

Using Mechanical Vapor Compression Plant to Reduce Volume of Salts in Concentrated Liquid

Dr. Khaled Morshed Al-naser

Mechanical Engineering Department - King Saud University – Saudi Arabia

Email: khaled88@gmail.com

Abstract

Mechanical vapor compression plant is illustrate new innovative developments in compressor and evaporator designs that is make it possible to reduce energy consumption so it is a more competitive alternative. Vapor compression is a reliable and robust desalination Technology that is attractive, Because of its capacity to treat large volumes of water with a Wide range of salt concentrations. However, compared to other major Desalination technologies such as reverse osmosis, Mechanical vapor compression has had relatively high Operating and capital costs.

Keywords: Mechanical, Vapor, Compression, Salt concentrations, Liquid

Introduction

Vapor compression is a reliable and robust desalination Technology that is attractive, Because of its capacity to treat large volumes of water with a Wide range of salt concentrations. However, compared to other major Desalination technologies such as reverse osmosis, Mechanical vapor compression has had relatively high Operating and capital costs. New innovative Developments in compressor and evaporator designs make it possible to reduce energy consumption so it is a more competitive alternative. Texas A&M University has developed an advanced vapor-compression desalination System that operates at high temperatures.

Advanced sheet-shell latent heat exchangers promote drop wise condensation allowing small temperature and pressure differentials between the saturated boiling liquid and the condensing steam, hence reducing the energy, Requirements. This newer system consists of a train of Non-scaling evaporators arranged so feed water flows counter currently, recovering heat from both the Condensate stream and the concentrated discharge Brine. A high-efficiency greater compressor provides the compression work required to return saturated steam to the initial stage of the evaporator train.

An experimental Investigation of hydrophobic copper plates describe below shows that extraordinarily high heat transfer Coefficients can be attained. The greater compressor is particularly advantageous for applications where either Electricity or mechanical energy is available.

Extensive studies in drop wise condensation show For Low Temperature differentials across the hydrophobic plate, Heat transfer coefficients will increase with elevated Steam pressures. According to the data described in this Study, dropwise condensation of saturated steam and Forced-convection boiling of saturated water separated, by a thin hydrophobic copper plate result in ultra-Efficient heat transfer. The forced convection in the Water chamber is produced by a liquid jet ejector.

Vapor-compression evaporation

Is the evaporation method by which a blower, compressor or jet Ejector is used to compress, and Thus, increase the pressure of the Vapor produced. Since the

Pressure increase of the vapor also generates an increase In the condensation temperature, the same vapor can serves the heating medium for its "mother" liquid or solution Being concentrated, from which the vapor was generated To begin with. If no compression was provided, the vapor would be at the same temperature as the boiling Liquid/solution, and no heat transfer could take place.

It is also sometimes called *vapor compression distillation(VCD)*. If compression is performed by a mechanically Driven compressor or blower, this evaporation process is usually referred to as **MVR** (mechanical vapor Recompression). In case of compression performed by High pressure motive steam ejectors, the process is usually called **thermo compression** or **steam compression**

Purpose of the Study

This research study attempted to:

- 1- Explore Process mechanical vapor compression plant.
- 2- Investigate innovative developments in compressor and evaporator designs.

Research Questions

This research is guided by the following questions:

- 1- How the mechanical vapor compression plant influence IN reduce energy consumption, to reduce salts from concentrated liquid.

2- Are there significant differences between types of Vapour compression systems in thermal process?

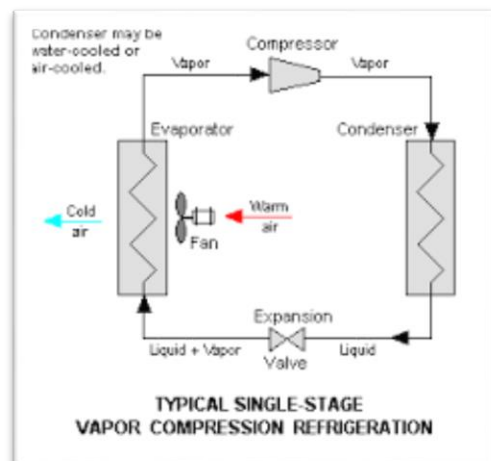
1-Process Description

Mechanical vapor compression distillation of saline water

Is a process in which mechanical energy is used as the Main driving force?

It is basically a heat pump process.

That pumps heat from a low-temperature reservoir to a higher temperature reservoir, just as in household Refrigerators where the heat is pumped from the air inside the refrigerator box to the ambient air outside of the box.



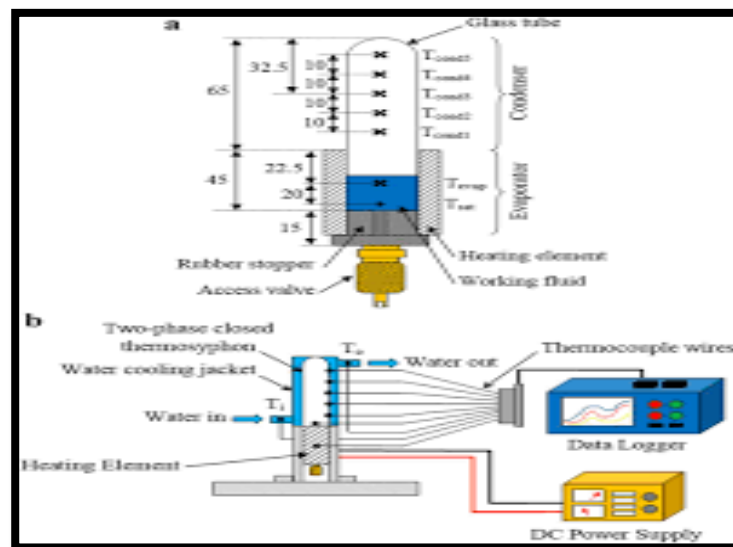
The main elements consist of an evaporator, a condenser, a compressor, and an expansion valve where refrigerants Such as Freon or ammonia are used as working fluid in a closed cycle. The coils inside the refrigerator box form the evaporator and the coils outside the box form the condenser.

Here the working fluid inside the coils in the evaporator, evaporates to absorb heat from inside the box, Compressed to raise its saturation pressure and Temperature and then enters the condenser coils outside the box to release its latent heat of condensation to the Ambient air. The high-pressure liquid refrigerant then enters the expansion valve where it flashes down to the Evaporator pressure to complete the cycle. In a vapor compression distillation of saline water, the system is not a closed cycle and the basic system consists of the evaporator-condenser and the compressor.

The working fluid is water vapor. Water vapor generated from the water layer on the evaporation side of the heat transfer surface is compressed to raise its saturation temperature and pressure and is then condensed on the Condensation side of the heat transfer surface, forming.

Condensate and releasing the latent heat of condensation to be transferred across the heat transfer surface into the Water layer on the evaporation side to cause further Evaporation of water.

The only energy required to pump the heat content in the vapor from the evaporation side to the condensation side of the heat transfer surface is the Mechanical energy required to drive the compressor.



2-Thermal Processes

Distillation works on the principle that the vapor Produced by evaporating seawater is free from salt and the condensation of the vapor yields pure water.

The Majority of modern plants use the multi-stage flash Thermal process (MSF) or the thermal vapor compression System multi-effect desalination (TVCMED).Mechanical Vapor compression MED (MVC-MED) units are less

Common; due to current limitations in Compressor Technology the maximum capacity of MVC-MED units is 3000 m³/d per unit. Recent practice has tended towards Installation of MSF units for distillers in the capacity range 30 000–90 000 m³/d with TVC covering the 10 000–68 000 m³/d range.

The feed water is usually desecrated and chemically treated to reduce the pH and Control calcium carbonate magnesium Hydroxide precipitation/scaling. In some plants, NF is used to reduce calcium sulphate scaling potential. Most Large thermal distillation plants are constructed as dual-Purpose stations for both desalination and the generation of power.

The trend towards higher operating Temperatures means that greater attention has to be paid to the reduction of Corrosion and the use of cost effective

Materials and chemicals to combat corrosion.

One of the major design parameters for all distillers is the Performance ratio – a measure of the efficiency of energy Utilization.

The amount of energy required to desalt a Given brine concentration varies according to the degree Of sophistication of the plant installed, that is annual Energy costs reduce as capital costs increase.

Other factors to be taken into account include size of Units, load factor, growth of demand, interest rate on Capital, and technical matters concerning the auxiliary

Services, repairs and maintenance. For detailed design Some 70 design parameters have to be settled.

Many of these are concerned with the safe or most economic

Limits For the temperatures, velocities and concentrations Of the Coolants, brines, brine vapor, steam, steam Condensate and boiler feed water. Other aspects that require careful Attention include the prevention of scaling, corrosion, Erosion, the purity of the distillate, the efficiency of heat Exchangers and the nature and cost of the auxiliary plant Involved.

Major problems, which formerly occurred with seawater Distillers, were scale formation on heat transfer surfaces Due to the presence of carbonates and sulphates of Calcium; internal corrosion due to hot sodium chloride And the presence of dissolved gases such as oxygen, Ammonia and hydrogen supplied; plant start-up problems And running at low capacity.

These problems have been largely overcome and continuous unit operation in excess of 8000 hours at variable load conditions in the range 60–100% of full load are commonplace.

Types of Vapour Compression Systems

There are two types of VC processes:

Mechanical

Vapour Compression (MVC) uses mechanical

Compression, while Thermal Vapour

Compression

(TVC) uses thermal compression.

For Single Effect Evaporation with

Mechanical Vapour Compression

(SEE-MVC): One of the main characteristics of the Stand-alone single effect

Evaporation system is that its performance ratio which represents the ratio between the unit productivity to the steam consumed (PR) less than 1.

The capacity of the SEE-MVC is Ranging from 50 -5000 m³/d. only electrical power needed for operation.

The SEE-MVC unit consists of five major Components: A mechanical

Vapour compressor, an Evaporator/condenser heat exchanger, Preheaters for the

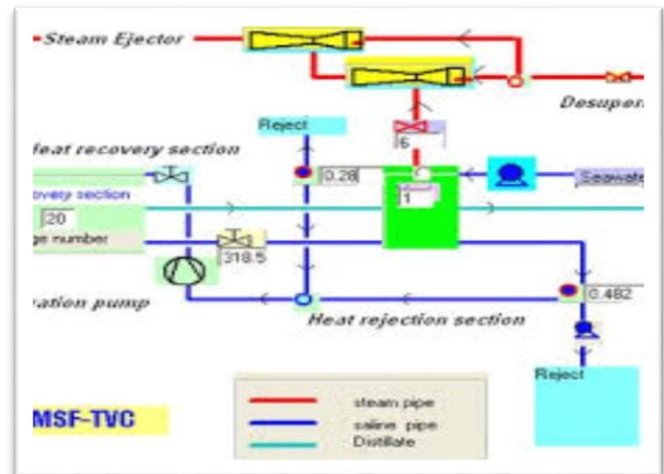
Intake seawater (Hxs), Brine, product, vacuum pumps, and A venting system.

Component

The Vapor Compression Refrigeration Cycle involves four components:

Compressor, condenser, expansion valve/throttle valve and evaporator.

It is a compression process, whose aim is to raise the refrigerant pressure, as it flows from an evaporator.



The high-pressure refrigerant flows through a condenser/heat exchanger before attaining the initial low pressure and going back to the evaporator. A more detailed explanation of the steps is as explained below.

1-COMPRESSION

The refrigerant (for example R-717) enters the compressor at low temperature and low pressure. It is in a gaseous state. Here, **compression takes place to raise the temperature and refrigerant pressure**. The refrigerant leaves the compressor and enters to the condenser. Since this process requires work, an electric motor may be used. Compressors themselves can be scroll, screw, centrifugal or reciprocating types.

2-CONDENSATION

The condenser is essentially a heat exchanger. Heat is transferred from the refrigerant to a flow of water. This water goes to a cooling tower for cooling in the case of water-cooled condensation. Note that seawater and air-cooling methods may also play this role. As the refrigerant flows through the condenser, it is in a constant pressure.

One cannot afford to ignore condenser safety and performance. Specifically, pressure control is paramount for safety and efficiency reasons.

3-THROTTLING AND EXPANSION

When the refrigerant enters the throttling valve, it expands and releases pressure. **Consequently, the temperature drops at this stage**. Because of these changes, the refrigerant leaves the throttle valve as a liquid vapor mixture, typically in proportions of around 75 % and 25 % respectively.

Throttling valves play two crucial roles in the vapor compression cycle. First, they maintain a pressure differential between low- and high-pressure sides. Second, they control the amount of liquid refrigerant entering the evaporator.

4- EVAPORATION

At this stage of the Vapor Compression Refrigeration Cycle, the refrigerant is at a lower temperature than its surroundings. Therefore, **it evaporates and absorbs latent heat of vaporization**. Heat extraction from the refrigerant happens at low pressure and temperature. Compressor suction effect helps maintain the low pressure.

There are different evaporator versions in the market, but the major classifications are liquid cooling and air cooling, depending whether they cool liquid or air respectively.

Advantages

1. A large amount of heat can be transferred with little work. For example, suppose we had a heat/work ratio of 10. This means that for every Btu of work added, we replace 10 Btu's of heat that would otherwise be required. This can lead to overall savings also. Assume we generate one Btu of electricity from three Btu's of fuel heat (33% efficiency). Then overall we save $10/3 = 3.33$ Btu of heat for every Btu fuel used by the vapor re-compression system over that of the conventional system.
2. The heat flow to supply the condenser or reboiler may be of particular value. For example if the column is cold, the cooling must be accomplished by expensive refrigeration. This is also true at high temperatures 500°F+ where energy added to the reboiler can no longer be supplied simply by steam.

The vapor re-compression cycle, by being balanced, is affected only to a limited effect by the relation of the actual temperature to the ambient. The pressure in a vapor re-compression column can be set where desired to achieve maximum separation.

3. By freeing the condenser and reboiler of the desire to hold temperature between a minimum of about 100°F to a maximum of about 500°F, the points easily reached by cooling water and condensing steam, we can set the temperature, and therefore the pressure, at any point we wish. This effect is of particular importance where changing the pressure effects the relative volatility.

Disadvantages

1. Premium electrical or steam pressure work energy is used for driving the compressor, and no advantage can be taken of possible existing low value sources of waste heat to run the rebuilder.
2. The additional cost for the compressor and its driver are required.
3. The condenser-rebuilder of vapor re-compression has the overhead and bottoms product on either side, leading to savings by having one half of the total area for the separate condenser and reboiler of a conventional column. This advantage is lost and more heat exchanger surface is required for the condenser reboiler as compared to the conventional condenser and reboiler.

Conclusion

Studies and experiments showed a better performance of the mechanical vapor compression plant to Reduce Volume of Salts in Concentrated Liquid system when fed with lower concentration brine. Increasing compressor speed has a positive influence on the performance, although the compressor power consumption decreases with compressor speed.

Acknowledgement

The author would like to express their gratitude to Academic Journal of Research and Scientific publishing. For this chance to publish my paper in the journal.

References

- Advanced Mechanical Vapor - Compression Desalination System

Jorge R. Lara, Omorinsola Osunsan and Mark T. Holtzaple Texas

A&M - University United States

- Mechanical Vapor Compression (MVC) Desalination System

Optimal Design

A.k. El-Feky Reactors Department, Nuclear Research Center,

Atomic Energy Authority

- MECHANICAL VAPOR COMPRESSION DISTILLATION-

Water Re-use Technology, Alamo, California, USA