DEVELOPMENT CONSULTANTS ASSOCIATION

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Presented before
Symposium on Desalination
its Scientific Methods,
Economics and Importance to
Domestic and Agricultural
Purposes in the Arab World

Cairo - Arab Republic of Egypt
6 – 9 November 1971

by:

Development Consultants
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" ABSTRACT "

An experimental multistage flash evaporator is now running satisfactorily at Alexandria. This plant being totally built by the local industrial capacities, starting from the early designing stages untill the starting of operation stage, has given a precious experience to the egyptian Engineers and Scientests.

This paper describes the design problems involved in translating the theoritical conclusions into engineering practice, together with remarks about the mechanical designs involved; This is followed by a description of the experimental equipment produced to prove these designs in practical operation, to establish ~~the~~ requisite design data and to evolve suitable operating technique.

Introduction

Multistage flash distillation is an evaporation procedure where hot brine as passed through a series of chambers(stages) each at a successively lower pressure of vapor so that a portion of the water will flash to vapour, and thus cool the remaining brine to the equilibrium temperature for this pressure. The chambers also contain tube banks (or nests) through which cooler brine is passed to condense the vapour as pure product water. The heat of condensation from all stages in succession provides the majority of the heat needed by the brine to become the hot flashing brine stream. The additional heat is provided by steam or hot water and the final vapour condensation is provided by cooling water.

Flash evaporators have been known and built for nearly as long as sumberged-coil evaporators and it would have been an obvious step to build multi stage versions of them on similar construction lines to those used for the submerged-coil evaporator. The following circumstances seem to have constributed to the fairly sudden emergence of the flash type.

The multistage flash plants are capable to use the low quality heat (e.g) low pressure exhaust steam or low temperature from electric power stations or similar installations.

In early practice, scale formation was accepted as inevitable in evaporators. In flash evaporator, scale could cause not only a loss of output but also a deterioration in the specific heat consumption and an appreciable change in the flow resistance of the brine circulating system. Modern methods of sea water treatment removed this disability from evaporators which can now be operated continuously over many thousands of hours, like chemical process plant. This improvement has been relatinely more important to the flash evaporator.

A considerable increase in the unit size of evaporators has taken place very recently in the years 1967/1968/1969 flash evaporating plants with a total capacity of about 520,000 m^3/day were ordered. The largest constructed plants have a daily output of 22,500 m^3 and they are provided for kuwait, This trend has caused a considerable increase of the vapour valume to be handled inside a single unit. At the same time there occurred a considerable increase in the specefic valume of the vapour, owing to the higher vacuum under which modern units have to poperate. The larger the total volume of steam produced the more natural it is to let the steam condense on the outside of tubes, which are circulated by brine, rather than to resort to the opposite technique employed in the submerged-coil evaporator. Designs have been evolved making possible the construction of flash evaporators with a larg number of stages, but avoiding the need of using separate shells for each stage. Connected by costly inter-stage piping. The flash evaporators designs have removed certain the modynamic disadvantages which handicapped the flash principle and have produced a great improvements in the economics of evaporators.

The rapid development of the flash evaporator is by no means completed and may be expected to continue over the next few years. It is making the evaporator an economically practicable proposition in an increasing number of applications, and it is therefore reasonable to expect that there will be an increasing trend twored the construction of more flash evaporation plants.

According to the working program putforward by the Development consultants Association of Cairo a team of experts has been formed to cover the different specialities which might be needed for the required design. Those experts were engaged in elaborate scientific and technological fields concerning the following items.

a) Oceanography and marine studies concerning the different localities in the arab world, this included chemical analysed of water, current, temperature, salinity... etc.

b) The studies of physico-chemical properties of matter (vapour, liquids and solid state of matters and best conditions of the change of the liquid to vapour stage).

c) Optimization studies on flash evaporation for designing suitable units.

d) Thermodynamics and hydraulics.

e) Heat and mass transfere

f) Mechanical, chemical and metalleurgical engineering

g) Computer sciences and operational research

h) Manufacturing technology (e.g) metal cutting, welding, forming, etc.

i) Corrosion and fouling prevention studies, choice of most suitable materials and the most convenient substitute from local production (e.g) Epoxy resins; polyester, glass fibers and non-porous concrete cement etc.

k) Automatic control

l) Low pressure technique

Infact the technical and scientific infrastructure in Egypt and arab countries has supplied all the above mentioned specialities with a very capable personnel. All the leading staff covering these topics are university prafessors and research workers from different institutes. If we considered the intellectual capacity and capability of the different.

Specialized groups of the D.C.A. till the point of detailed design. It is worth mentioning the great local industrial capability on which the D.C.A. depends upon in the manufacturing of the produced design in the different well equipped shipyards in alexandria where the local trial and experimental work on the sea shore are existing. Several firms specialized in light metal production and alloys such as Cu.Ni and aluminium brass are available in cairo and alexandria which facilitates for the production of any particular material required by the designers.

Design Considerations

If a flash chamber is considered with its associated heater. Forming part of a multi-stage flash evaporator. 5 distinct transport problems are recognized.

1) Brine being heated has to be transported through a succession of heat-transfer surfaces belonging to progressively hotter flash chambers.
2) Hot flashing brine has to be cascaded through a succession of flash chambers.
3) Flashed-orr vapour has to be transerred from the flash chamber into the associated heater, passing through moisture separators if required.
4) The distillate condensing on the heat transfer surfaces has to be extracted from the system, generally by cascading it to the next lower heater.
5) Venting mixture has to be extracted from the heaters or, alternatively, cascaded down the system

Type of the flash evaporators

There were two design version to select the evaporator among them. Namely the vertical evaporator design and the Horizontal (eigher cross tube or long tube) evaporators. In the vertical evaporator designe the flash chambers and the associated heaters are arranged vertically side by side with straight partition walls separating them from one another (fig. 1). It is easily seen that 4 of the 5 transport problems listed before, namely transport of flashing brine from flash chamber to flash chamber. Transport of distillate and venting mixture from heater to heater, and transport of vapour from flash chamber to heater, are colved simply and cheaply by arranging suitably dimensioned apertures in the relevant partition walls. The transport of heated brine from one set of tubes to another is achieved equally simply by having a common tube plate covering a number of heaters and a water box with suitably arranged partitions ensuring that the flow of brine through the heater tube passes in the correct sequence.

This design approach removes at one stroke most of the practical limitations to a vastly increased number of stages. Apart from eliminating the need for any interestage piping or ducting the design has considerable structural advantages for a vessel designed to withstand vaccum.

In a vessel of a given size an increase in the number of stages will cause a decrease in the sieze of flash chambers and heaters. This will within certain limits, make the hole structure lighter and cheaper, if the partitions are used as structural members. There are obvious limitations to this approach, the most important one bieng accessibility to individual chambers. The economic number of stages is found by striking the balance between the reduction of the heat-transfer surface possible with an increased number of stages and the increase in fabrication costs and the reduction in accessibility. which occurs when the number of stages exceeds a certain maximum which depends mainly on the size of plant. In the Horizontal evaporator design the heat-transfere tubes are arranged horizontally. (Fig. 2); The flash chambers and their associated heaters can be arranged in two, three or four tiers. Each tier is split by a longitudinal vertical partition wall, and on each side of the partition wall there is one tube pass. The two passes in a tier are circulated in series by the brine which is then pumped up to the next higher tier. Vertical transverse partition walls, acting also as tube supports, separate each pass into a number of chambers and the brine is cascaded through the flash chambers, in counterflow to the brine flowing through the heat transfere tubes. The vapour produced condenses in the heater section where it is collected in the throughs surrounding the heater tube banks.

The Horizontally tubed evaporator requires a lower heat-transfere surface for a given duty because of the higher heat transfere coefficients which are obtainable with horizontal tubes. In addition the total flash chamber surface available for flashing - off of the brine is equal to the plan area of the main vessel multiplied by the number of tiers. The same area in the vertical design of flash evaporator cannot exceed say 80 percent of the total plan area of the vessel. the rest being occupied by the tube bundles. Both these arguments are in favour of the horizontal design of evaporator, on the other hand, for a given specific heat consumption and brine circulating velocity, the designer must in fact accommodate a given total length of heat-transfer tube through which the brine has to flow (expressed as a multiple of the tube diameter), and in horizontal evaporators of low unit output this results in a very narrow vessel in which ultimately the width is dictated not by the output but by accessibility requirements. In a vertical unit the designer is free to choose both the height of the vessel and the number of tube passesto be used in any single stage. For lower unit outputs the vertical evaporator can therefore be designed to produce a more attractive and cheaper vessel. This can outweight the increased cost of the head transfere surface caused by reduction in the number of stages and by the lower heat-transfer coefficients obtainable with vertical tubes.

Development Problems:

Before the designs discribed above could be put to commercial use a considerable number of operational problems had to be solved, suitable design data had to be aquired, and a great deal of development was necessary. In order to tackle these development problems, the first experimental evaporator was built and erected at Alexandria, where an adequate supply of clean sea-water, steam, vaccum services, etc., are available. This evaportaor is built on an industrial scale and this had the great advantage that the results and the experience obtained could be translated into industrial designs without undue, if any scaling-up in size.

Description of the Evaporator:

The schematic diagram of this test unit is shown in (fig. 3). The evaporator consisted of a heat input section followed by six vertically arranged flash chambers with their associated heaters, such design is recommended for the low capacity units as mentioned before. Normally an evaporator of this type and size would have according to the optimization studies, at least 12 stages, but in the case of this test unit, the tail of the evaporator was out off, and can be either replaced by a cooler or run the unit as it is.

Adjustment of the heat supply and of the cooling water flow through the cooler made it possible to run the unit over a whole range of heat loadings and temperature levels. Brine velocities through the tubes could be changed by adjusting the speed of the brine circulating-pump, and normal flow and temperature instrumentation (measuring orifice, and mercury-in-glass thermometers), combined with pressure measurements using mercury filled tubes, made it possible to measure heat-transfere coefficients over a wide range of conditions. Provision was made for blowdown (measured through an orifice), for feed and feed dosing, and for distillate measurement using a volumetric tank. The heat input section condensate was discharged from the system separately, and was measured volumetrically. The pressure prevailing in each chamber is primarily determined by the capacity of the condensing element and hence is more of less automatically regulated by the temperature of the brine inside the condenser tubes. To help maintain such a pressure the chamber is connected to a vaccum producing device which continuously bleeds the non-condensable gases and prevents their accumulation.

The vapour velocities and the demisters dimensioning were adjusted so that adequate distillate purities were obtained. The heat-transfer surface provided in the heat input section and the 6 heaters of the unit, and the rating of the brine circulating-pump would correspond to an industrial evaporator of about 100 m^3/day output. Since the low pressure stages of the evaporator were missing, the gained output of the test evaporator under normal operation conditions is only of the order of 1.5 - 1.8 m^3/hr.

Functions of the Evaporator:

I) Deposition problems and scale prevention:

Sea water has about 35,000 ppm - 45 ppm. of various dissolved salts. At high temperature and concentrations there is a tendency for the precipitation of scale on the heating surface of flash evaporator. (fig. 4). These scale depositis are composed of alkali scale (calcium carbonate and magnesium hydroxide) and non-alkaline scale (calcium sulphate). The build-up of scale deposits on heat transfere surface offers a resistance to the flow of heat. Also scale deposits can accumulate in pipelines, orifices, and other flow passage to the extent that flow of process fluids is seriously impeded. These two important effects result ultimately in an increase in the ratio of energy input to product from the plant. This gives strong economic incentive to prevent scale deposition. To fulfill this aim, the following methods are available.

i) modification of the nature of the deposits to make them less adherent, less resistant to heat transfere or both, using some additives particularly polyphosphate.

ii) Effective removal of part of all of materials responsible for scale formation from the working fluids using acids especially sulphuric acid.

iii) Provision of alternative places for scale to precipitate, preferentially as compared with the heat transfere surface and flow passages.

iv) Operation of the plant in a range of conditions (temp) where scale precipitations is minimized.

(fig.) showed that calcium sulphate scale formation could be completely avoided by controle of brine concentration and temperature within operationally acceptable limits. The decision was therefore made to proceed on the lines indicited under (i) & -iv), that is to use additives.

Such additives which are under test now is a mixture of sodium tripolyphosphate and colloidal forming powder. It is an easily handled, readily soluble, dry powder. It is known that treatment with this powder (will be registered later under commercial name) was likely to cease to be effective at maximum brine temperatures of the order of (8[illegible] - 89°C) mainly due to the transition from calcium carbonate to magensium hydroxide. It was known that with this treatment, and at the temperatures in question, deposits formed on the outside of the heat transfere tubes of submerged coil evaporators were in the form of a coft and loose powder. It could therefore be expected that the limitations of the treatment will be less pronounced in the case of flash evaporators where the powder is deposited inside the tubes and should be, to some extent at least, washed off by the forced circulation. The initial programmed test which is now under action is to run the unit on the range around 85°C and to assess the deposit thickness by the hydrochlorid acid test.

II) Heat transfere measurements:

Owing to fluctuations in the work services supplied to the evaporator it was difficult to run it steadily enough to obtain accurate heat transfere figures.

It was found that the results obtained agreed quit well with the information available about the performance of heaters and condensers. This was to be expected. Since the plant was mostly operating under clean conditions.

The best method of reducing scatter was found in a suitable modification of the well known wilson plot (McADAMS, W.M. 1954 "Heat transmission" third edition (McGraw-Hill Co., New York & London).

III) The flashing-off process:

The mentioned evaporator is also used for the study of flashing-off process. Where a large number of stages is used the plan area of individual flash chambers will te...

to become smaller for the same circulating brine quantity. Abviously flashing off will invalve additional losses unless every particle of the circulating brine, in every flash chamber, is discharged above the general brine level and gives a chance to release vapour.

The problem was solved by developing specially shaped baffle on the downstream side of the partition wall between two adjoining flash chambers. This bafle forms a secondary orifice discharging the flashing brine upward and avove the general level of fluid in the chamber. This liberates the vapour with a minimum of pressure loss. In addition, the secondary orifice, avoids the loss of steam from one flash chamber to the other by building up a back pressure inside the baffle as soon as a minute quantity of steam enters. The hight and wedth of the orifice is externally controlled by a special device in order to obtain the optimum heights under different running conditions.

This control system have the ability to be fixed during the running without need to dismantle the unit.

The evaporator is also used to obtain design information about the interrelation of the various features influencing the flash process, for experimental confirmation of the design of splash guards mounted above the baffle, etc.

Corrosion problems and material of construction:

The corrosion problem and the material of construction differs greatly for the larg plants running with dearation systen and small plants (or expernental units) which it's size and economics cannot compensate for the required additional cost of dearator. The material of construction of the evaporator units varies between cu Ni allowy (which is locally manufactured and shaped in Egypt) with its superior corrosion properties and the normal carbon steel for sections which are not a subject of severe corrosion. The economics of small size plants proves that these units can be built totally by Cu Ni for the evaporator shell, water boxes, tube plates and condenser tubes but in larger units (output more than 300 tons/day) deareation systen can be additionally supplied evaporator is made of carbon steel without protective coating. It is assuned that the oxygen contents of the sea water to be fed into the plant, is reduced in an upstrean connected deaerator to such an extent that corrosions are excluded. In case of a very good deaeration, i.e., when the residual oxygen content in the feed water is less than 0.010 mg/lt and with a perfect sealing of the manhole covers and openings in the vaccum chambers there will be a corrosion factor of about 0.1 to 0.2 mm/year. For a depreciation period of 20 years, consequently a corrosion allowance of 3 to 5 mm should be sufficient. Corrosion will exist uniformally over the total steel area.

The tube plates of the evaporator can be made of various copper alloys. (e.g) Aluminium brass or Cu Ni 10 which are directly welded to the evaporator shell. The tube plates can be of course also flanged on and in this case they can be made of muntz metal. A flanged connection, however, must be very tight in order to prevent air leakage inside the evaporator which would increase the danger of corrosion in the evaporator. The tubes can be made of aluminium brass which is a very cost saving material. With respect to water boxes care should be taken that the differences in the electric self-potentials are not too high. Because of excessies carrosion rates it is not possible to use copper-nickel plates together with steel chambers, that is why the boxes must be either internally coated with plastic materials or plated with sheets of copper alloy.

The distillate collecting trays arranged in the evaporator are made of steel.

Manufacturing technology & welding of Cu Ni alloys:

It is of utmost importance to follow a very accurate procedure during the manufacture of the multistage flash evaporator components. The degree of success of the unit depends to a large extent on its tightness to vaccum together with accurate internal dimensions. Special care should also be paid for the erection procedure due to the largs number of components and auxiliaries existing in the same unit it is recommended to utilize a time saving techniques during the construction of the flash evaporator (e.g) P.E.R.T. (project evaluation and review technique).

In the other hand, if special alloy is applied the welding technology and the skill of labour must be of the highest quality. The D.C.A. has carried out a series of experiments on the welding of Cu Ni sheets and tubes the results was very promising, and will be directly applied in the production of a totally build Cu Ni shell for small size evaporators (50–250 m^3/day distillate). Welding of such alloy is mainly carried out in the form of argon arc welding with tungesten electrodes followed by special heat treatment. In order to release the residual stresses.

Special care must be taken to maintain a high quality of the argon to keep the oxidation of the weld surfaces as low on the inner surfaces as possible. Not more than a thin blue grey oxids filln can be accepted.

All welds are to be completely radiographed. to attain this high quality of weld.

If the material thickness exceeds 3 mm, the welded ends must be prepared with 2.5 mm thick weld lips which were butt welded without filler metal. After radigraphing this root pass, the weld was built up to the full thickness by electrodes which gave the same analysis for the filler metal as the basic material in the sheets.

For material thickness not exceeding 3 mm, the ends are to be plain out and then buttwelded without filler metal. Most of the welding without filler metal is to be carried out using an automatic welding machine, with expected very good results.

Future outlook

The designs and development results described in this paper are the autcome of a basic theoritical investigation of the subject, followed by a certain amount of the design effort. This was baked by Alexandria test multistage flash evaporator intended specifically to prove the design and the operational methods. In view of the rapid development in this important field. The program of work planned by the D.C.A. still carry a lot to realize. Among those efforts which are now under execution are the following:

1) Development and execution of a water saparation test unit with facilities for varying the circulating brine quantity, the brine concentration, the quantity of the vapour flasing off, the temperature level at which the flashing off takes place, the vapour velocity and the geometry of the flash chamber.

   A large number of test will be carried out on this test unit, including special tests in which the geometry of the flash chambers corresponding to the horizontal evaporator design was reproduced.

Various types of separators will be tried, including cyclones, wire mesh separators, impingement-type baffles, etc. In order to avoid joints and mechanical surfaces inside the evaporator vessel, the separators will be mounted in very simply arrange water seals.

2) Carrying out the theoritical mathematical studies and calculations including the development of mathematical model for the optimization of large multistage flash evaporation plant designs, and the off-design performance analysis by applying the computer simulation of the process. These studies are based on the works 1 (MANDIL, & ABDEL GHAFOUR & EL ANSARY)

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REFERENCES

1 - Silver. R.S. — Fresh water from the sea (London, justitution of Mechanic... Enginers, 1964).

2 - A. Frankel — Flashevaporators for the distil-lation of sea water. "Proceedings of the Institution of mechanical engineers - volume 174, No 7".

3 - William H. McADAMS — "Heat transmission" MC GRAW HILL third edition 19..

4 - M.A. MANDIL & E.E. ABDEL GHAFOUR — Optimization of multi-stage flash evaporation plants "Chemical Engineering Science 1970, Vol. 25, PP. 611-621. Pergamon press)

5 - LAGELIER, W.F. CALDWELL, D.H., LAWRENCE, W.B. and SPAULDING, C.H. 1950 — Industr. Engng. Chem. Vol. 42, P. 126. "Scale controle in Sea water distillation Equipment

6 - U.S Department of THE INTERIOR — SALLINE WATER CONVERSION PROGRAMME research and development progress report N 212.

7 - UNITED NATIONS — Water Desalination in Developing Countries. Department of Economic and social of fairs (New York, UN.N, 1965)

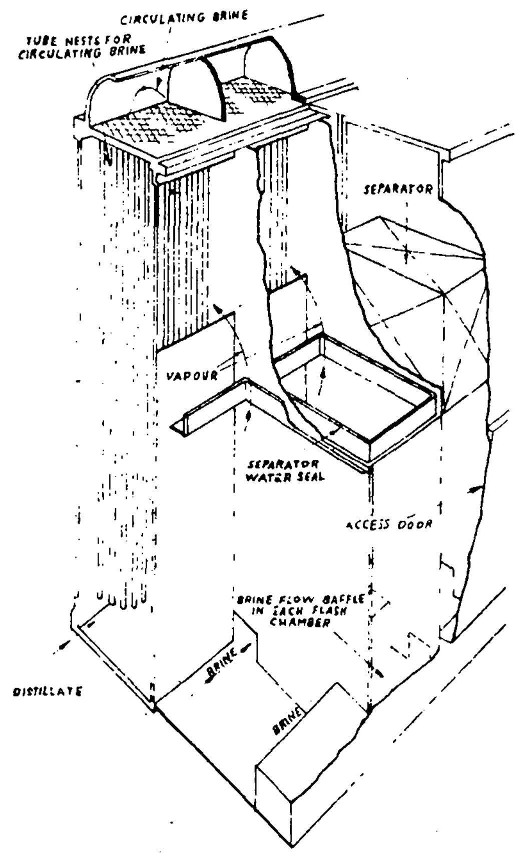
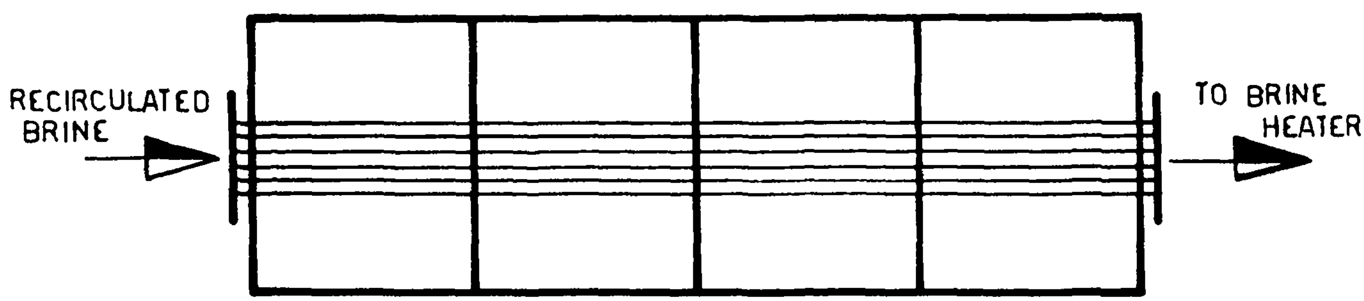
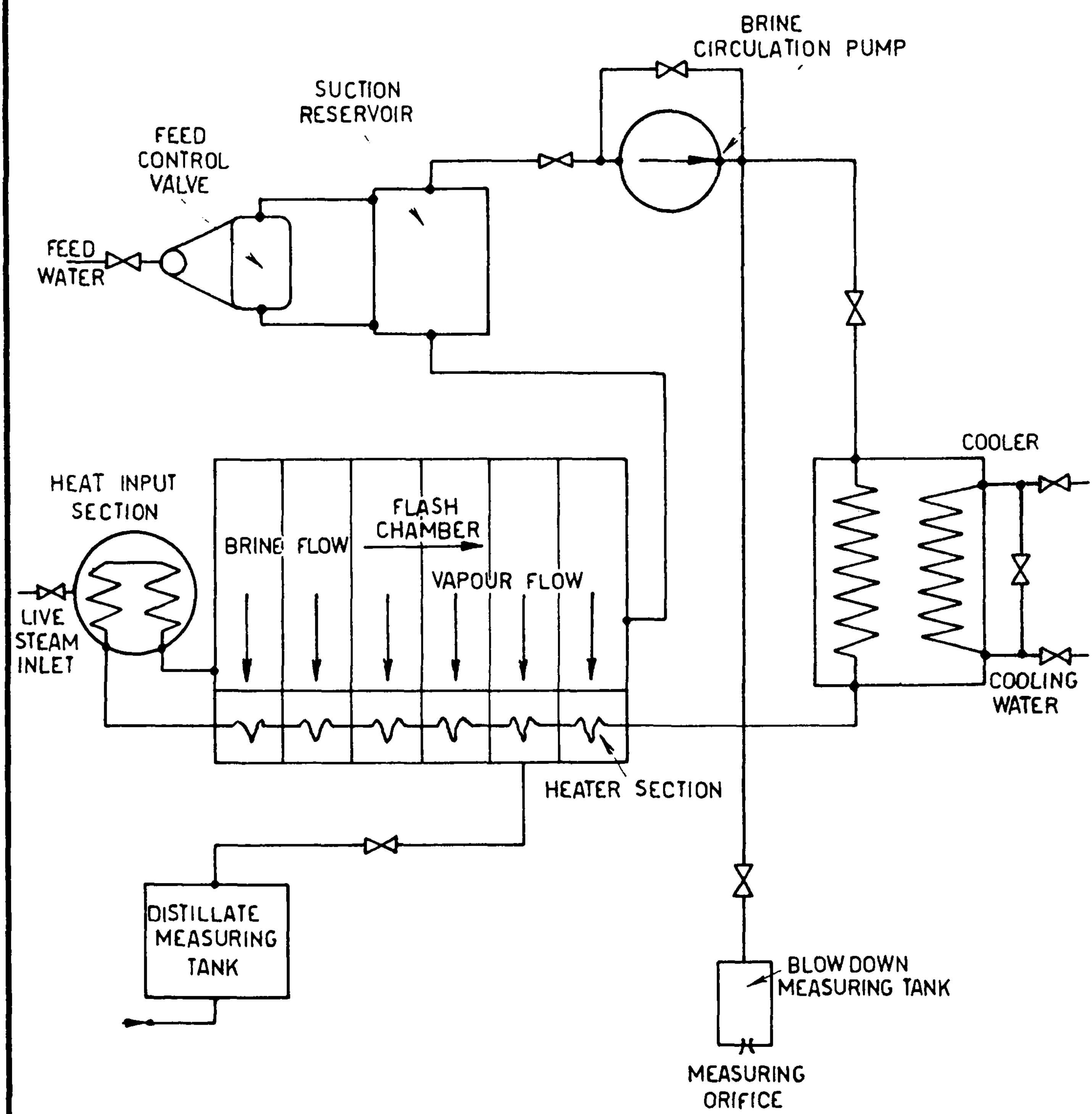


FIG (1) VERTICAL EVAPORATOR DESIGN



FIG(2)
HORIZONTAL EVAPORATOR
DESIGN



FIG(3) SCHEMATIC DIAGRAM OF THE TEST EVAPORATOR

FIG (4)
RELATION BETWEEN TEMPERATURE AND SCALE CONSTITUENTS