GEYSIR AG, BASEL

Project: Sea-water Desalination Method based on Multiple Distillation & Flashing (MDF)

Preliminary Description of the Sea-water Desalination Method based on Multiple Distillation & Flashing (MDF)

September 1992

1. Evaluation criteria for desalination processes:

1.1 Thermodynamic criteria:

1.1.1 Small temperature differences between media,

1.1.2 Heat exchange coefficient: if possible using condensation and evaporation for heat exchange,

1.1.3 No mixing of media of different temperatures,

1.1.4 Re-use of the initially available amount of heat for multiple, stepwise distillation,

1.1.5 The desalination process should use waste heat of a steam-cycle or of a gas-turbine cycle; thus co-generation of electricity should be possible.

1.2 Manufacturing criteria:

1.2.1 Modular design of simple elements,

1.2.2 Easy, simple assembly process of components.

2. Currently used methods:

2.1. Reverse Osmosis (RO):

Mechanical pressure forces salty water across a semi-permeable membrane. The new design for membrane is in the form of hollow fibre.

Simple, modular design. Most of new plants use this technology.

Disadvantage: - uses electricity as power source (neither co-generation nor the use of solar energy with thermal collectors are possible),

- requires biologically and mechanically clean water, which has to be chemically neutral: costly pre-treatment needed.

- the product still has about 300 ppm total dissolved solids (TDS).

2.2. Multiple Stage Flashing (MSF):

Cold saline water passes a row of containers (stages) where it is used for condensation and is progressively heated up (fig. 2.1). At the end it is additionally heated up by steam and passes counter-current wise the same containers. The heated saline water flashes stepwise in each of the containers. The vapour generated from flashing condenses on the cold tubes and is collected in a tray.

Most widely used process. May use waste heat from steam cycle (Co-generation). The sea-water is heated up counter-current wise, the latent heat of the product-water is used as well, the temperature differences are small: conditions 1.1.1 through 1.1.4 are met.

Disadvantage: - large containers and heat-exchangers required.
- limited possibility of modular design.

2.3. Multiple Effect Distillation (MED):

The salty water is heated up and is sprayed over heat exchanger registers in a row of containers (effects). The vapour generated by evaporation on the register tubes condenses consecutively in the HEX tubes of the adjacent effect (figure 2.2). The product water as well as the brine is collected in each of the effects.

Advantageous for co-generation plant.

Disadvantage: - container design used (conventional thin tube HEX's).

- the heating up of the sea-water occurs on the evaporating tubes; temperature differences are considerable large,

- product water and brine of different temperature is mixed; latent heat difference is not used.

3. The Multiple Distillation & Flashing (MDF) process:

3.1. Main design characteristics and heat source:

The Multiple Distillation & Flashing (MDF) process is a thermal desalination process. The bulk energy used by the MDF process is low temperature heat.

Like all the other thermal processes for sea-water desalination also the MDF process needs a small amount of electric power for pumping sea-water, brine and product fresh water as well as for vacuum generation for eliminating of non-condensable gases. The low temperature heat is supplied by condensing vapour of a adjacent steam-cycle or by other low temperature heat sources, like solar energy. The vapour is required to have around 110 degree C. Thus if the heat source was a steam cycle, part of the thermal energy used for the MDF system is lost for the power generation. In this respect the MDF system is equal to the other thermal processes.

The main characteristic of the MDF process is that all heat exchange and evaporation/distillation processes take place inside plate heat-exchanger modules (see figure 3.1). Because of their extremely simple design plate heat exchangers represent the most economical mean for heat transfer. The main aim by the development of the MDF process was to find a thermal process - by modifying the known thermal processes - which may work entirely within a plate heat exchanger.

There are multiple evaporation/distillation processes known in the chemical process technology, also with the evaporation/condensation part working within plate heat-exchangers, but the vapour separation and the pressure drop devices are always separate, outside the plate HEX. In order to built an economical desalting device, which may compete with the RO process, it is mandatory to be as simple as possible. This simplicity is only achieved, if the entire process took place within a HEX.

3.2 Description of the MDF process:

Each module starts with an evaporator and ends with a condenser (see fig.3.1). Between evaporator and the condenser there are a number of effects, where the heat supplied by the external heat source is used again and again for drinking water production, like in all other thermal processes. The cold saline water is used as heat sink in the condenser. Part of it is also taken as feed for the desalination process: this part of the sea-water flow is divided into parallel flows corresponding to the feed flow to the different effects. The distribution of the flow is achieved by holes in a diaphragm right at the entry of the saline water into the preheater. Each of the feed flows enter into the preheater section of the MDF unit and flows from effect to effect until it reaches its proper effect, where it joins the evaporator flow . The same condensing vapour, which is used for evaporation in each effect also heats up here the sea-water (see figure 3.2). Thus preheating is achieved in contra flow, with small temperature differences.

At the other end of the MDF unit the external vapour supplying the heat enters the evaporator where it condenses. It evaporates part of the saline water here (see fig. 3.3). The vapour generated out of saline water in the evaporator goes to the first effect of the MDF-module where it condenses. Similarly vapour generated in each MDF-effect condenses in the following effect. Thus the evaporation side of each effect is provided with a connection to the condensation side of the next effect (see figure 3.2). Therefore the pressure at the outlet of each of the evaporation sections corresponds to the pressure on the condensation side of the next effect.

The temperature difference required for heat exchange is assured by the corresponding pressure difference between the condensing vapour and the evaporating brine. Thus there is a pressure drop from effect to effect. This pressure drop is generated by the height of water-columns between the effects on special pressure drop plates. Such pressure drop plates are placed on both sides, on the condensation side and on the evaporation side between the effects (see fig. 3.5), On the condensation side the pressure drop of an effect is given by the height of the product-water-column after each effect. The corresponding pressure drop on the evaporation side is given by the head of water on the pressure drop plate before each effect. Thus on the condensation side the pressure always correspond to the higher pressure of the previous effect and on the evaporation side to the lower pressure on the condensation side of the next effect. Thus the temperature difference between evaporation side and condensation side corresponds basically to the pressure drop between adjacent effects (in fact it is somewhat smaller because of the boiling point elevation due to saline water).

In the evaporator the surplus bine water overflows from the top to the pressure drop plate to the next effect (see figure 3.1). The right amount of feed saline water preheated in the preheater joins the brine flow at the bottom of each pressure drop plate on the evaporation side.

The vapour generated in the evaporator passes to the condenser of the next effect. In order to avoid the carry-over of salty water droplets from the evaporation side to the condensation side, there is a demister provided between the top of the evaporation channels and the vapour channels to the next effect (see figure 3.2 and 3.3). This demister is composed of stainless steel meshes. The product water stream passes from the condenser through the pressure drop plate after the effect t to the condenser of the next effect. Thus the product water flow joins the vapour stream at the top of the pressure drop plate.

The evaporation take place by flashing in the evaporation section. Two phase flow in a single channel is never stable. Stability of the average flow is achieved by subdivision of the evaporation side into a number of parallel channels (see figure 3.3).

3.3 Design of the MDF unit:

The MDF modules are composed of plates and subdividing packing between the plates (see figures 3.2 and 3.3). The plates of the HEX are relatively thin (typically 0.3 mm). They are corrugated in order to increase the turbulence and the heat exchange (see figure 3.5). The space for packing around the active surface as well as for the subdivision of the evaporation section and for the preheater sections are plane.

The plates are symmetrical only with respect to their vertical axes. Therefore there are two kind of plates: the ones corrugated by V groves and the ones corrugated by A groves on their active heat exchange surface. Both kind of plates have their plane groves for packing at the same side. Thus plates with A groves and plates with V groves are packed alternately in the unit .

The MDF unit is covered at both ends by massive steel plates. Like on any other plate heat exchanger all the connecting fittings are mounted on this cover plates.

The number of effects of a MDF unit depends on the total temperature difference the system is planned for. Typically the optimum subdivision between the high end temperature of 110 degree C and the low end temperature of 30 degree C and with current energy and plate prices is into 12 effects. In special cases, when the energy costs have much more weight as the plate costs, more effects may be used. However with increasing effect number (and by constant total temperature difference) the heat transfer deteriorate quickly and the plates become ineffective.

Geometry of the MDF unit:

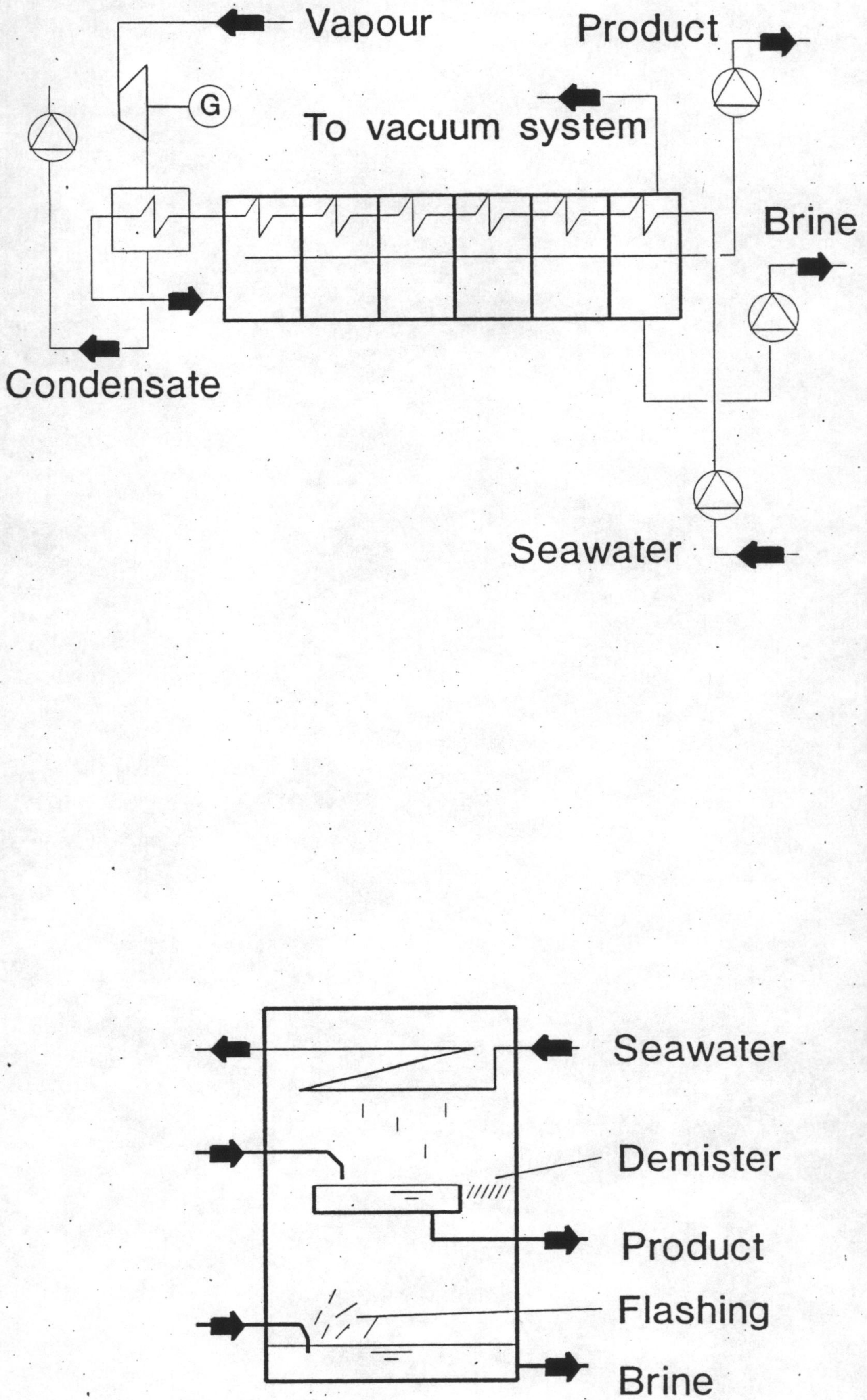
Number of effects:	11
Number of plates:	
in the effects:	66
in evaporator:	6
in condenser	7
pressure drop plates	22
total plates:	101
Plate dimensions:	
Height:	1.005 m
Width:	0.943 m
Thickness of plates:	0.3 mm
Distance between plates:	6 mm
Total depth of unit between end plates:	0.636 m

3.4 Working characteristics of the MDF unit:

Independent units or modules of such relatively small plate heat-exchangers are coupled by an extensible pipe heat distribution system (see figure 3.6).

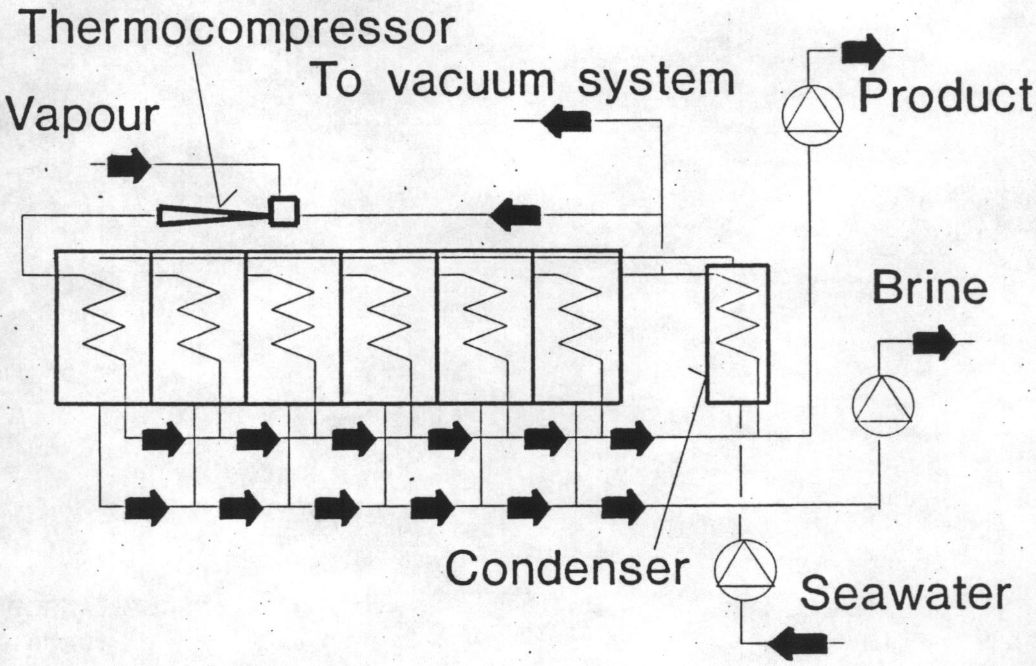
Drinking water production:	6.2 QM/day
Power consumption:	21.0 kW
Vapour consumption:	29.2 kg/hr
The total amount of feed to the unit:	403. kg/hr
The total amount of brine leaving the unit:	132.6 kg/hr
The cooling water requirements of the unit:	488.0 kg/hr
The performance ratio of the unit is:	3.92
The gain output ratio of the unit is:	8.76

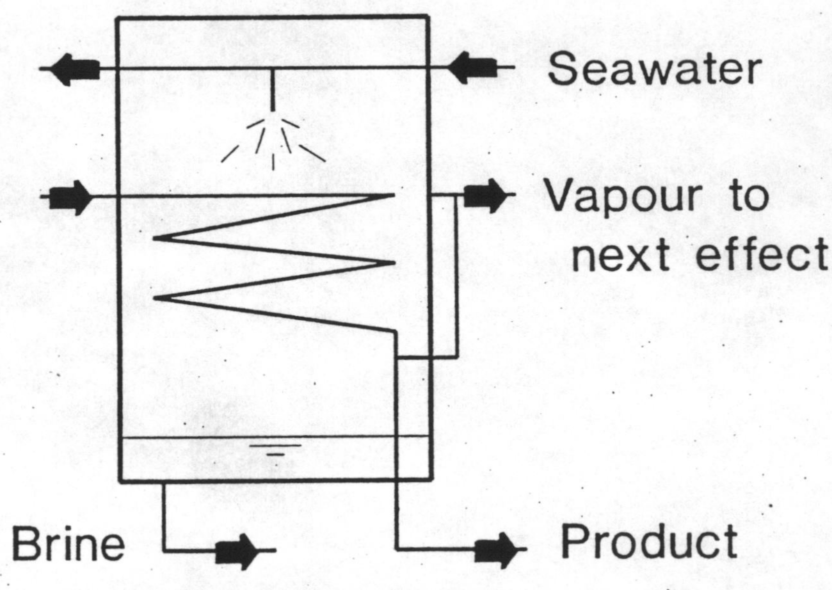
(the relation of the amount of produced drinking water in kg to the amount of steam used for the process in kg)



Multiple Stage Flashing

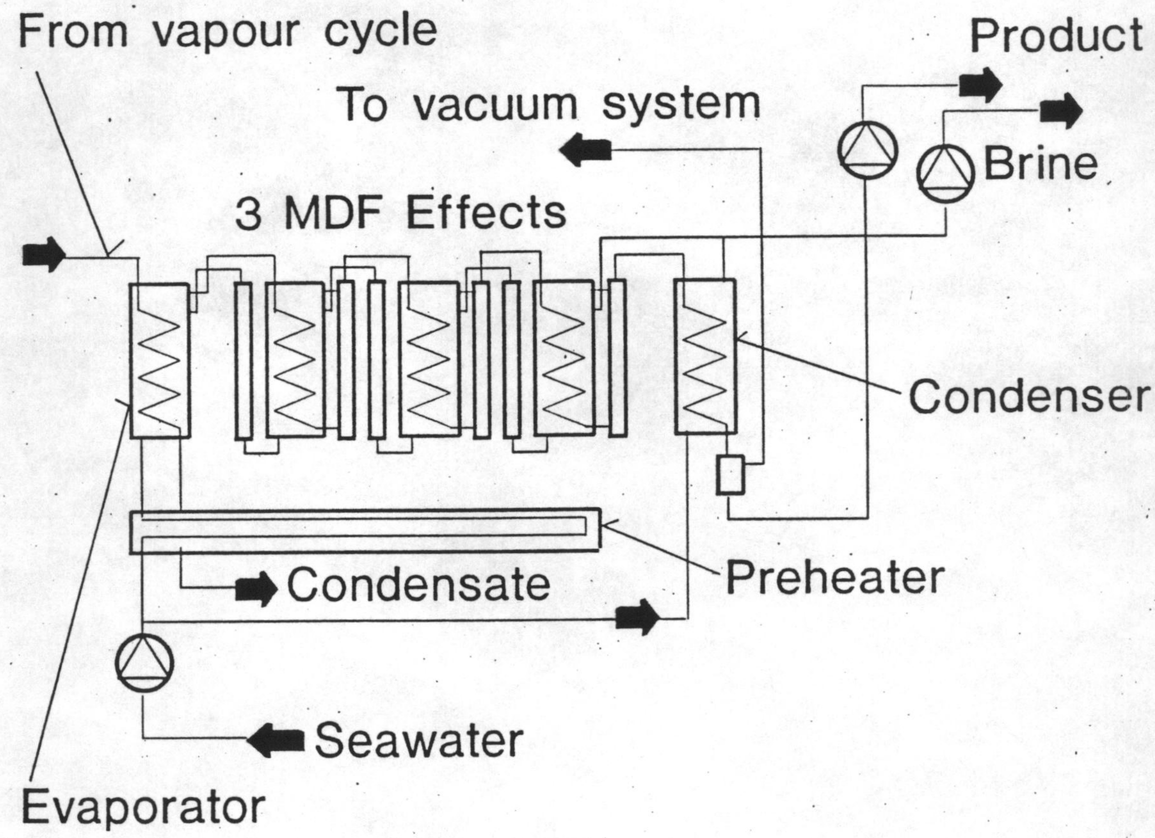
Fig. 2.1

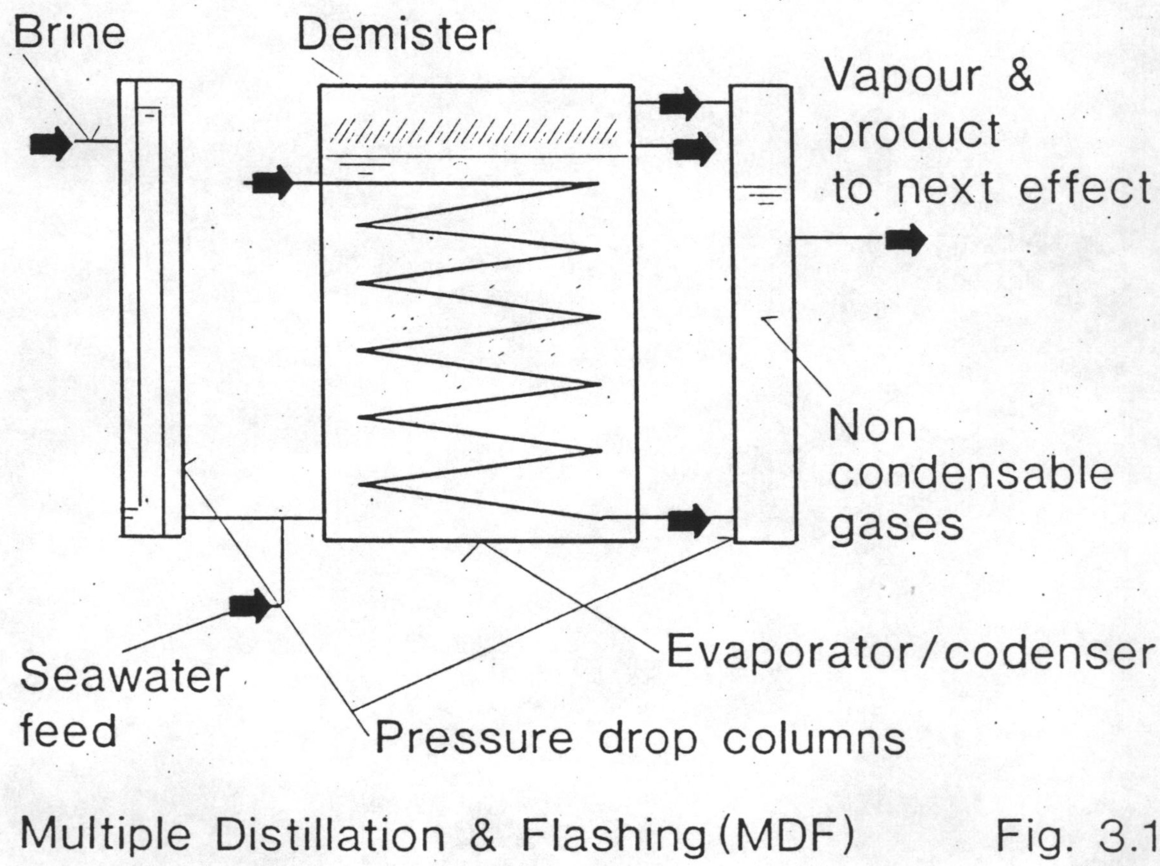




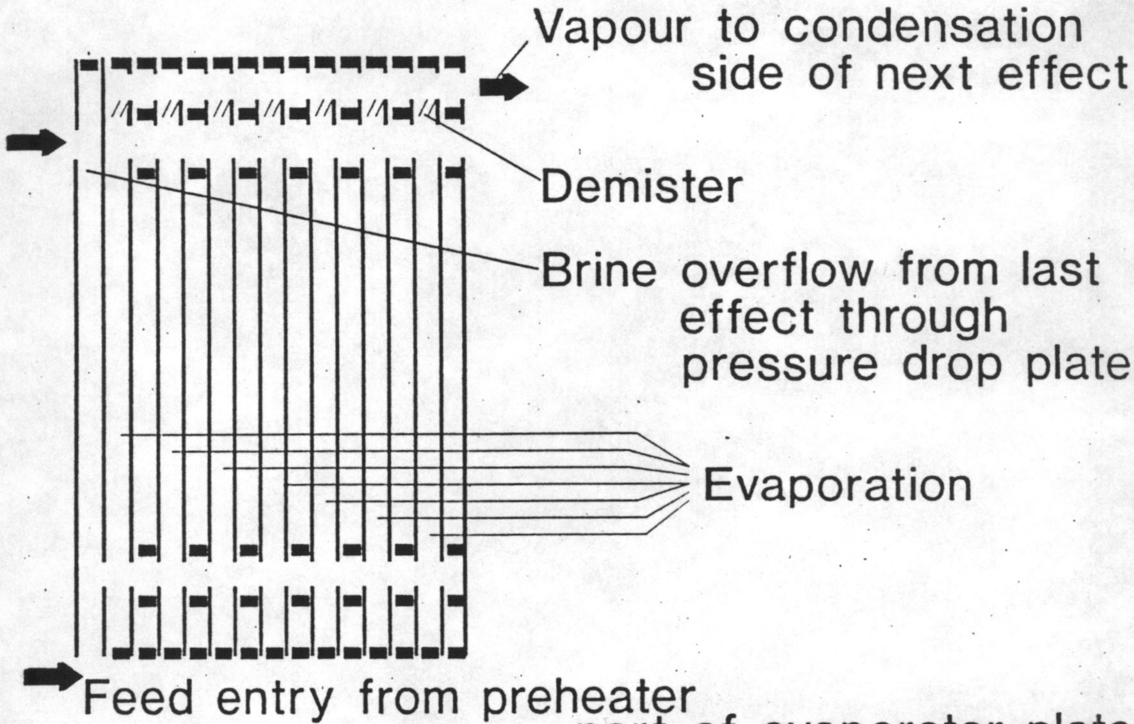
Multi-Effect Distillation

Fig. 2.2

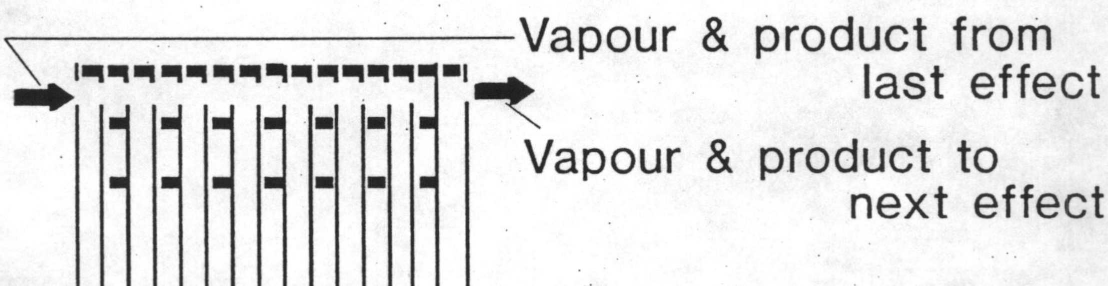




Multiple Distillation & Flashing (MDF) Fig. 3.1

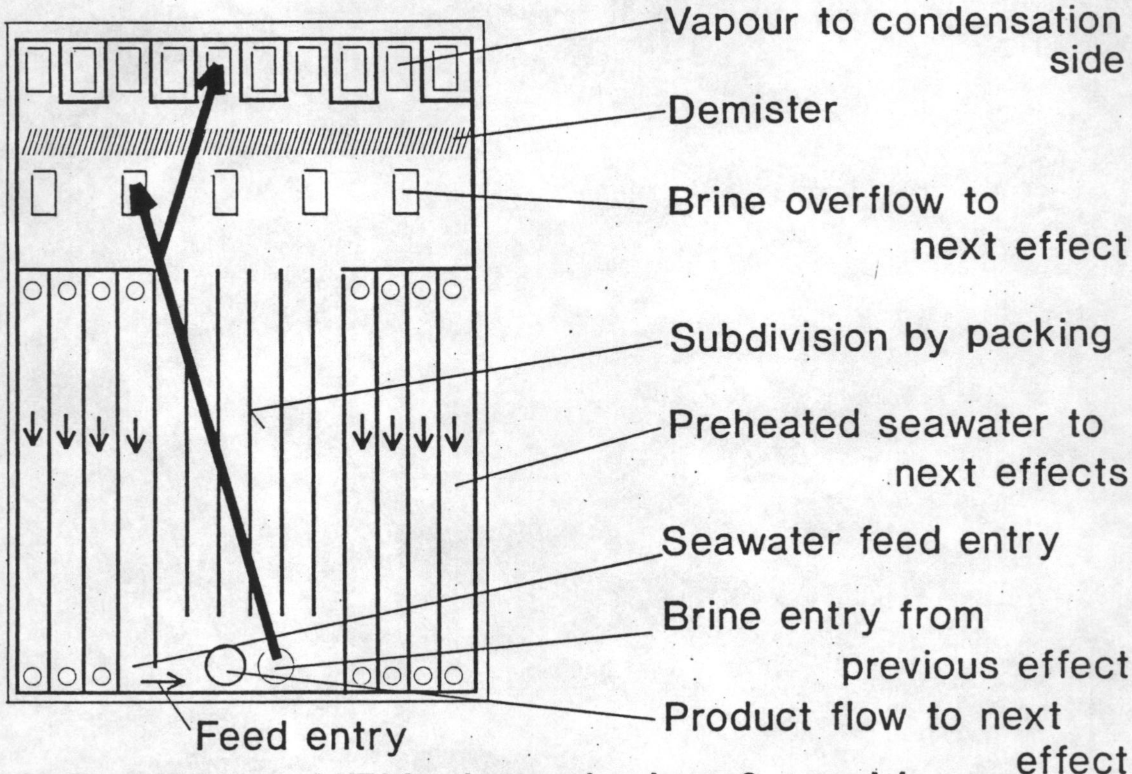


MDF plate HEX, evaporation side of effects with pressure drop plate

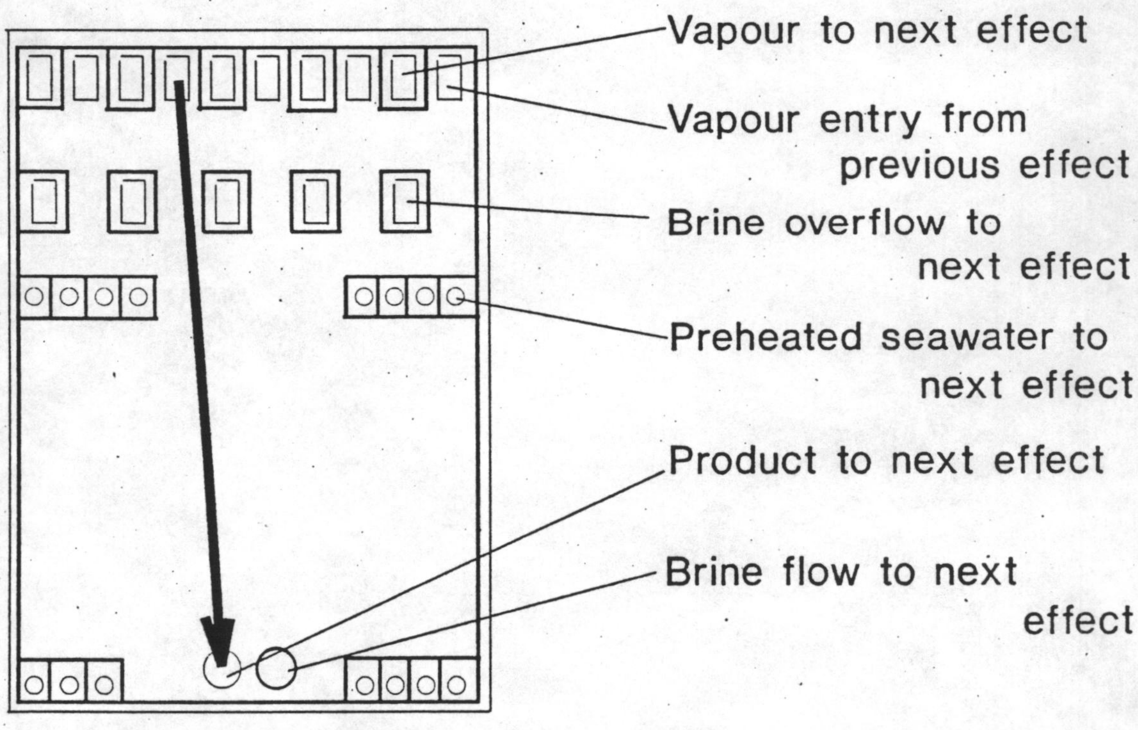


MDF plate HEX, condensation side of effects with pressure drop plate

Fig. 3.2

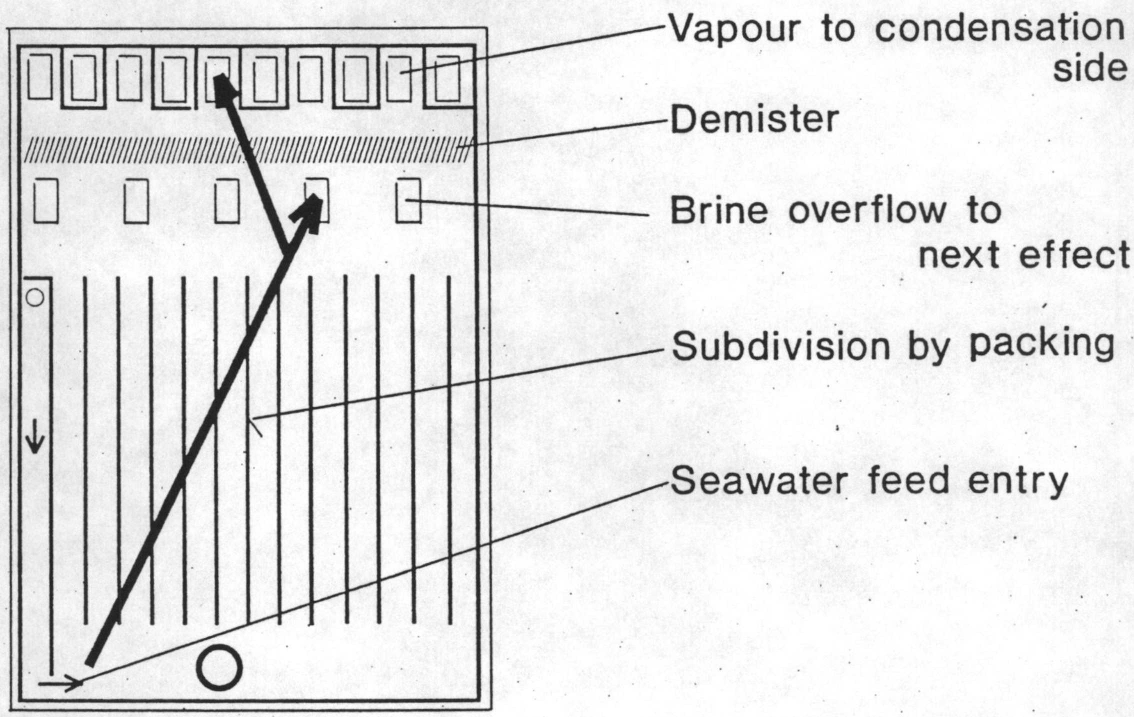


MDF effects, HEX plate design & packing, evaporation side

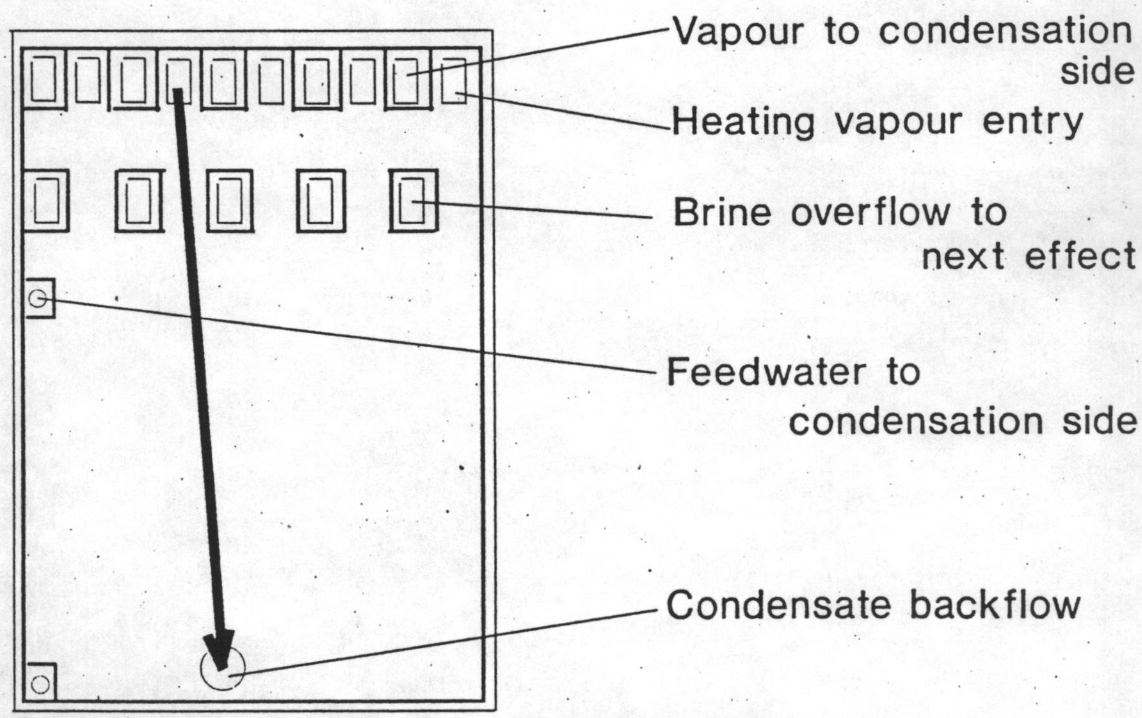


MDF effects, plate design & packing, condensation side

Fig 3.3

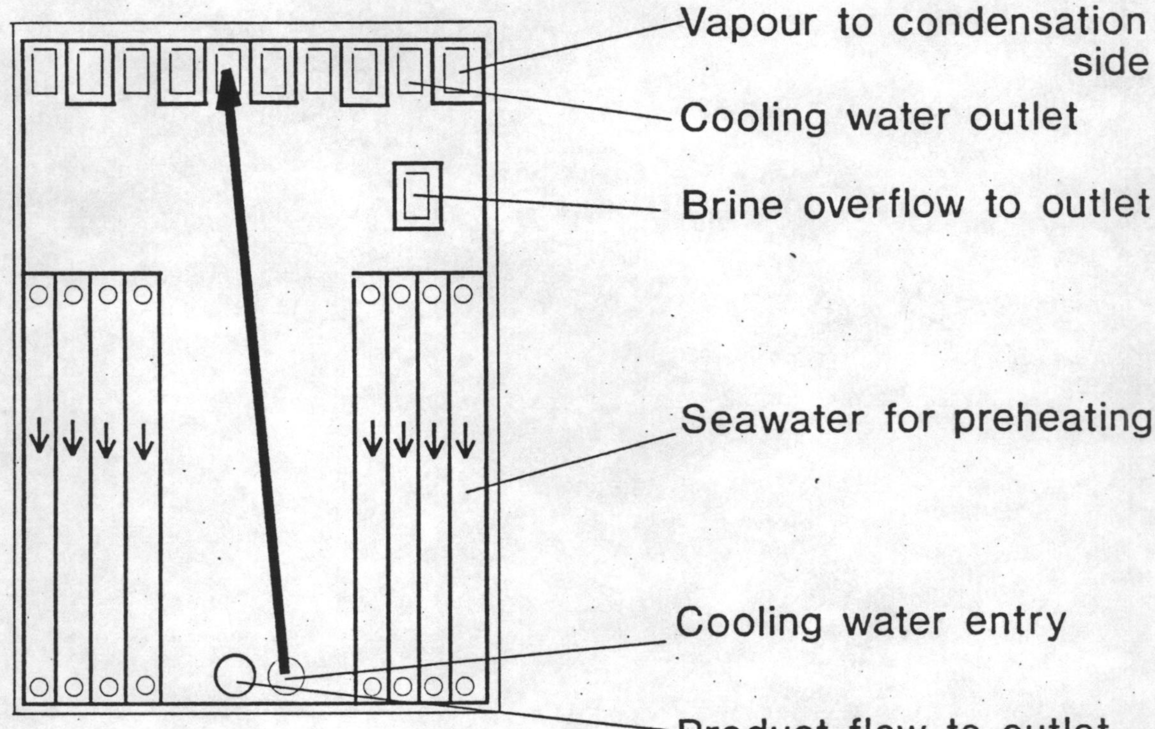


HEX plate design & packing, evaporator, evaporation side

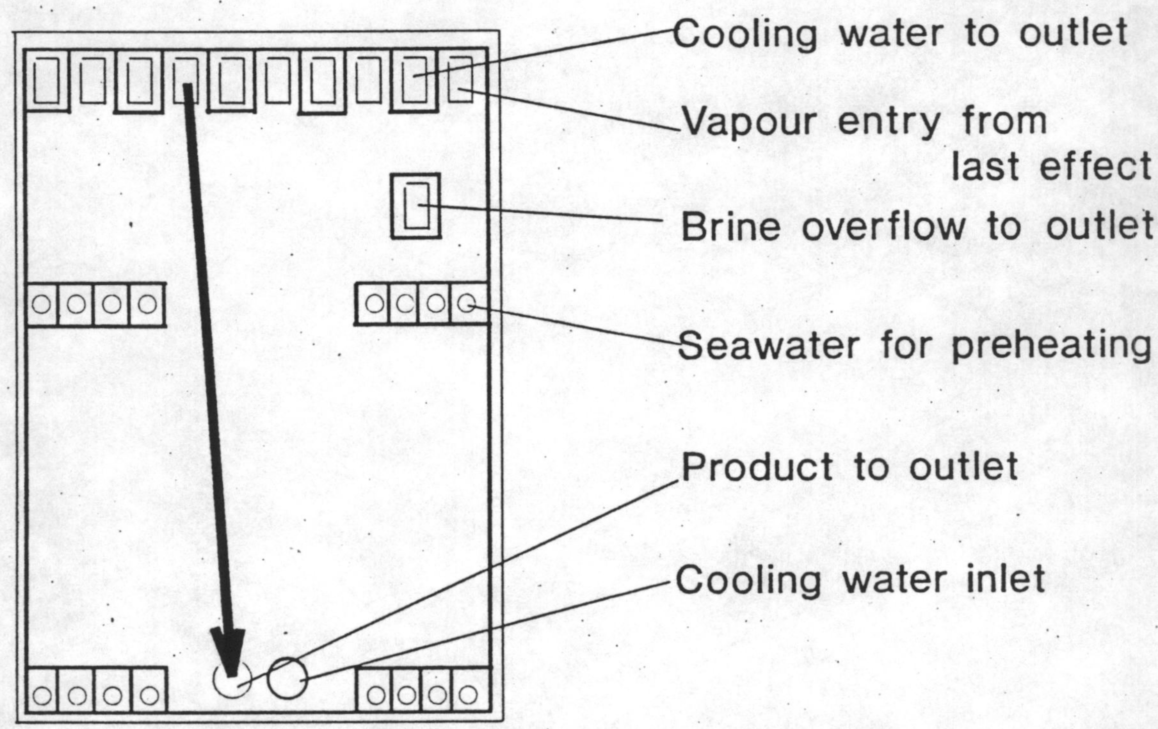


HEX plate design & packing, evaporator, condensation side

Fig 3.4

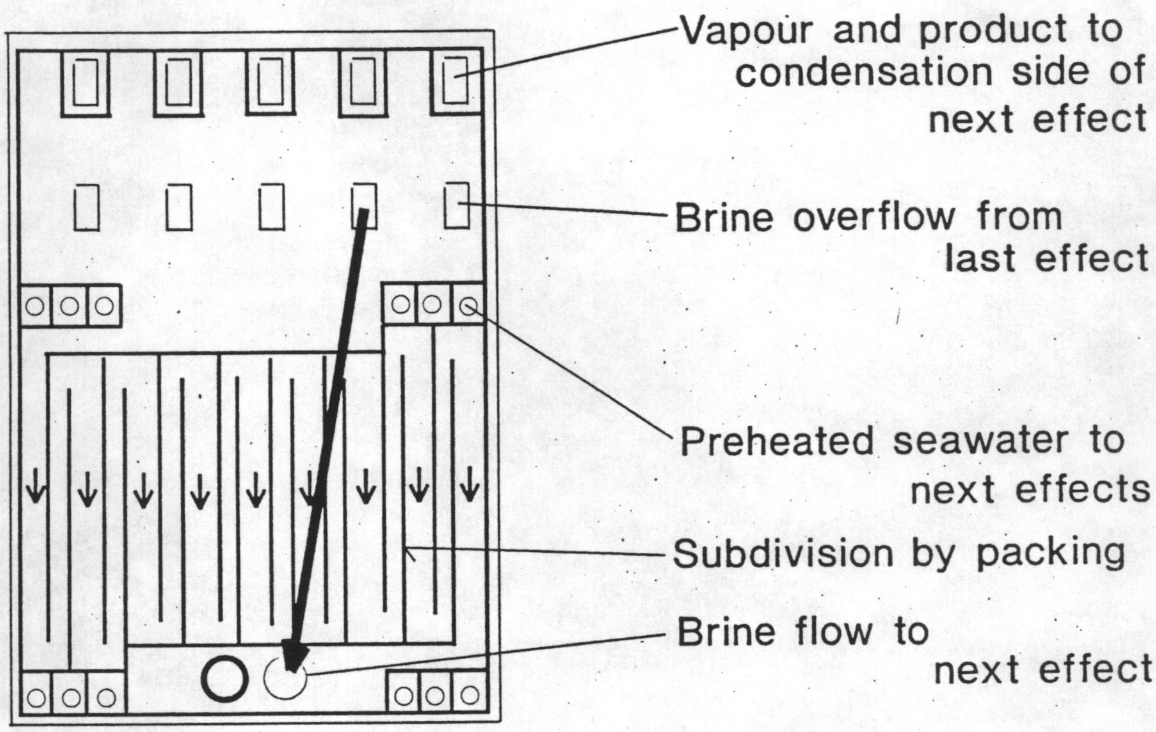


HEX plate design & packing, condenser,
cooling water side

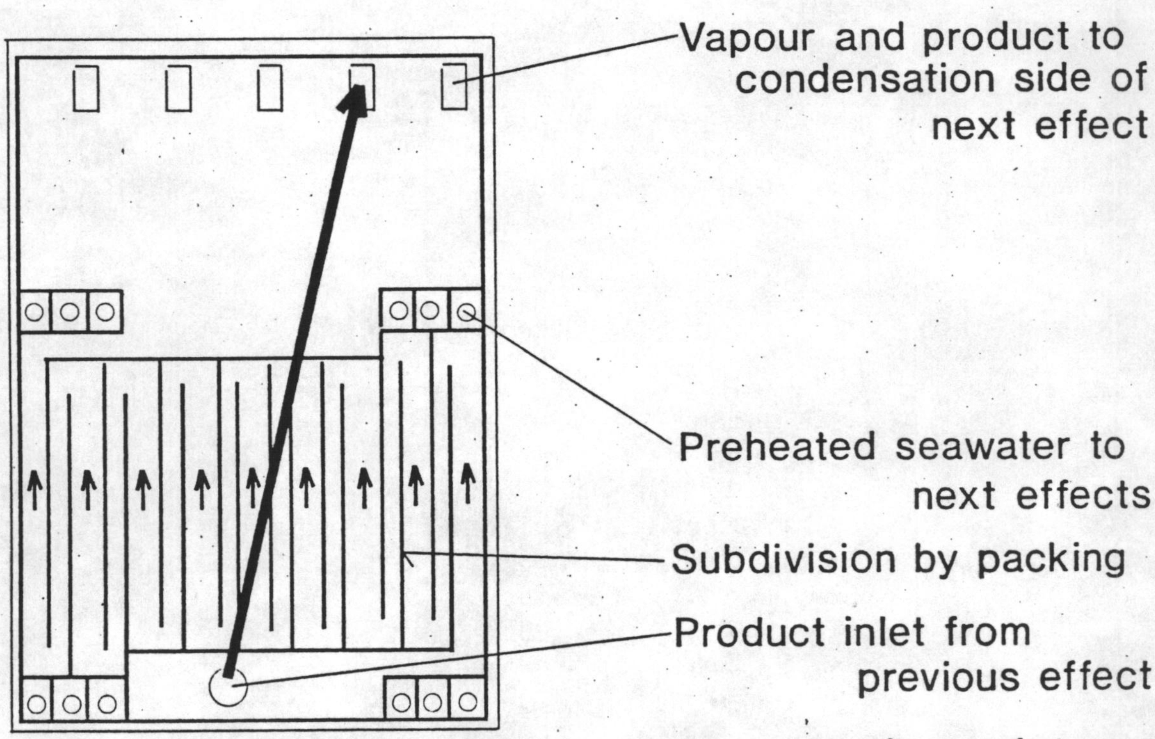


HEX plate design & packing, condenser,
condensation side

Fig 3.5



HEX plate design & packing, pressure drop plate, evaporation side



HEX plate design & packing, pressure drop plate, condensation side

Fig. 3.6