BE FAIR TO FLASH

BY

LIEUTENANT-COMMANDER J. E. T. MIDDLEDITCH, R.N., A.M.I.Mech.E., M.I.Mar.E.

Having tested ' flash ' distilling plants for over 10,000 hours and having gained the utmost confidence in their performance, it is felt that some attempt should be made to impart this sentiment to those who are interested in the subject.

This confidence has been built up over a period of time and can be attributed to the following features of operation :—

(a) Except for two occasions—accountable through abnormal conditions—the whole of this testing period has been with scale-free conditions in the heat exchangers. The two exceptions will be discussed at a later stage.

(*b*) For the majority of this period, the plants under test have operated in an exceptionally stable manner. Although not fitted with any control devices, they have run continuously for periods of three to four weeks without attention, and this includes any minor adjustment by a watch-keeper. There is little doubt that with simple control devices such plants could run without the necessity of a permanent watchkeeper.

(*c*) Every case of fall off in performance can be attributed to a failure of auxiliary equipment or materials. Except when such auxiliary defects have arisen, all other operation has been at full output for the conditions imposed for specific tests.

As the design of flash plants for naval purposes is still in its infancy, it is considered fair to say that the plants under test are in the nature of prototypes which are expected to produce numerous teething troubles. Bearing in mind that it is most unjust to form any opinion based on the performance of auxiliary equipment, which consists of a group of separate, though interrelated, subjects, it is quite remarkable that the basic flash operation has come through unscathed.

All testing has been carried out without chemical feed treatment.

Troubles Encountered During Running Experience

PLANT A

Symptom	*Cause*
Initial erratic flashing and high brine outlet temperature	Back pressure on air ejector condenser drain—due to being connected to heater drain
Heat loss in condensers and a big increase in heater steam input	Severe choking of 3 of the 4 stages of the condensers by sea weed
High brine outlet temperature	Final stage condenser flooded—erratic running of distillate pump Air ejectors dirty Air ejectors being used under incorrect steam pressure (the figure finally used was very different from the design figure)

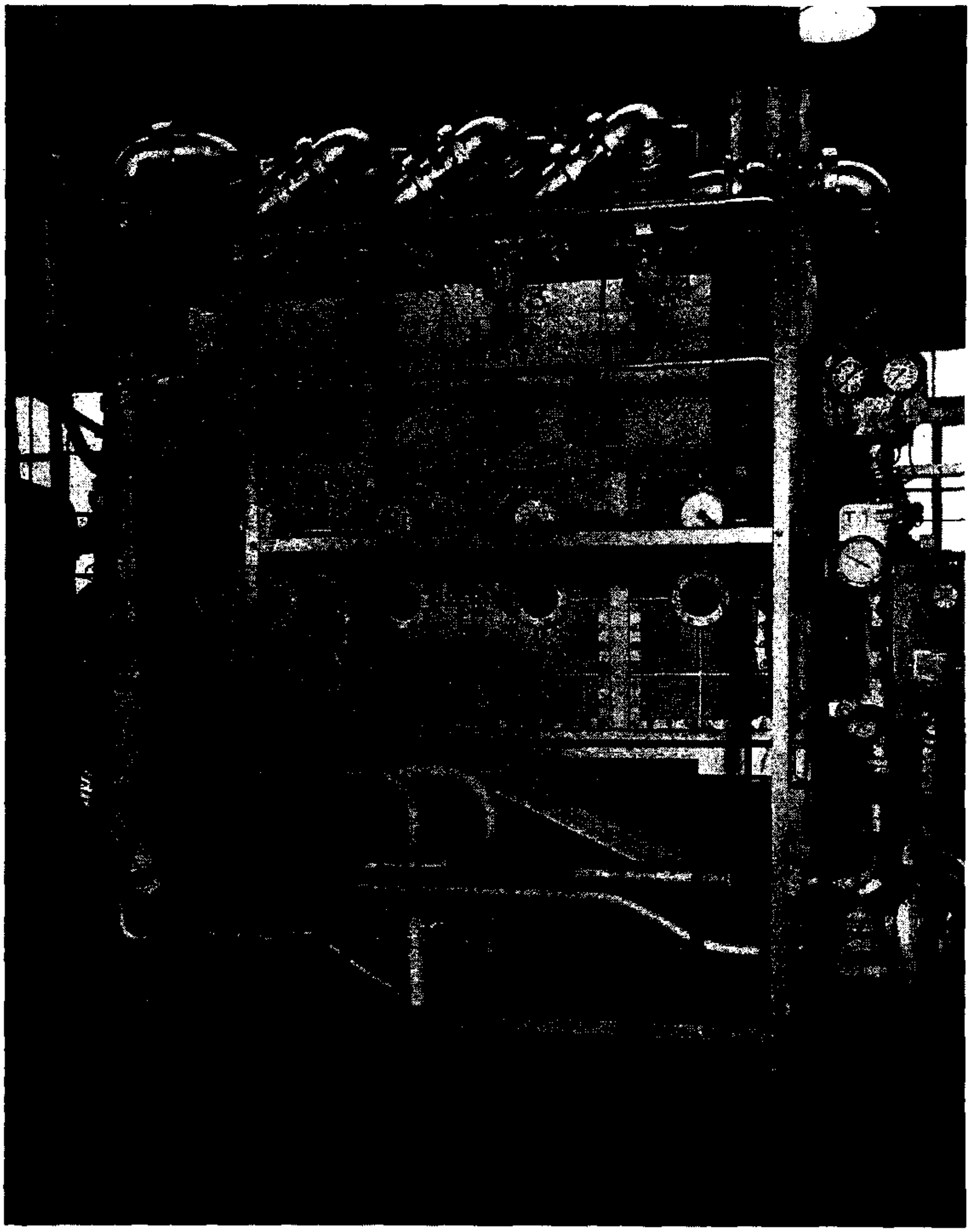

FIG. 1—BUCKLEY AND TAYLOR FLASH PLANT

High brine level (feed had to be reduced)	Gland packing of brine pump defective
Difficulty in maintaining feed rate	Accumulation of corrosion products in the final heater
High salinity	Final feed temperature too high and feed rate too low

It can be seen that most of these troubles can be easily overcome by establishing reliable auxiliaries. By fitting a mechanical seal to the brine pump, by eliminating erratic running of the distillate pump (an electrical defect on the motor), and by regular examination and adjustments of the air ejectors,

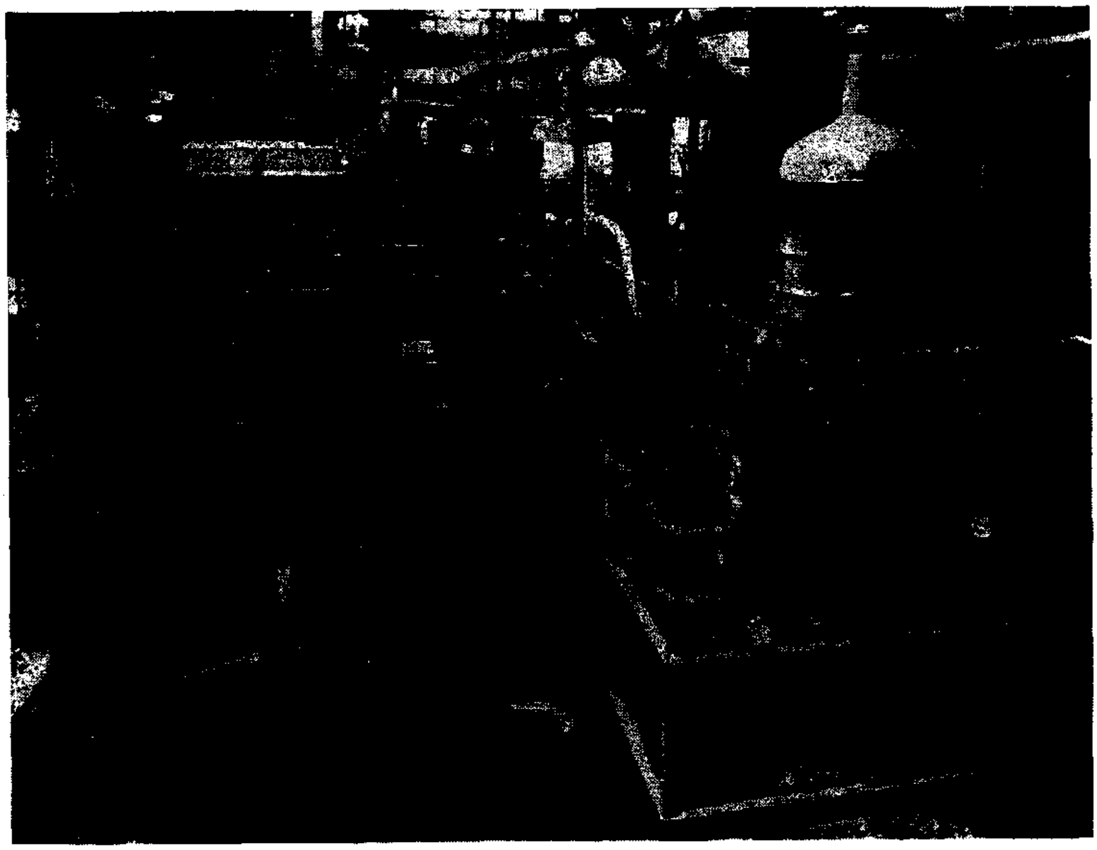

Fig. 2—Admiralty Distilling Experimental Station Test Shop

Left foreground—Aiton 24 ton/day Flash Plant
Right foreground—Caird and Rayner 10 ton/day Flash Plant
Left background—Boiler
Right background—Turbo Generator

the plant was run for many continuous hours. Runs were usually limited to about 1,500 hours due to the formation of corrosion products which tend to build up on the condenser and heater covers and, over a period of time, appear to harden up. Lumps then begin to break off and get stuck in tubes, particularly in the final heater.

These corrosion products were easily removed by washing through with a diluted inhibited HCl mixture, but are obviously undesirable. This points to the need for the use of non ferrous materials in the feed system.

PLANT B

Symptom	*Cause*
High brine outlet temperature and low output	Air pump extraction system faulty. Sealing water cooling arrangements inadequate

Modifications were made to the system and the plant was run for 2,000 hours without trouble. However, on examination of the heat exchanger heavy fouling by lumps of corrosion products was found.

On later runs this was found to cause a limitation on the feed rate. As this plant was being tested under constant heat input conditions, this resulted in a drop in output.

The feed system on this plant is also made of ferrous material.

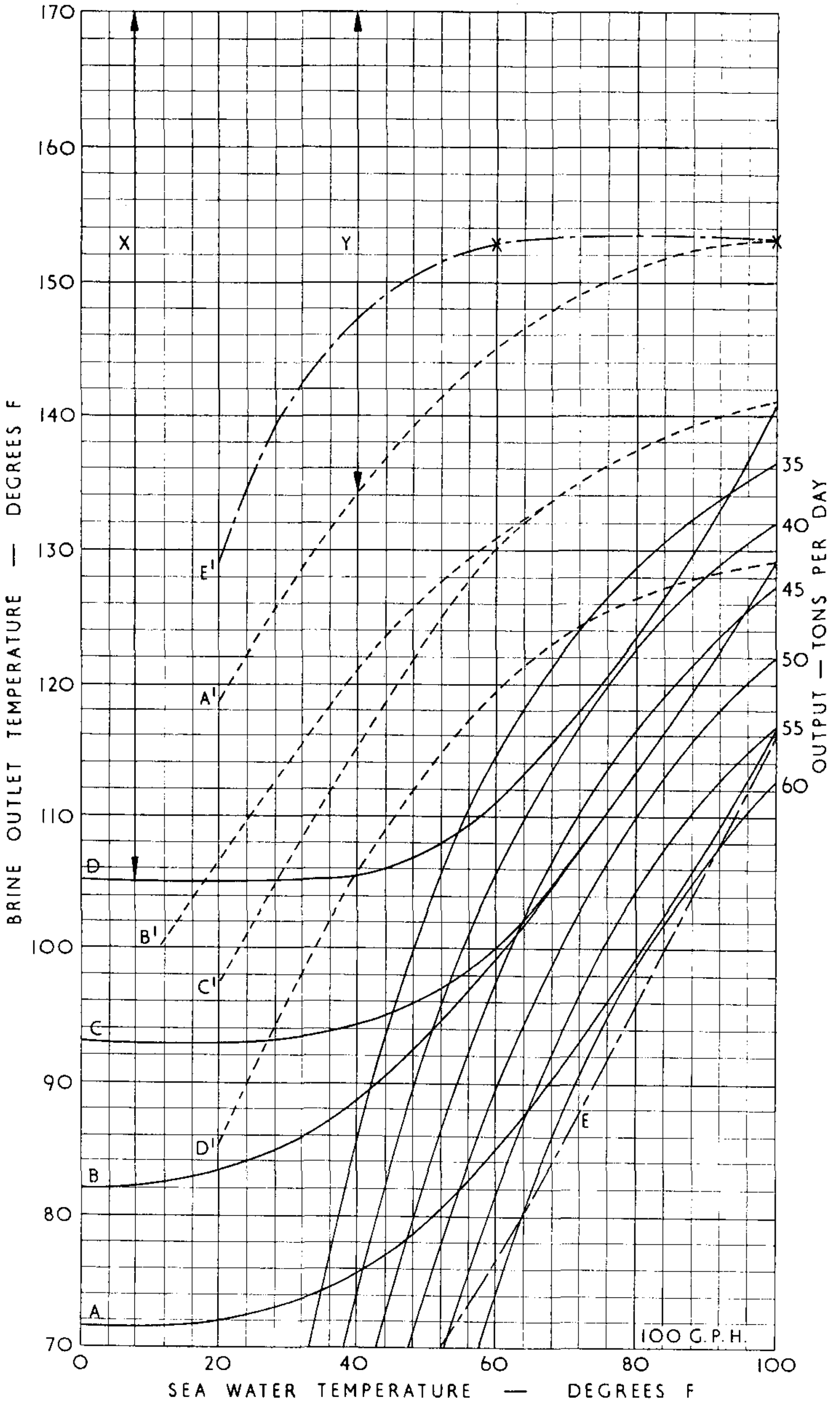

FIG. 3—CHARACTERISTIC CURVES FROM TEST RUN READINGS

PLANT C

Unfortunately, the distillate pump on this plant was of a rather close design which did not permit the extraction of any excess water when the output fluctuated upwards, nor was there any scope for a drop in performance of the pumps.

This plant was constructed with non ferrous materials throughout and has run for 2,000 hours without any significant drop in performance.

GENERAL ASPECTS OF FLASH PLANT OPERATION

The basic requirement for a distilling plant is an overall stability and this can be summarized by :

(*i*) Stability of output
(*ii*) Freedom from rapid scale formation.

Stability of Output

$$\text{Output} = \frac{\text{Throughput} \times \text{Flashing Range}}{\text{H}} \qquad \text{H} = 1025 \text{ (approx.)}$$

Hence, assuming a constant throughput for any given condition :

OUTPUT is directly proportional to FLASHING RANGE.

Now, by design, the final feed temperature is kept at a fixed figure and therefore the output is directly related to the lower end of the flashing range—i.e. the brine overboard temperature. This in turn is directly related to the vacuum condition of the final stage. It is therefore essential that design and operation must be focussed on this end of the plant.

Under varying sea water temperatures this vacuum will vary considerably but the design of the condensers and air extraction methods should endeavour to ensure the most favourable characteristic curve.

Reference is now made to FIG. 3.

A, B, C and D are characteristic curves showing brine outlet temperature (plotted vertically) against sea temperature. These curves were obtained from test run readings.

A, B and C are from separate plants.

D was obtained when a plant was operating under reduced efficiency, due to faulty air extraction.

X represents the flashing range, assuming a final feed of 170 degrees F.

Thus, assuming a constant given throughput, X represents output.

Output curves have been superimposed and by following the relevant curve, is indicated on the scale on the right vertical axis.

The wide variation in output from curves A, B, C and D is evident, likewise the expected variation of output with sea water of differing temperature can readily be assessed.

Curve E is regarded as an ideal curve at which to aim for design purposes.

The horizontal axis can also be used as a throughput scale, and can give the output under varying feed rates for any given flashing range.

Although these curves have been prepared without allowance for losses, and with certain assumed approximations, one universal chart has been used throughout all test runs to forecast results under varying conditions.

The expected curve for any plant—using design figures—can be plotted and this can regularly be compared with results actually being obtained. It will also immediately indicate where the likely cause lies for low output—i.e. low flashing range or low feed rate.

Scale Free Operation and Heat Transfer

Much has been written on this subject and it is not intended to add to this. However, the generally accepted theories are repeated here as there is little doubt that each has its application to flash plant operation :

(*a*) High heat flux promotes scale
(*b*) High temperature difference promotes scale
(*c*) Pressurization of water suppresses scale
(*d*) Heat transfer is reduced by a drop in water velocity
(*e*) Heat transfer is reduced by fouling or scale formation.

Of these, the indications have been that (*a*) and (*c*) are the most important, and every possible step should be taken to ensure that loading of the final heater is kept within certain limits. Obviously (*d*) and (*e*) will tend to affect this loading adversely, but plant operating conditions may do so far more.

The feed temp. out of stage 1 = sea temp. + flashing range
Final feed temp. — temp. out of stage 1 represents demand on heater.

Thus, referring back to FIG. 1, curves A′, B′, C′ and D′ represent the temperature out of stage 1 related to the sea temperature and brine outlet curves.

Y is a measure of the loading of the heater.

The difference in heater loading as indicated by curves A′ and D′ is quite remarkable. Taking a constant feed of sea water at 40 degrees F:

Heater demand from A′ = 36 degrees
Heater demand from D′ = 64·5 degrees
i.e. the loading is nearly doubled.

E′ is the curve obtained if a plant is operated on curve E. Besides having a reduced loading, there is a wide range (40 degrees) over which the heater loading is constant.

With reduction of sea water temperature from 100 degrees F, there is a steady improvement in vacuum (brine outlet — flashing range) which tends to counterbalance the heater demand required to deal with the colder water. However, once the sea water temperature is down to 50—55 degrees there is unlikely to be any improvement in vaccum, hence the heater demand is increased directly as the sea temperature is reduced. This will result in a rapid increase in the heater loading, and may well produce a heat flux condition in the heater which could produce rapid scale formation.

Under cold water conditions the output will increase. In order to partially reduce heater loading, feed rate can be cut, provided design output is still maintained. Further reduction would tend to cause impurities being carried over through the separators. It must be remembered that reduction in feed rate will produce a lower water velocity and hence a lower heat transfer coefficient, i.e. a tendency towards an increase in the heater load.

During over 10,000 hours' operation of flash plants, twice only has scale (about 0·01 in. thick) formed in the heat exchanger :

(*i*) When the condensers became choked with sea weed. The heater demand was considerably increased as feed did not pick up the usual heat from the condensers. Feed flow was low and the water in the heater was under 10 in. vacuum
(*ii*) During a special test the brine was recirculated and after 250 hours scale began to form due to increased density.

BE FAIR TO FLASH

The two groups of people who are concerned with a flash plant installation are :

(*a*) Purchaser/User
(*b*) Manufacturer/Designer

The Purchaser

The purchaser must first realize that there are certain limitations to the operation of flash plants.

The average plant is designed for the sea water condition of 75/85 degrees F, that is, the heater and condenser tube surface areas are calculated for this condition, with allowance made for a limited variation.

Various sea conditions affect the design of these two surfaces oppositely :

High sea temperature	—Smaller heater surface Larger condenser surface
Low sea temperature	—Larger heater surface Smaller condenser surface.

Hence it is evident that a compromise must be reached and at the same time the previous remarks on heater loading must be remembered.

The purchaser must therefore bear in mind these aspects and must study carefully the overall conditions under which the plant will be expected to operate, e.g.

What will be the average conditions?
What could be an expected extreme condition and for how long ?
Could a condition outside this extreme occur and if so to what extent ?

He must also remember that while it is nice to have a piece of equipment which will operate under any condition, it will be more than probable that its size would be out of all proportion to his average requirements.

With land installations it should be possible to specify a comparatively narrow range of conditions under which a plant would be expected to work —e.g. in the United Kingdom, sea water would vary from 40/45 up to 70 degrees F.

With marine installations, where variation could be considerable, it is even more important to give accurate specification. Many ships are designed for specific purposes, to operate in certain specified areas under conditions of limited variation. An ice breaker will operate in the cold. Likewise certain ships are designed for operation in the tropics. Larger passenger vessels tend to operate along fixed sea routes. To a lesser degree H.M. ships could be divided into categories.

It is suggested that in all cases the stress be laid upon the *average* condition and steps taken to deal with the extremes as separate items. The normal expected extreme of heat is automatically absorbed within the plant, which leaves the extreme cold. Such an extreme could be overcome by :

(*a*) Fitting an additional final heater for use when sea water temperature is below, say, 50 degrees F. This could also be used as a reserve heater to enable the other to be acid cleaned.
(*b*) Fitting a waste-heat feed preheater
(*c*) Brine recirculation with acid treatment to feed water
(*d*) The use of waste-heated water as feed to the plant—condenser discharges
(*e*) Dropping the final feed and reheating the distillate to 160 degrees F.

A flash distilling plant, working to its design figures, can produce a very steady output for very long periods without feed treatment.

With conventional coil plants there has always been a tendency, usually created by necessity, to run them at maximum or even over maximum design output. With a flash evaporator such treatment may have disastrous results, possibly leading to a very rapid decline in performance. Thus it is equally important to specify required output accurately.

In practice there will be a natural tendency for manufacturers to produce plants of a specified output. The purchaser should not indulge in false economy by obtaining the plant nearest, but below, his requirement, in order to save a few pounds.

Sea water, or rather feed water analysis should be undertaken in conjunction with the manufacturer for plants which will operate in fixed or limited areas.

A realistic figure for required purity must be specified.

The User

For ' flash ' to merit a name it so justly deserves, the user must respect the conditions under which a plant is run. Any deviation from a design characteristic curve must be tackled at once.

It is important to establish a figure for the heater loading at which scale may begin to form, and the rate of forming. Thereafter every step should be taken to ensure that such a loading is an absolute maximum.

As previously stated :

$$\text{Output} = \frac{\text{Throughput} \times \text{Flashing Range}}{\text{H}}$$

Therefore ensure this flashing range is correct. Are the thermometers reliable—check, recheck and yet again check and recheck.

To illustrate from figures from a 50 ton/day plant :

$$50 = \text{F} \times 70/\text{H} \quad \text{for flashing range of 70.}$$

Now assuming a flashing range of 65 :

$$\text{Output} = \frac{65}{70} \times 50\text{—or 93 per cent}$$

This represents about $\frac{3}{4}$ ton/day drop in output/degree drop in flashing range.

But, even worse, a 5-degree drop in flashing range will result in the heater having to heat the feed an extra 5 degrees. With a heater dealing with a 25-degree increase (an average figure) this added load represents 20 per cent. This in turn leads to a higher temperature difference between steam and water. The net result is a heater that could be in a ripe condition for producing scale.

An accurate knowledge of temperature range is essential ; hence the importance of the accuracy of thermometer readings cannot be stressed too much.

A correct thermometer will not rectify faults, but an incorrect thermometer can disguise defects, resulting in incorrect operation. Such defects could be :

Air leakage into plant chambers
Faulty air and non-condensible extraction
Faulty distillate extraction resulting in partially flooded condensers
Incorrect throughput.

The user must ensure that any condition which may promote scale formation is avoided.

The Manufacturer/Designer

There can be no doubt that the flash plant is a great improvement on the conventional coil type plant. However, many misleading results and reports are liable to be circulated, hinting at deficiencies in flash plant operation, whereas the fault is more likely to be in basic design, particularly with respect to auxiliaries or materials.

Bearing in mind that the primary requirements for marine use are stability in operation and of designed output without chemical feed treatment, and reduction in maintenance, designs should be put forward with these points in view.

It is the duty of the designer to ensure that a plant is of sufficient scope to be able to comfortably handle any normal fluctuations in services, and to operate under the specified variation range.

Special attention should be given to the auxiliaries.

Beware of cheap or ferrous materials, particularly in the feed system.

Instrumentation

The minimum number of thoroughly reliable instruments should be fitted, top priority being given to :

Measurement of flashing range, i.e. final feed temperature, brine outlet temperature
Distillate output
Final stage vacuum
Visual indication of distilled water level in final stage condenser
Automatic dumping arrangements.

General Suggestions

(*i*) Can condenser design and air extraction methods be improved to give a better plant characteristic curve.

(*ii*) Can any further steps be taken to reduce the likelihood of scale to be formed, e.g. heater design—water velocities.

(*iii*) There is evidently room for improvement in the use of materials. Has the use of plastics been explored.

(*iv*) Can auxiliary pumping arrangements be improved, with particular attention to air leakage through glands due to either spindle wear or defective packing.

(*v*) It is an accepted fact that scale will form in the 1st stage chamber. From experience it has been found that there is a tendency for the separator (demister) in this stage to become scaled. After a time this could affect the operation of the plant. Separators, particularly that in the first stage, should be easily removable for cleaning or renewal.

GENERAL SUMMARY

Purchaser

Present a fair specification of requirements.

Beware of false economy :

(*a*) Do not underestimate output requirements
(*b*) Do not indulge in the use of cheap materials.

User

Operate the plant fairly.

Do not force the plant—keep to design data.

Immediately investigate irregular readings, however slight, and in particular the brine outlet or final chamber temperature.

Check and recheck instruments regularly.

Manufacturer/Designer

Be fair to the User.

Do not skimp.

Ensure the best auxiliaries.

Study materials.

If necessary, forego some of the profit and reap reward by the results.

DEPARTMENTAL COMMENT

D.M.E. welcomes this timely article.

The variations of the performance of the designs shown in graphical form depend upon the basic design requirements of each unit. It is not true to say in every installation that the unit having the highest performance ratio (made water/heat supplied) is the most suitable. The performance is often reduced to effect a decrease in size or weight, or merely to provide a ' sink ' for excess exhaust steam.

The suggestion to use average conditions could not be reasonably implemented as the consumption of water varies widely between ships, also the period during which a ' tropical demand ' can be expected cannot be predicted. All H.M. ships must therefore be fitted with sufficient distilling capacity to enable them to operate anywhere indefinitely. Any reduction in the requirement can be obtained by reducing the number of running-hours. It is agreed that the plant must always be run at the designed output.

The suggestions to overcome the extreme cold conditions (p. 375 ~~401~~) are reasonable but it is considered undesirable to resort to acid feed treatment, nor has it been definitely established that partial recirculation requires such action. The densities likely to occur may vary between designs but in general all are below 15 degrees Admiralty. As far is possible, quick and simple methods of cleaning heat exchangers are designed into flash plants to avoid any possible necessity to use feed treatment.

The suggestion (*e*) is one method of ensuring sterility of the made water, but there are many other simpler alternatives which can be introduced, e.g. chlorination or activated silver.

In general, method (*a*) is preferable to all others.