Production of Vacuum Salt Based on Seawater as Raw Material

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ABSTRACT

This paper will give an idea about various processes and their selection based on different energy cost assumptions.
Processes to be discussed are

- *Solar evaporation up to concentrated brine followed by thermal evaporation—crystallization*
- *Electrodialysis as preconcentration step followed by thermal evaporation—crystallization*
- *Multi-stage flash distillation (MSF) plant for preconcentration followed by thermal evaporation—crystallization*
- *Thermal evaporation—crystallization based on seawater.*

For the process of thermal evaporation a comparison between multiple effect and mechanical vapour compression and the use of geothermal energy will be discussed.

INTRODUCTION

Crude salt from the crystallization basins of salines is the normal basis for the production of vacuum salt from seawater, but the climatic and geologic requirements for installing salines cannot be met in all parts of the world. This is one of the reasons why some alternative processes have become approved practice.

Because of rising prices for raw materials over the last decade, energy aspects, partly depending on local site conditions, have an increasing effect on the selected process in this production field. Therefore, this subject is dealt with, in the following, without regard to investment cost.

The processes of up-to-date technique which are used in the production of vacuum salt from seawater are shown schematically in Figure 1.

The conventional process includes the use of a solar saline to produce the crude salt, which is dissolved and recrystallized in a vacuum plant. This vacuum plant uses either the vacuum cooling or the vacuum evaporation crystallization.

In regions of less favourable, climatic conditions, it can be advantageous to use the solar pond for producing concentrated saturated brine instead of crude salt. This brine is processed to vacuum salt in a subsequently arranged vacuum evaporation crystallization plant. This ensures production even under worse weather conditions.

In climatically or geologically unsuitable regions or in states with lower energy costs, this preconcentration is effected by other processes.

In OPEC's arid regions, where mainly multi-stage flash (MSF) plants are used in large-scale seawater desalination, the effluent liquor discharged from these plants serves as preconcentrated feed solution. This concentrated seawater (CSW) is either fed for further preconcentration, if possible or convenient, to a solar pond of an area re-

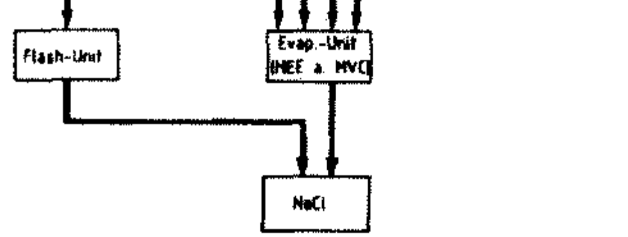

Figure 1. The different processes for the salt production from seawater

quirement consequently reduced to half the volume, or is directly processed to vacuum salt by vacuum crystallization. Because of the energy situation in the Arabian Gulf states, this direct processing of CSW is of considerable importance. In the 1970s, a special process has been developed for this purpose which considers the particular risk of incrustation by $CaSO_4$ on feeding CSW instead of solar brine. This advanced process has been realized several times and represents a well approved technique.

In arid regions as well as in regions unsuitable for solar ponds and having no rock salt deposits, the electrodialysis, used as preconcentration process, entered the group of the alternative processes. The electrodialysis is made on the basis of seawater. Because of its higher $CaSO_4$ concentration, CSW involves some difficulties. Vacuum salt is produced in a subsequently arranged vacuum evaporation crystallization plant.

In addition to the electrodialysis, reverse osmosis also acts as preconcentration process, although the degrees of concentration that can be obtained at present are lower in comparison with electrodialysis. Vacuum evaporation crystallization follows in this case, too.

The processing of salts and brines from solar ponds, as well as brines from the alternative preconcentration processes to produce refined vacuum salt, can be effected, in principle, by using different technologies.

Figure 2 shows the processes together with the respective heat and material balance for single stage operation. NaCl can be produced by means of the two vacuum crystallization processes, i.e., by using either the vacuum cooling crystallization, herein referred to as MSF (multistage flash), or the vacuum evaporation crystallization, which again applies two technologies: the multiple-effect evaporation (MEE) and the mechanical vapour compression (MVC).

The MSF crystallization can be used only where the available raw material is crude salt. Because of the lower specific evaporation rate, the MSF crystallization requires considerably less energy than the MEE. Both MSF and MEE units are generally equipped with 3 to 4 stages. The competitive use of the MVC technology, especially in view of the investment cost, must be determined individually for each single case.

The operation of the MSF crystallization calls, however, for qualified and intense process control, as otherwise slightly undersaturated feed brines or small heat losses can nullify the energy advantages of MSF over MEE. Consequently, every decision in favour of this process implies the very careful study of all local site conditions.

The energy costs of these 3 processes on the basis of the costs for steam and electric power in central Europe are compared in Figure 3. The diagram shows the specific energy costs related to the number 3 stage of MSF and MEE units. The dotted line represents MVC, which always consists of one stage only. As a result, and with a view to refining crude salt, the MSF unit with a minimum of four stages can positively compete with the MVC unit.

For the processing of concentrated brines, and only the MEE and MVC evaporation processes can be applied for this purpose, the MVC process should be preferred from the standpoint of energy conservation. In reality, however, the MEE crystallization is not only preferred for the simple process operation but is as well justified in dual purpose systems.

Of course, changed energy costs may reverse this evalu-

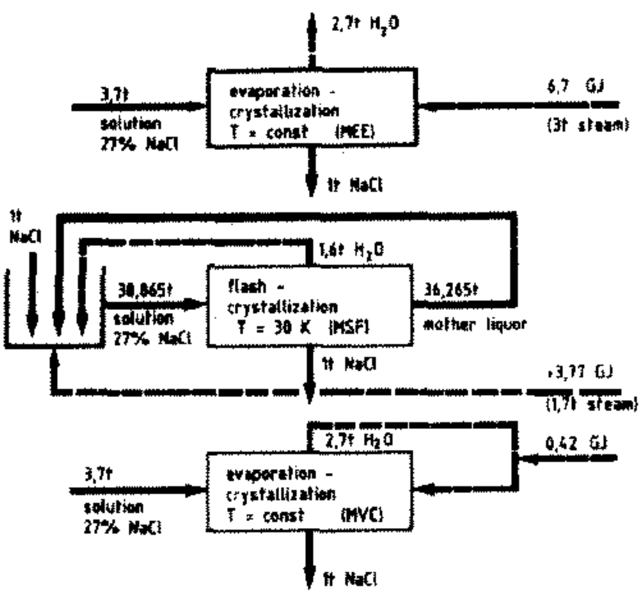

Figure 2. Specific heat consumption of the different salt crystallization processes

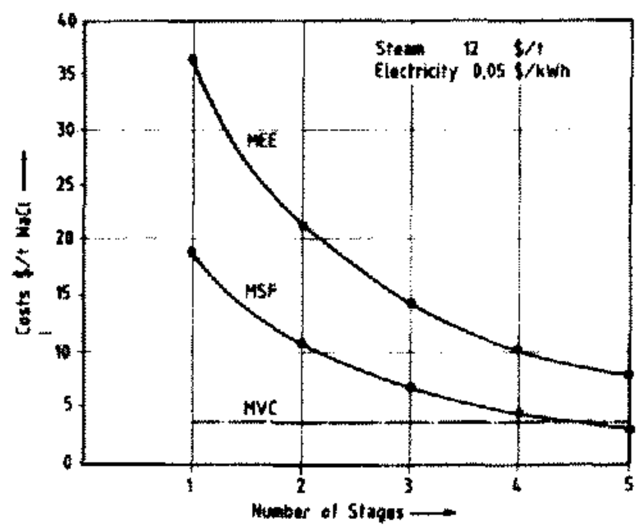

Figure 3. Influence of the number of effects on the specific costs for the different salt crystallization processes.

ation as demonstrated in Figure 4 on the basis of the prices for waste steam. There, both MEE and MSF units can be operated at considerably lower costs than the MVC unit, which requires electric power.

A comparison of all alternative processes for the production of vacuum salt from seawater, the preconcentration and the crystallization stages and the energy consumption data is given in Figure 5, along with the respective, specific energy costs per ton of NaCl on the basis of the prices applying in central Europe and Arabia.

The electrodialysis working in conjunction with the MVC represents, in view of the energy costs, the most appropriate process for all states with energy prices applying for central Europe, whereas in the Arabian states the advantage of utilizing CSW through the simple MEE technology is evident.

There is one further alternative process to be included in this evaluation of energy aspects for the production of vacuum salt from seawater, and, therefore, the production method which is using geothermal energy sources.

The use of geothermal energy as an alternative process can only be discussed individually. Figure 6 gives one example showing the combined utilization of geothermal steam. This natural steam, which normally contains corrosive agents such as H_2S and NH_3, is first used to produce pure process steam by means of a steam generator. Consequently, the special construction material problem in view of the present H_2S and NH_3 refers to this process unit. The process steam obtained in this way is used directly for operating a MEE vacuum salt plant as well as for generating electric current by means of a steam turbine. The waste steam from this turbine is used for preconcentrating the seawater of the cooling tower circulation, whereas the generated electric current ensures the entire electric power requirement of the plant.

At a prime cost of $0.64 per ton of geothermal steam, the specific costs consequently amount to $29.25 per ton of NaCl.

These comparative statements do not pretend that they are generally valid. For such a purpose, the local site factors are too many-sided. Besides, such important factors as maintenance and repair costs as well as investment cost and availability had to be excluded, as they can only be discussed individually for each project concerned.

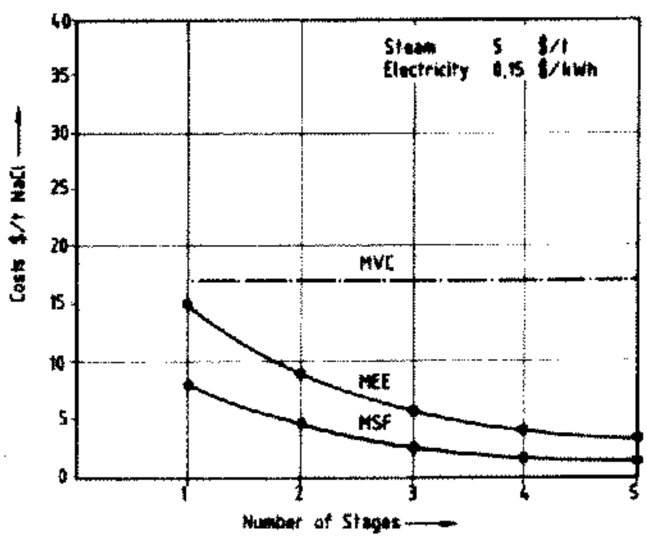

Figure 4. Influence of the number of effects on the specific costs for the different salt crystallization processes

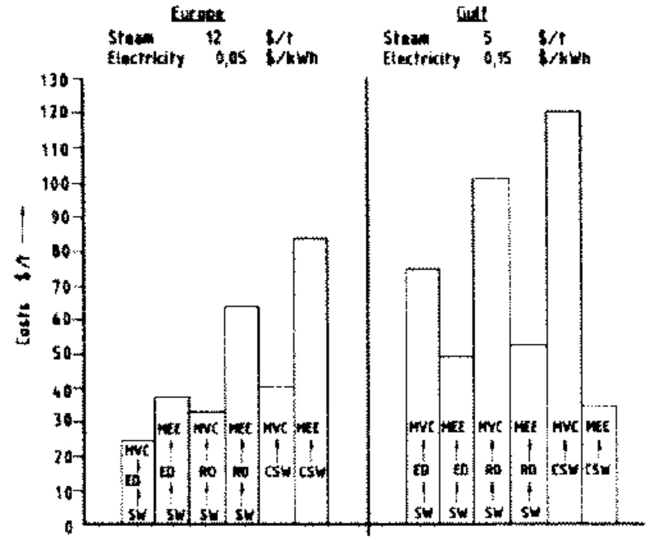

Figure 5. Influence of different energy prices on selection of salt production processes

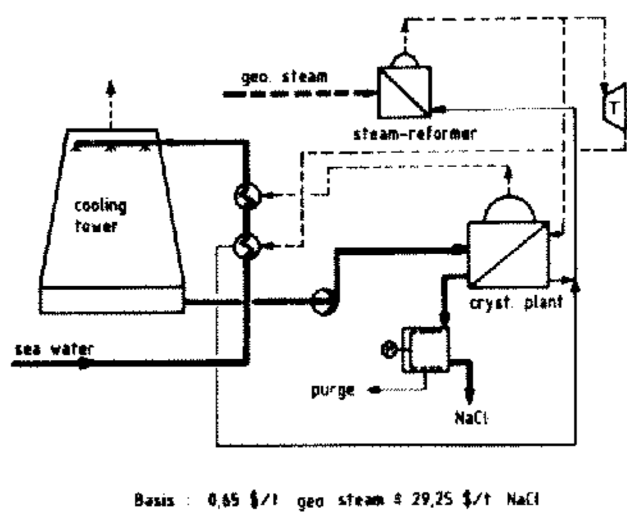

Figure 6. Use of geosteam for salt production from seawater