VACUUM CREATING EQUIPMENT

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Summary

The vacuum creating equipment for desalination plant has common features with all other vacuum creating equipment installed for other purposes in power plants.

For instance, we have vacuum creating equipment in power plant condensers, or on petrochemical plant, nevertheless the design of a vacuum system for desalination plant has a much more direct impact on the overall desalination plant performances.

The design of the vacuum system for evaporative desalination plant has to be considered with a direct link of the heat exchange surface design of the same evaporator since the vented rates to the vacuum system depend on the brine recirculation flow rates and temperature profile inside the evaporator.

For desalination plant, the design standards have been, in general, developed on the basis of each manufacturer's expertise, taking into account the input design given by the

evaporator designer and manufacturers.

The linkage between the evaporator design and the vacuum system design has to be carefully considered in order to evaluate the real desalination plant performances and the vacuum system rangeability.

One of the major aims of the present article is to give guidelines either to the manufacturer of the vacuum system or to the evaporator designer in order to carry out a complete and optimum design.

1. Introduction

Vacuum creating equipment has great importance in the operation of any evaporative desalination plant. Its operation, in fact, is related to the proper venting of the flashing stages and, therefore, affects the heat exchange coefficient, and, in turn, the overall desalination plant performances. In particular the blanketing effect on the tube bundle caused by the presence of stagnant pockets of uncondensable gases brings about an additional resistance to the heat flow, which decreases the heat exchange coefficient.

The consequences of this are non-negligible detrimental effects on the plant performances and operation. The effects are the subject of a separate chapter. The present chapter aims at describing the typical feature of the vacuum creating equipment starting from the process and structural design in the various possible configurations which can be achieved.

The thermodynamic aspects related to the design of the vacuum creating equipment together with the economical impacts that the adoption of one configuration instead of another could bring about are considered.

The article is also oriented to the reference standards and codes which are considered as good design practice as well as the correct passage of information between the various parts involved in the design and construction of a vacuum system.

2. Design Standard

There is a wide availability of standards which help in the design of vacuum creating equipment. The application of one standard in preference to another, especially as far as the structural design is concerned, could affect the price.

For instance the adoption of TEMA standards for the design of the condensers tubeplate could impose excessive thickness which could be avoided if the same were designed in accordance to the ASME VIII division 1 standards with the finite element practice.

Table 1 lists the most significant standards available in the technical literature which can be used as a guideline for the specification of the vacuum creating equipment.

Item	Standard	Description
1	TEMA	Classification and design of heat exchangers

Item	**Standard**	**Description**
2	ASME VIII DIV 1	Methods for heat exchangers' structural design
3	BS 2975	Methods for heat exchangers' structural design
4	HEI	Classification process and structural design of heat exchangers
5	ASME VIII DIV 2	Quality control for the design of heat exchangers
6	Hydraulic Institute Standards	Proper installation of the barometric tail on heat exchangers

Table 1. Major standards and codes available in the literature relevant to vacuum system components design and specification.

3. Classification of the Various Processes

Various processes have been developed to set the proper vacuum creating equipment and are chosen in accordance with the following criteria:

1. Investment cost
2. Operating costs
3. Availability of process steam for motive steam ejector
4. Availability of power for vacuum pumps
5. Availability of sufficient cooling water flow rate
6. Particular process emergencies

The main process so far employed in the desalination field are:

- Barometric type condenser vacuum system
- Shell and tube type vacuum system plus steam ejector
- Air pumps

These processes are described in the following sections but as there are some features in common between the choices another section considers the methods used to design and specify the vacuum systems.

3.1. Barometric Condensers' Vacuum Systems

The barometric condenser is employed as a means of removing air and other vapors from vacuum equipment. The principal feature of the barometric condenser is that injection water may be discharged through a tail pipe by gravity, without requiring a pump. Another advantage is its immunity from flooding, in the event of priming or liquid entrainment. In most plants, the vapor exhaust connections of vacuum apparatus are located at considerable elevation above ground level. Since there are no moving parts, maintenance is low. The condenser requires little space and is readily installed.

Barometric condensers consist of two basic types:

1. Concurrent, or parallel flow, in which the vapor to be condensed enters at the top of the unit and flows in the same direction as the water,

2. Counter-current, or counter flow, in which the vapor enters near the bottom of the equipment and passes upward against the water flow. Injection water is delivered to the condenser in the form of jets, sprays, water curtains or a combination, depending upon service required.

The operation of any condenser is described by a simple heat balance. The heat added to the system is the quantity of steam being condensed, expressed in kilograms per hour, multiplied by the latent heat of vaporization expressed in kilowatt hours (kwh) per kilogram.

This must be equal to the heat removed by the condensing water, which is the quantity of water expressed in kilograms per hour multiplied by the temperature rise from inlet to outlet times the specific heat (which is 1.0 in the case of water).

Under theoretically perfect conditions, a condenser could operate under a vacuum corresponding to its tail and discharge water temperature, but not higher. Under normal operation this, of course, can never occur. Air entering with the injection water and non-condensables entering with the vapor load exert a partial pressure.

Ultimate condenser pressure is the sum of the vapor pressure at the tail temperature, plus the partial pressure of the non-condensables present. The difference between the temperature of the tail water and the temperature corresponding to saturated water vapor at the actual condenser pressure is known as the "terminal difference". It is a measure of efficiency of condenser operation.

The condenser is generally employed where low cost water is available in ample quantity. It is the simplest design of all barometric condensers and requires no auxiliary air pump or precooler. It is probably ideal when load conditions are constant and there is little air leakage.

Condensing water is delivered into the nozzle case and ejected through the nozzles. These are carefully designed to handle specified amount of water at stated pressure and guaranteed vacuum. The water jets are directed into the tail-piece condenser, come into direct contact with the converging water, and are condensed. Non-condensables are also entrained and discharged by the water jet action. Terminal difference obtainable with this type of condenser is 12-16°C (11-13°F).

Figure 1 illustrates a typical use of a standard barometric condenser with evaporators. The steam vapors from the evaporator pass through a separator or catch-all, where any liquid carried in suspension is collected and drained back into the evaporator. The vapors pass into the top inlet of the condenser where the condensing is accomplished by the spray nozzles. The water jets entrain the air and non-condensable gases and discharge them into the barometric tail pipe which drains by gravity into a hot well. Condensing water is delivered to the nozzles at a slight positive pressure (1-2 kg), but with light steam loads, the injection water may be throttled and water flow adjusted to meet the vapor load. As indicated in Figure 1, no air pumps are required and the installation is remarkably simple and foolproof.

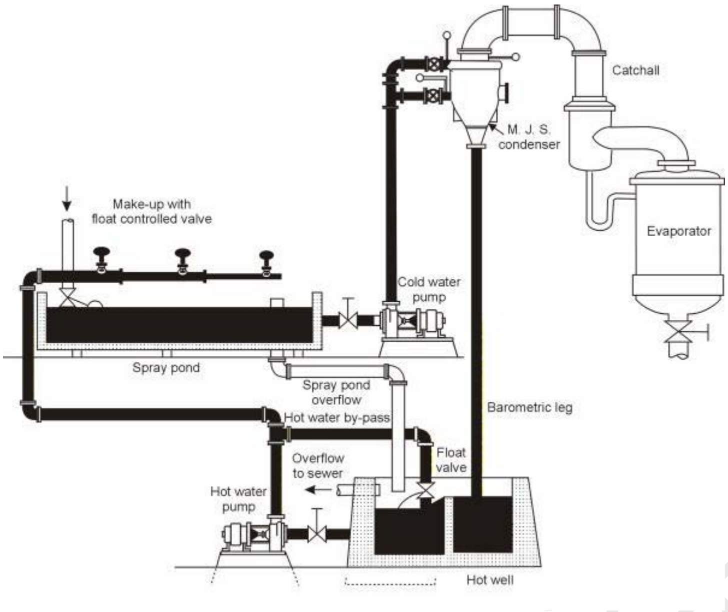

Figure 1. Typical barometric condenser installation and layout.

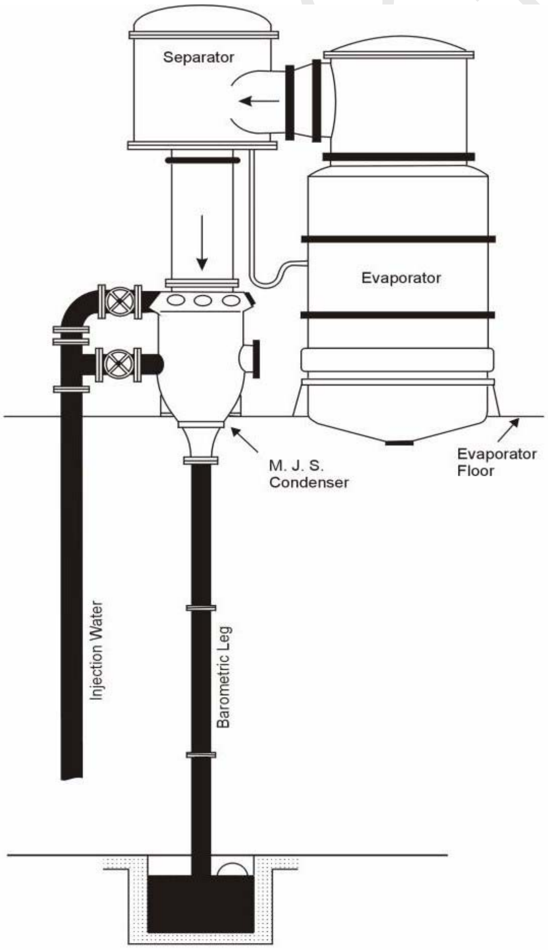

Figure 2. Typical barometric condenser and layout with spray pond to hot well.

In cases where there is a shortage of cooling water, it is necessary to apply a recooling system. This is done effectively by a spray pond arrangement, as shown in Figure 2. Two centrifugal pumps are employed; one for delivering the warm water from the hot-well to the spray pond, the other for pumping the cooled injection water to the condenser. Automatic level control is provided by an overflow pipe from spray pond to hot-well.

This kind of condenser, due to the absence of moving parts, is highly reliable and offers the possibility of achieving a high degree of vacuum, theoretically the same vacuum corresponding to the saturation pressure of the cooling water.

It is preferred to use barometric type condensers where limitations exist in the supply of the cooling water to the vacuum system.

Figure 3 provides a typical counter current barometric type condenser.

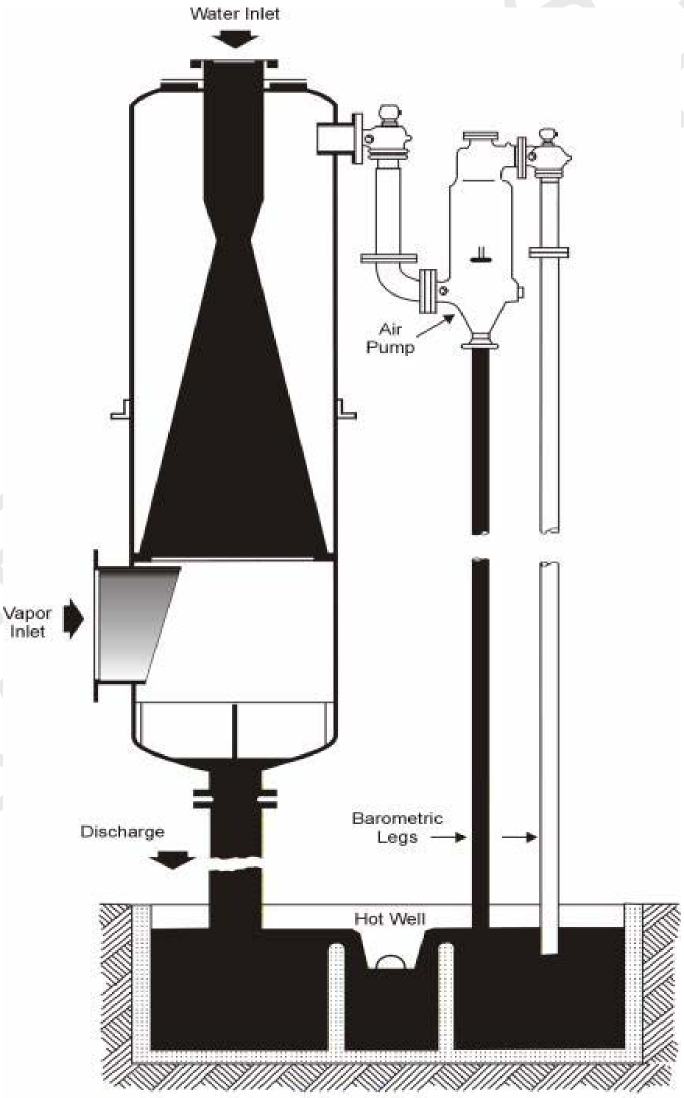

Figure 3. Spray type condenser layout.

The cooling water enters the condenser through a water nozzle at the top of the unit. A distribution tray in the shell provides a sort of curtain through which the vapor is obliged to pass. Most of the vapor entering the condenser is condensed in the lower part of the shell whilst the non-condensables are required to travel upward through the water curtain. A baffle arrangement is provided in order to limit the amount of carry over. Also, in this case, minimum terminal difference is required and, therefore, with a relatively low amount of cooling water, a very high degree of vacuum can be obtained.

3.2. Steam Ejectors' Vacuum Systems

The jet apparatus consists of three principal parts: a converging nozzle for liquid actuated jets or an expanding nozzle for gas actuated jets; and a diffuser and a body to hold these parts in their proper relative positions. The ejector transforms energy of pressure into energy of motion and operates as follows.

Motive power is provided by a high-pressure stream of fluid directed through a nozzle designed to produce the highest velocity possible. The motive fluid, issuing from the nozzle, entrains the suction fluid in the mixing chamber (body) which produces a uniformly mixed stream traveling at a lower velocity. The diffuser is so shaped that it gradually reduces the velocity and converts the energy to pressure at discharge with as little loss as possible. Steam jet exhausters and compressors are air and gas pumps designed to operate on the jet principle at moderately high vacuum with live steam as the motive force. In operation, live steam enters the exhauster through an inlet and flows through an expanding nozzle. Issuing from the nozzle at high velocity the jet discharges into the diffuser, produces a powerful suction which entrains air or vapors through suction connection, and compresses the air or vapor enough to discharge against back pressure.

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Bibliography and Suggestions for further study

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