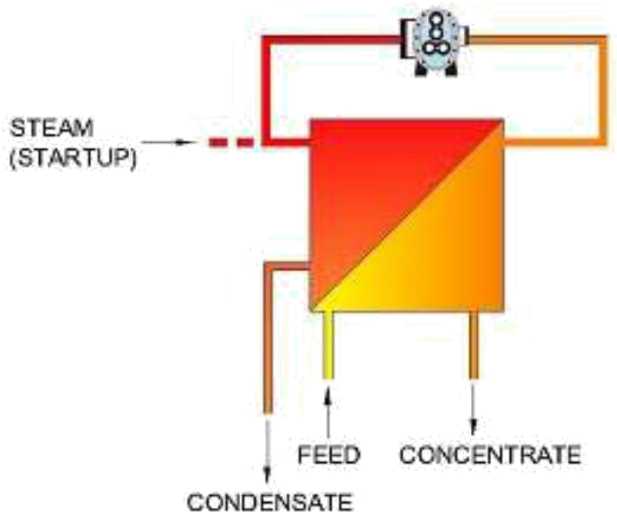


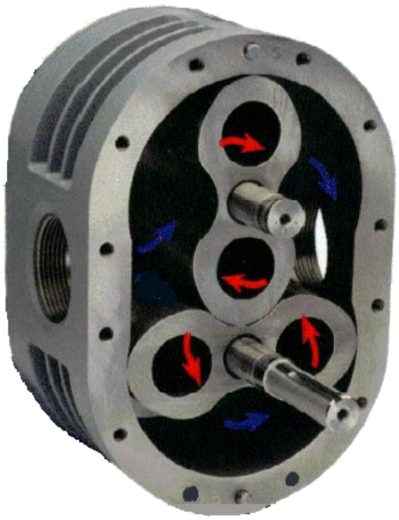
Fig.- (3)

The vapor compression is carried out by a radial type fan or a compressor. The MVR compressor provides higher compression ratios as compared to lower compression ratios in radial fan. This results in high heat transfer surface area and an extremely energy efficient system.

This technique requires only enough energy to compress the vapour because the latent energy is always re-used. Therefore, an MVR evaporator is equivalent to an evaporator of over 100 effects. In practice, due to inefficiencies in the compression process, the equivalent number of effects is in the range of 30 to 55 depending on the compression ratio.

The energy supplied to the compressor can be derived from an electrical motor. The operating economics are extremely good.

1.2.2 OPERATING PRINCIPLE:



The two symmetrical, figure of eight shaped rotary lobes and the casing of the compressor form the compression compartment. As the lobes turns, the gas flows into these compartment is transferred from the suction side to the discharge (pressure) side. There is no internal compression in the rotating impeller. The gas is compressed in the compartment on the pressure side by the PositiveDisplacement principle. Since a small gap remains between the lobes during rotation, and they do not actually touch, the machines are literally maintenance free.

For MechanicalVapour Compressors, theSpecific energy input depends upon the compression ratio (ratio of Discharge pressure (P2) to Input pressure (P1)). Compression ratio(P2/P1), thereforemust be maintained to the lowest required.

Fig.- (4)

1.2.3 MECHANICAL VAPOUR RECOMPRESSION EVAPORATORS

MVR evaporation provides an extremely energy efficient technique for the concentration of solids in effluent. Usually the initial capital cost of an MVR system is higher than a comparable steam driven evaporator. However, as the capacity of the system increases the relative cost difference decreases.

The basic principle of MVR is to remove the steam that is evaporated from the product, compress it in a mechanical device, and use the high-pressure steam, which has a corresponding higher saturation temperature, to provide the heating medium for the evaporation. No steam input is required once the system is operating. The small difference in enthalpy between the vapours on the condensing and boiling sides is the theoretical energy required to perform the evaporation. Essentially, the process re-uses the latent heat of the vapours. A typical single effect forced circulation evaporator with MVR as re-compressor is explained below.

2. A TYPICAL SINGLE EFFECT FORCED CIRCULATION EVAPORATOR WITH MVR AS RE-COMPRESSOR:

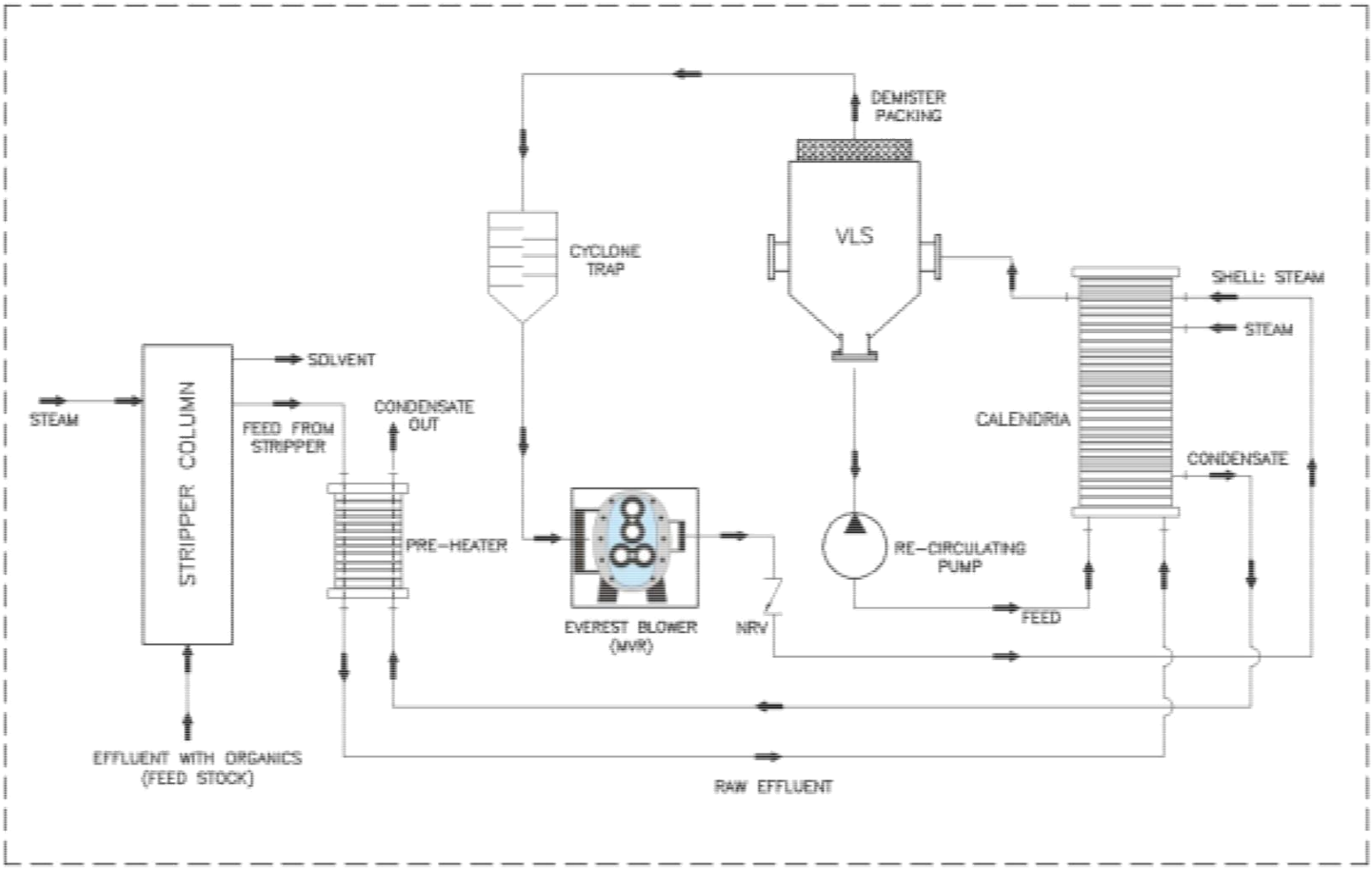


Fig.- (5)

2.1 TYPICAL MVR EVAPORATION PROCESS:

i) Raw effluent containing organics is fed to stripper column where organics are separated by means of steam etc.

ii) Raw effluent free from organics is fed to the calendria thru feedstock pre-heater.

iii) Initially steam is passed into the calendria to start with the evaporation.

iv) Once vapour start generating thru the vapour liquid separator they are passed thru the MVR where they are further compressed to desired pressure and temperature and sent back into the calendria where they give up their latent heat to the counter flowing effluent and condense.

v) High temperature distillate flows out of calendria to the feedstock pre-heater giving up sensible heat to feedstock effluent.

vi) Upon reaching steady state when complete process has come into equilibrium feedstock effluent is fed into the feedstock pre-heater at a constant rate to raise feedstock temperature before sending into the calendria.

vii) Concentrate is periodically discharged based on temperature, conductivity and time thru the residue pump.

3. THERMODYNAMICS OF MVR

3.1. The working cycle of Everest MVR for steam, as fluid handled, is explained under by means of a T-S diagram for steam.

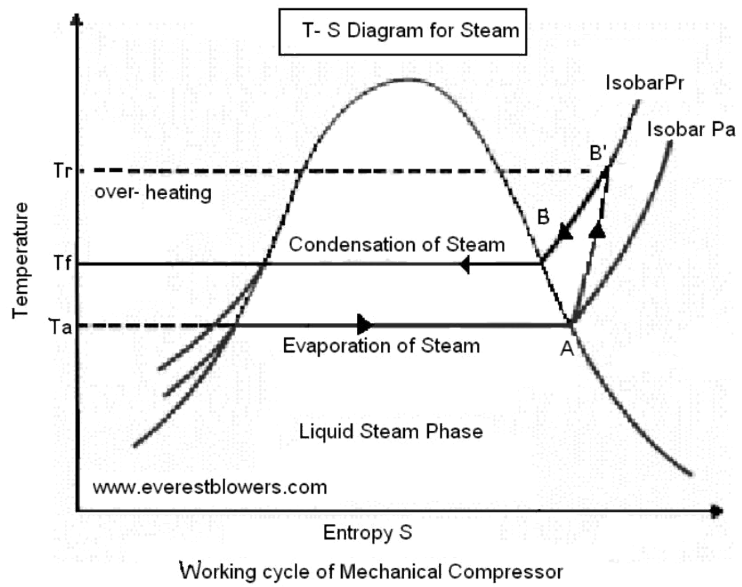


FIG.- (6) Working Cycle of Everest Mechanical Vapor Re-compressor.

The vapour is sucked from the evaporator, at point A for P_a, T_a Pressure and Temperature conditions. It is adiabatically compressed to pressure P_r at point B'. The heat of compression raises the temperature of the steam to T_r. The super-heated vapour at the discharge of the compressor are cooled, and brought to final saturation point B, (T_f, P_r). The compressed vapour is condensed in the indirect condenser to recover the latent heat. The condensate, at temperature T_f is discharged.

In case of **Everest Mechanical Vapor Re-compressor,** the latent heat of evaporation of steam can be recovered back by spending much smaller quantity of electrical energy. The input electrical energy to MVR is estimated by the PV curve.

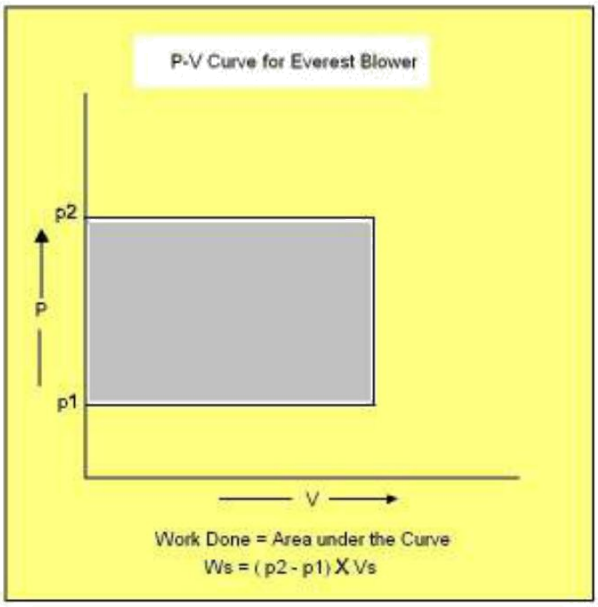


FIG.- (7) P-V Curve for Everest Mechanical Vapour Compressor

Everest compressors consist of two lobes in the shape of figure eight rotating in opposite directions through a pair of timing gears. As the rotors move past the inlet they draw vapors at inlet condition P_1. As the rotor rotates the vapors are pushed out to discharge against the pressure P_2. The work done is the area under the curve, given as W_s.

$W_s = (P_2 – P_1)$ X Vs W_s = Specific work done KJ/kg.

P_2, P_1 = final and initial pressure (KPa) Vs = Specific Inlet volume (m^3/ kg).

3.2 The process is best explained by reference to the Mollier-enthalpy/entropy diagram for steam.

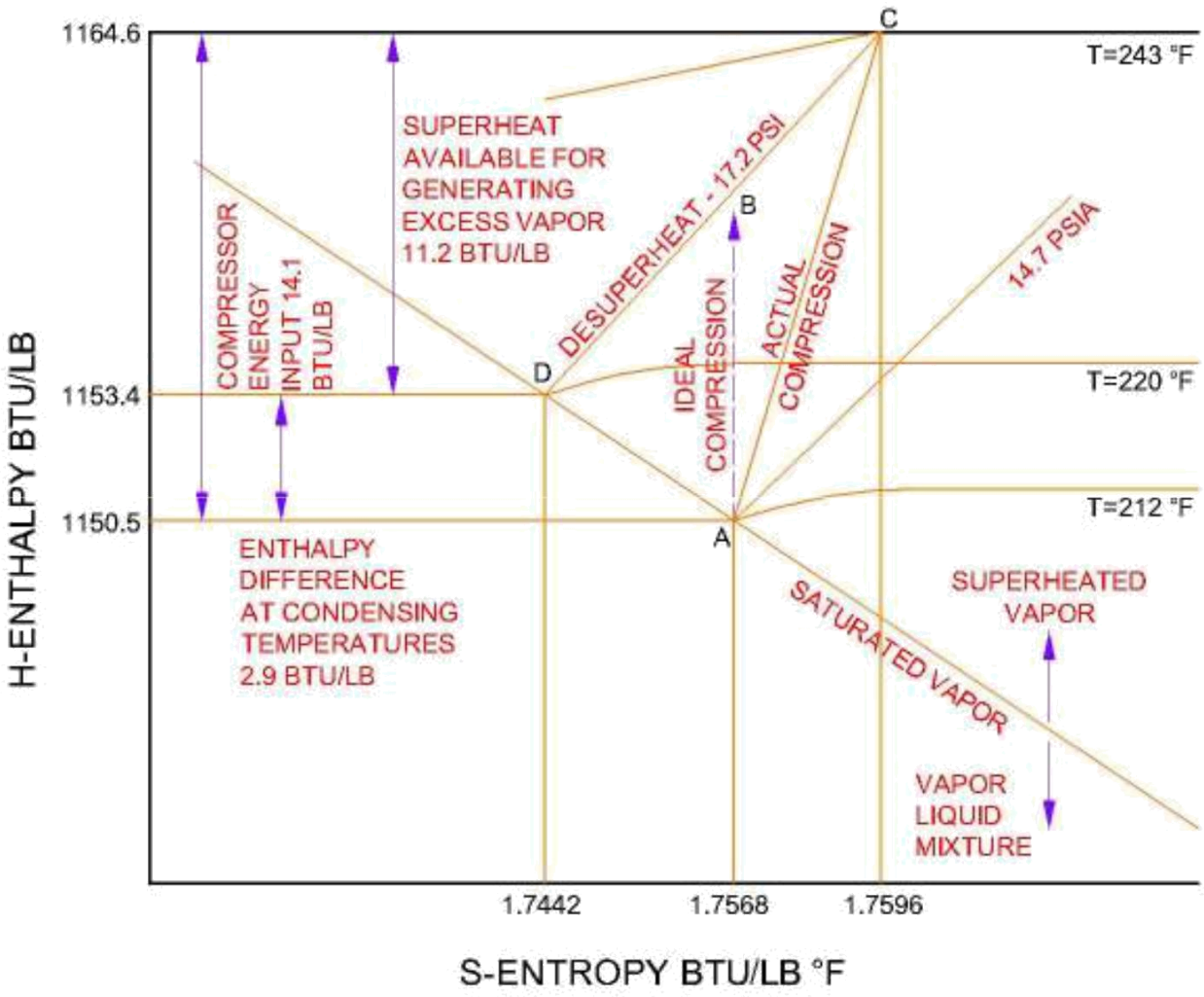


Fig.- (8)

The vapour evaporated from the product is represented on the Mollier diagram at point A. The vapour enters the compressor at point A. The vapour is then compressed to the higher pressure, at constant entropy at point B. In actual due to inefficiencies, there is an increase in entropy above that of the entropy at inlet. This is represented by point C. Vapour at point C is at the required pressure for the steam jacket of the condenser. However, it is superheated and must be cooled in order to condense I n the evaporator. The de- superheating is usually performed by the introduction of a spray of condensate into the vapour duct. This condensate vaporizes as the vapour is cooled back to the saturation temperature, and generates more vapour. This condition is represented at point D. At this point, most of the vapour s condensed in the evaporator.

It should be noted that pressure losses through the evaporator ducting, calendria and separator must be absorbed. This can be achieved by either a higher boost from the compressor at a higher r, or by accepting a lower temperature difference and increasing the surface area of the calendria.

4 ADVANCED ENERGY SAVING

Evaporation and distillation processes are traditionally very energy-intensive. Against the background of rising energy costs it makes sense to search for design solutions that cut energy consumption without entailing excessive investment costs. The use of mechanical vapour recompression can lead to a significant reduction in the costs for specific energy in many applications.

In all thermal separation processes involving a transition between the liquid and gaseous phases, the latent heat of vaporisation must first be input and then removed from the process again after separation if a liquid product is needed. The useful temperature difference on the heating surfaces is normally limited by the maximal possible media temperatures as well as by the economically viable condensing temperature level. A central question is therefore how to design the net energy balances so that they make technical and commercial sense. Multi-stage plants or installations based on mechanical vapour recompression are two examples of energy-saving designs whose potentials are compared in the following. Thermal vapour recompression using steam injectors can be used to advantage in both cases to reduce energy consumption, providing there is a sufficient pressure level above the process for the heating or control steam and the loss of live steam condensate is accepted. This is not considered to constitute a category of its own, however, because the benefits are limited in practice.

4.1 MULTI-STAGE PLANTS

Multi-stage plants utilise the heating steam according to the number of stages. There is usually a pressure drop from one stage to the next. The outgoing vapour from the stage that is operated on the higher pressure level is used to heat the next stage, operated on a lower pressure level, by condensing the incoming vapour. The vapour from the last stage must be condensed. The condensing power that is transferred to a cooling medium at the end of the process must be roughly equivalent to the heating power at the beginning. Most multi-stage installations work with a condensing pressure of 150 to 50 mbar (a). The outgoing energy stream cannot therefore be utilised without further treatment.

The principle of a multi-stage installation is explained taking the example of a clean water distillation plant for 6000 l/h. The higher the number of stages, the lower the specific energy consumption at both ends of the installation. The maximum number of stages is limited to the available temperature difference between the heating medium and the condensing level, the maximum allowable temperatures at the medium and the economically viable heating surface dimensions. The useful temperature difference of each individual stage is reduced as the number of thermal stages increases. In a single-stage installation, the same gaseous energy is theoretically needed for heating as for evaporation, providing there is no change in chemical composition. If we consider aqueous solutions, where the phase change to gaseous consists of water vapour, 0.25 kg of live steam is theoretically required per kilogramme of evaporated water in a four-stage plant. In practice, the energy demand is higher for all of these processes. All heating surfaces have to be vented continuously in order to keep the concentration of gases that cannot be condensed under the prevailing conditions sufficiently low to enable the condensing temperature to remain at a constant high level.

4.2 MECHANICAL VAPOUR RECOMPRESSION

In contrast to multi-stage installations, in simple mechanical vapour recompression plants, the evaporated gaseous phase is condensed on the other side of the heating surface compared to evaporation. A compressor ensures the necessary temperature difference on the heating surface by raising the pressure. This allows the latent heat to be locked inside the process apart from the amounts needed for venting. The plant can be designed in various ways, depending on the specific process requirements.

Mechanical vapour recompression permits the continuous recycling of the energy stream by recompressing the vapour to a higher pressure and therefore, higher energy content. Instead of live steam, electric energy is used indirectly to heat the plant.

Mechanical vapour recompression reduces the energy costs and the CO_2 foot-print and, consequently the environment load.

4.3.1 CASE STUDY:

Taking a practical installation at one of the chemical units in Maharashtra where Everest Mechanical Compressor is installed to compress 1800 Kg/hr of steam from sodium chloride aqueous solution. The inlet design pressure P_1 is 101.3 KPa, Vapour temperature T_1 is 102ºC and the compression ratio is 1.5.

Ideal Specific Input work,
W_s = (152 – 101.3) x 1.6729
= 84.8 KJ/kg.
Taking compressor overall efficiency 65%
Specific Energy input = W_s / 0.65
Specific Energy input = **130 KJ/kg …….. (1)**

Latent heat of evaporation of Water at 100ºC and 1 bar (as per steam tables) is 2257 KJ/kg. It implies so by compressing the vapour through electrical input energy of 130 KJ/Kg, the process is able to recover 2257 KJ/Kg of energy.

Heat energy recovered on condensation = 2257 KJ/Kg ……. (2)

Performance Ratio = 2257 / 130 = 17.36

This ratio of 17.36 indicates that the process of Mechanical Vapour Recompression is similar to a 17 stage evaporator, making it highly energy efficient.

4.3.2 CASE STUDY:

In good old age multiple effect evaporators with equal area in each effects were used, one such installation was with Gujarat State Fertilizer Corporation, Vadodara for concentration in recovery in Ammonium Sulphate, thereafter Thermo Vapour Compressor were used to recompresses 50% of first effect vapour with motive steam pressure of 8-10 kg/cm2. Almost all Multiple Effect Evaporators operate under similar operating conditions, Table A Shows steam economy of various effect namely single, double, triple &Quadruple effect evaporators, VS cost incurred using MVR.

The table shows motive steam required for TVR & Power required to MVR for evaporation from & at boiling point of liquid corresponding to pressure in the vapour separator (flash Tank).

4.3.3 COST ANALYSIS OF OPERATING TVR VS MVR

Case Study: Taking a practical installation at one of the chemical units in INDIA where Everest Mechanical Compressor is installed in Multi- effect Evaporators. The Process Details are mentioned as under:

	UNITS	VALUES
No. of Effects in MEE	No.	3
Mass flow of the Vapour to Compressor (Steam) (Total Effluent Load)	KG/HR	3000
Inlet Pressure of Vapour at Inlet to TVR	BAR	0.75
Inlet Temperature of Vapour at inlet to TVR	DEG CEL	92
Outlet Temperature required for Saturated Steam Vapours from TVR	DEG CEL	106
Corresponding outlet pressure of Vapour from TVR	BAR	1.25
Differential Pressure Delta P	KG/CM2	0.5
Vapour PH level(corrosive/non-corrosive)	PH	8.5
Pressure of Motive Steam going to TVR	KG/CM2	6
Quantity of Motive Steam going to TVR	KG/HR	950
Operating Hours of TVR per Day	HR/DAY	24
Total Operating days per Year	DAYS/YEAR	300
Details of fuel used /cost (PNG Gas having calorific value 8250 Kcal/kg)	RS./KG or SCM	28
Calorific Value of fuel	KCAL/KG or SCM	8250
Cost of electricity per KW	RS. / KW	6.5
Power Consumed Per Hour	KW/HR	92
The Saving Calculations are as under:		
COST OF STEAM GENERATION (FUEL – PNG Gas)	**UNITS**	**VALUES**
Cost of PNG Gas	RS./SCM	28
Calorific Value of PNG Gas	KCAL/SCM	8,250
Steam Generated by Burning 1 SCM of PNG Gas	KG	15.28
(Calorific Value of PNG Gas / 540 Kcal)		
Total Steam Generated by Burning 1 SCM of PNG Gas (after line losses etc.) Efficiency 70%	KG	10.7
Cost of steam per kg (Cost of PNG Gas per SCM / Total Steam Generated by Burning 1 SCM of PNG Gas)	RS/KG	2.62
OPERATING COST OF USING TVR (MEE - III EFFECT)		
Motive Steam required to run TVR per Hour	KG/HR	950
Motive Steam required to run TVR per Day (24 Hr. * 1 Day)	KG/DAY	22,800
Total Motive Steam required to run TVR per Year	KG/YEAR	6,840,000
(300 days x 24 Hr. x 1 Day)		
Total Cost of Steam Consumed Per Year to operate TVR	RS/YEAR	**17908364**
OPERATING COST OF USING MVR		
Initial steam required to start the Process i.e. approximately for 20 min / Start (1 kg Water needs 1 Kg of Steam to get evaporated)	KG / START	1000
Total Steam required to start the Process per Year (i.e. 4 start per year)	KG/YEAR	4,000
Total Steam cost Per Year to Start the Process	RS/YEAR	**10,473**
Power Units consumed by MVR per hour	KW/HR	96
Power Units consumed by MVR per day (24 Hr. * 1 Day)	KW/DAY	2,304
Total Power Units consumed per Year (300 days x 24 Hr. x 1 Day)	KW/YEAR	691,200
Cost of electricity per KW	RS/KW	6.5
Total cost of electricity per Year	RS/YEAR	**4,492,800**
Total Steam Generated per KW by using MVR (Mass flow of the Vapour to Compressor (Steam) / Power Units consumed by MVR per hour)	KG/KW	**32.6**
Cost for Generating 1 Kg of steam by using MVR (Cost of electricity per KW / Total Steam Generated per KW by using MVR)	**RS/KG**	**0.20**
TOTAL OPERATING COST		
Total Operating cost of running MVR Per Year	RS/YEAR	45,03,273
Total Operating cost of running TVR Per Year	RS/YEAR	1,79,08,363

After Installing EVEREST Mechanical Vapor Re-compressor they are getting the saving of

Rs. 1, 35,00,000 /- per year.

ADVANTAGES OF ROOTS BLOWER AS MVR:

i) Low specific energy consumption.

ii) Higher Performance co-efficient.

iii) Gentle evaporation of the product due to low temperature differences.

iv) Reduced load on cooling towers since no residual vapour.

v) Simplicity of process, operation & maintenance. Live steam consumption is very low, just for start-up and make-up, being electric energy (the energy input to the plant) used instead of steam for recompressing the vapours.

vi) Due the complete recompression of the process vapour, cooling water consumption is negligible.

vii) Easy capacity controlling through Variable Frequency Drive (VFD).

viii) Operating costs are significantly low.

TYPICAL APPLICATION AREAS INCLUDE:

i) Sugar plants – wash down to sugar recovery.

ii) Milk and juice processing plants.

iii) Chemical solution concentrations.

iv) RO Reject concentration.

v) Brine concentration.

vi) Ethylene Glycol (Anti-Freeze) Refortification

vii) Car wash recycling.

viii) Borers removal from wash down.

ix) Generating dry effluent.

MECHANICAL VAPOUR RECOMPRESSION VS THERMAL VAPOUR RECOMPRESSION:

i) Thermo Vapour Re-Compressor is low capital cost equipment.

ii) Thermo Vapour Re-Compressor are used under reduced pressure operating conditions.

iii) Multiple effect operates at reducing pressure and temperature effect by effect, last effect being operate at 55-65-degree C and 550-600 mm Hg.

iv) TVR requires 9.11 kg/cm2 motive steam to achieved desired steam economy.

v) TVR re-compressor 50% of the vapour generated from first effect to re-compressor with high pressure motive steam and mixed steam at a lower pressure of motive steam and higher pressure than 50% steam sucked by TVR.

vi) Mechanical Vapour Re-compressor compresses total vapour generated by each effect of evaporator and send back as high temperature pressure steam to calendria.

vii) Existing multiple effect evaporators can be connected to single or double MVR depending upon total evaporation required.

viii) For NEW requirement only single effect is required for MVR Connection eliminating multiple numbers of circulation pumps, cooling water and result in each of operation.

ix) MVR are available from 200 Kg/hr to 6000 Kg/hr capacity.

x) Differential pressure range varying from 100 mBar to 1000 mBar.

xi) MVR imparts energy to vapour, resulting in 27-32 kg evaporation per KWH consumed.

Article compiled by Technical Team of Everest Blower Systems (P) Ltd.
For further details, contact us at:

EVEREST BLOWER SYSTEMS (P) LTD.
PLOT NO. 6, SECTOR-16, HSIIDC, BAHADURHARH
HARYANA-124507, INDIA.
Telefax: 91-11-45457777 (100 LINES)
Email:vacuum@everestblowers.com , marketing@everestblowers.com
Web: www.everestblowers.com