WATER FOR WARSHIPS

BY

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' The supply of good wholesome water to our gallant army in the Crimea and Fleet in the Black Sea is causing great anxiety to our Government .... A vessel is now in course of being fitted out at Portsmouth with a patent apparatus, by which a sufficiency of good, wholesome water can be distilled in the course of 24 hours to supply from 30,000 to 40,000 men.'

(Extract from *The Despatch* June 17th, 1855).

The author has no details of this plant but doubts whether it provided a domestic water allowance of 30 gallons per man per day, which is the present aim.

THE REQUIREMENT

The provision of an adequate supply of domestic and boiler water in warships has been a problem that has continued to the present day. This article is an attempt to arrive at the reasons why the problem is so difficult and to show how the Engineer-in-Chief's Department and plant manufacturers are now trying to cope with it.

After the 1939–45 war, when a number of new warships were coming into service, it became evident that, although the distilling capacity provided in these ships was greater than ever before, it was still inadequate under tropical conditions without resorting to some degree of rationing. A small working party was set up consisting of representatives of D.N.C. and E.-in-C. under the chairmanship of D.N.E. The panel's task was to examine all aspects of the water problem in warships, including distilling equipment, water storage, design of water-using equipment, and the layout of water systems. The panel was empowered to co-opt additional members from the Admiralty departments, where necessary, to do any field investigations. On completion of their deliberations, the panel was to report and make concrete proposals.

The findings and recommendations of the panel are at present under consideration by the Board of Admiralty, and it would therefore be improper to include them in this article. However, the investigations brought to light a number of practices in both the design of distilling plants and design of water systems, which could be improved without needing a major change in Admiralty policy. For example, the replacement of existing spur systems for hot water by a ring main in which the water is kept circulating, would avoid the necessity for running off several gallons of cold water, before the hot becomes available and would effect a considerable reduction of waste. By avoiding excessive pressures low down in the ship, and starvation higher up, there would obviously be better distribution and probably a saving in consumption.

So far as the distilling machinery itself was concerned, it became increasingly evident, quite apart from any findings of the Fresh Water Panel, that a new look was necessary. Higher capacity, greater reliability, a degree of automatic operation and a reduction of the maintenance task was needed but, at the same time, there was a premium on space, weight and fuel consumption in all ships.

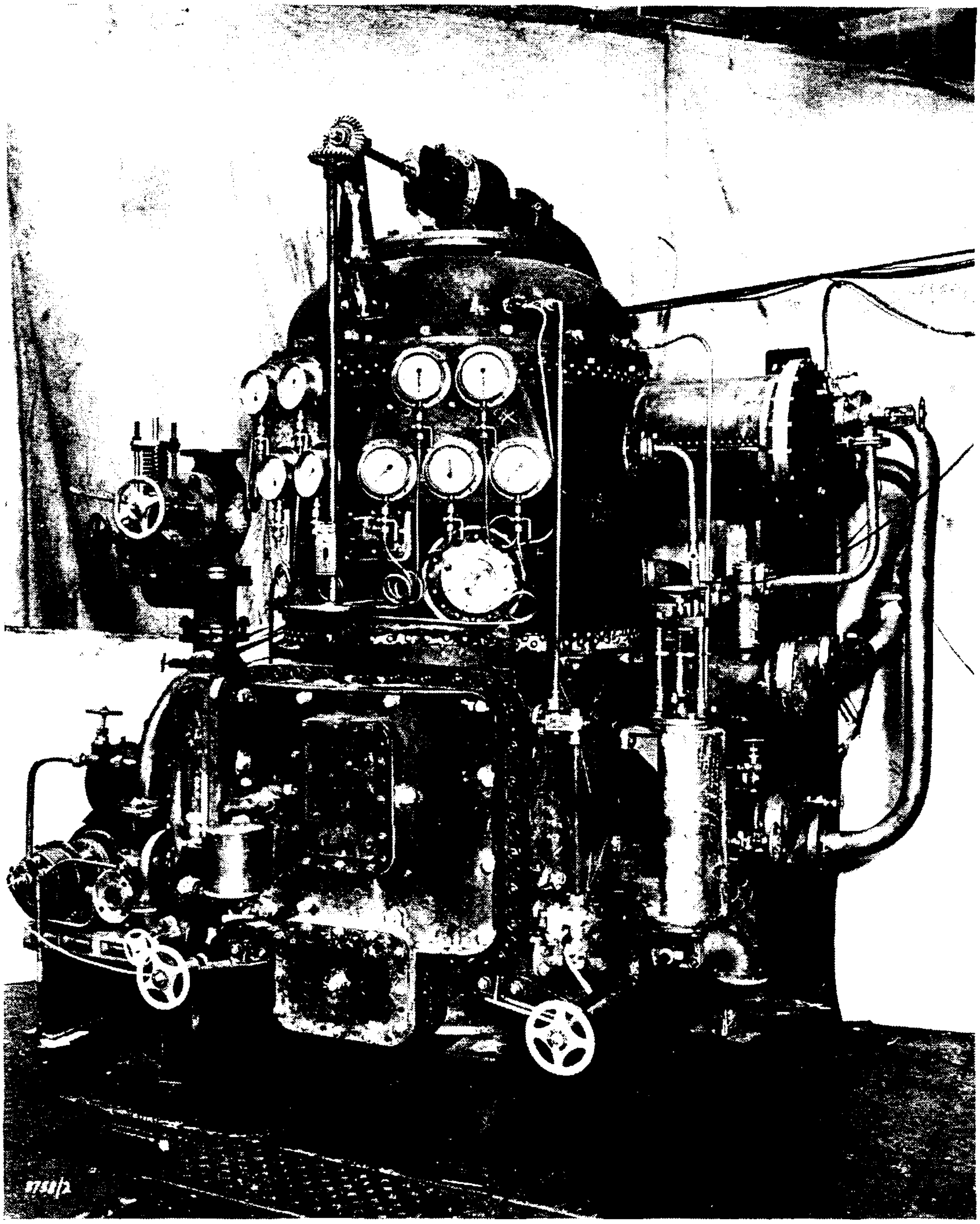

FIG. 1—LOW PRESSURE EVAPORATOR

PRE-WAR DISTILLING PLANTS

Most engineer officers know something about the pre-war big ship distilling plant. It usually consisted of two shells capable of being operated in compound or single effect, on boiler steam from the reduced saturated range or on closed exhaust. It was provided with a vertical motor or turbo-driven combined pump in which the circulating and feed pump, the brine pump, fresh water pump and in some cases the air pump were all mounted on the same shaft. To say the least, it was a difficult pump to maintain and was prone to erosion troubles. The majority of these plants have now been converted to single effect running only, with a view to obtaining maximum output per plant, and the use of boiler steam is now almost universal because of the difficulty of obtaining a steady pressure from the exhaust range. When this type of plant was first installed it was necessary to remove the coils for descaling, at approximately 500-hour intervals, though the brine system often needed descaling more frequently.

In small ships, single shell plants were universal and, although they were fitted for closed exhaust operation, most ships preferred boiler steam for the same reason as big ships.

After the war a great effort was made to put into practice the lessons learned during wartime operation of distilling plants. The problem of scale formation was tackled in conjunction with the Admiralty Materials Laboratory and eventually Admiralty Evaporator Compound was introduced. After overcoming the initial difficulties with injection equipment, it became possible to run distilling plants for 3,000–4,000 hours between removal of coils for descaling. Orifice control was provided in some plants to give a measure of automatic compensation for scaling, to provide a more stable steam condition, and to reduce the need for frequent adjustment by the watchkeeper.

CURRENT DESIGNS

When it became necessary to work out a design of plant for the A/S frigates, it was decided to try to incorporate all the lessons learned into the new plant but, at the same time, to try to reduce the weight. (FIG. I.)

The plant was to be a single-shell type, designed for full output on a reduced range pressure from a deaerator with orifice control. With a controlled range pressure of 9 lb/sq in gauge, to obtain the necessary critical drop through the orifice, meant that the steam pressure at entry was slightly sub-atmospheric. To obtain the required heat transfer rate from the coils with this very low pressure, it was necessary greatly to increase the coil area. This, of course, partially off-set weight and space saving elsewhere in the plant and, in addition, it was necessary to provide a coil drain pump. The usual ball float type of feed regulator was omitted and in its place an adjustable overflow weir was fitted to control the brine level. Brine density was controlled by adjusting the rate of feed inlet as opposed to the brine extraction. A modified design of baffle was fitted which enabled the overall height of the plant to be reduced and this lessened the tendency to prime under unstable conditions. The combined pump, as we know it, was abolished and in its place three motors mounted in a delta arrangement drove separate pumps. By this arrangement it was possible to drive two pumps, one from each end of the motors, each pump being relatively small and easily removed for refit or replacement. The normal injection equipment for evaporator compound was provided.

Very satisfactory results are being obtained from the first of these plants which is now in service.

THE FUTURE

About the time when the first A/S frigates were running shop trials, it became obvious that the increased distilling capacity, which would be required in future big ships and, to a lesser degree, in small ships, carried a very large weight, space and (where boiler steam was used) endurance penalty.

A normal single effect distilling plant, running on boiler steam with 20 in vacuum in the shell and a brine density of 20° Admiralty, will produce approximately 9 tons of water per ton of fuel. A normal compounded plant will produce about 15 tons of water per ton of fuel. If such plants can be run on exhaust steam the cost of producing the water is negligible. The introduction of satisfactory methods of controlling exhaust range pressures has made it possible to utilize all surplus exhaust steam in the evaporators but, as the demand is now, under certain steaming conditions, in excess of supply, it is necessary to maintain the pressure in the exhaust range by topping up from a source of live steam. It is an absolute requirement, therefore, that evaporating plants of new design shall be capable of economical running without introducing a difficult watchkeeping and maintenance problem. What would such a plant look like ?

DEVELOPING A 'NEW LOOK' DISTILLING PLANT

The main difficulties with distilling plants in the past have arisen from :—

Unsteady steam conditions
Scaling of the coils
Internal fittings, especially feed regulators
Brine systems.

Unsteady Steam Conditions

The difficulty of maintaining a steady pressure in the closed exhaust range led to the almost universal use of boiler steam, usually taken from the reduced or so called saturated range. This steam was throttled through a coil-steam valve to the pressure required by the coils to give the necessary output. As the coils scaled up, and output tended to fall off, coil pressure was increased until scaling was so severe that the output became unacceptably low and descaling was necessary.

Orifice control of coil steam was introduced to permit a degree of automatic control, the metering action of the orifice permitting steam to enter the coils at a fixed rate, irrespective of the degree of scaling. Provided the available heat transfer surface, in the scaled condition, was sufficient to maintain the coil pressure below the critical drop for the orifice, the output remained constant and the watchkeeper was relieved of the need to be constantly adjusting the steam and coil drain valves while running and after each routine blow down.

Scale Formation

It is only comparatively recently that a detailed theoretical and practical investigation has been made into the chemistry and mechanics of scale formation in evaporators. In this country, great progress has been made by the Admiralty Material Laboratory and by Messrs. G. and J. Weir's research team. There is still, however, a long way to go before the problems will be fully understood. Generalizations are dangerous, but it may be said that, so far as Naval distilling plants are concerned, the formation of scale follows the following lines :—

Calcium Carbonate—The major constituent of the scale (90 per cent or over) when brine temperature is below 170°F.

Magnesium Hydroxide—The major constituent (90 per cent or over) when brine temperature is above 190°F.

Calcium Carbonate—Magnesium Hydroxide Mixture—Between brine temperatures of 170°F. and 190°F. with more carbonate at the lower temperatures and more hydroxide at the higher.

Calcium Sulphate—Forms at the expense of hydroxide at brine temperatures above 190°F. when there is a high temperature difference between the coil steam and the brine. It is also formed at lower brine temperatures when the brine is kept in contact with the coils for a long time, i.e. at high brine densities (above 25°) or in stagnant pockets of brine.

It must be emphasised that many quite local effects can, and do, upset these rules. For example, calcium carbonate may remain the major constituent when brine temperatures are above 170°F. if the brine density is reduced below 20°. Each of the three types of scale have different physical and chemical characteristics and treatment suitable to combat one will not necessarily be suitable for the others.

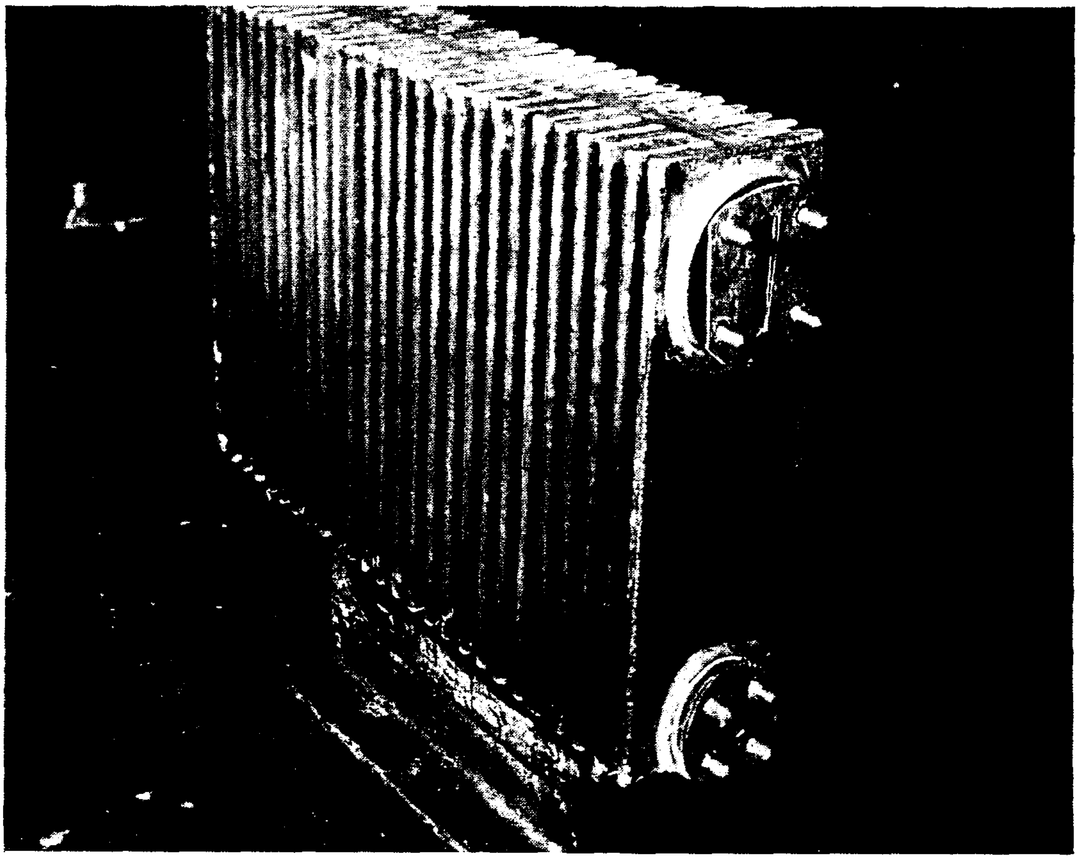

Fig. 2—Construction of Heating Element. This is a Prototype Model for Trials. In the Production Model, Steam and Drain Connections are on a Door, integral with the Element

By providing a very much greater coil area than was needed for clean coil operation and introducing Admiralty evaporator compound, it was found that, after about 500 hours running, the evaporator settled down to an almost constant output, the rate of build up being balanced by the rate of cracking off, the latter being considerably increased by the use of the compound. To achieve this state of affairs and to maintain a reasonable output, however, the coil area had to be increased to about three times that required for clean coil conditions.

Although orifice control and evaporator compound have proved their worth, it was felt that something better could be achieved. The nigger in the woodpile was undoubtedly scale. If the formation could be completely prevented, or if a plant which disposed of the scale as it is formed could be devised, then an important battle would be won. Coupling this with a steady steam supply, an almost automatic and relatively trouble free plant would be obtained.

In a normal Service type compound distilling plant, with a low pressure (temperature around 220°F.) in the first effect and a 20 in vacuum (temperature 160°F.) in the second effect, parallel feeding and brine densities of 20° Admiralty, one would expect to find mostly magnesium hydroxide scale in the first effect and calcium carbonate scale in the second. Magnesium hydroxide scale is the more difficult to deal with, for it is more adherent and harder than calcium carbonate ; hence one reason for running single effect plants with 20 in vacuum in the shell, the corresponding temperature being sufficiently high for sterilization, but low enough for the scale to be in the calcium carbonate range.

The most difficult scale of all to deal with is calcium sulphate, for it is not acid soluble and is extremely difficult to crack off. This scale forms round the coils at the steam inlet ends where the temperature difference between coil steam and brine is high, or when the brine is held in contact with the heating element for a long time, a condition which occurs when the brine density is high. In Naval plants a brine density of 25° is the top limit before calcium sulphate becomes troublesome, while reducing the brine density below 20° Admiralty, is more likely to increase the rate of formation of the other two scales rather than to decrease them, since a lower density means more feed and, therefore, more scale-producing salts entering the evaporator.

Acid Treatment

Scale can virtually be prevented by injecting comparatively small quantities of acid into the feed. If the brine is only slightly acid, the scale-forming salts which give most trouble will be brought out of solution before reaching the coils and be discharged overboard with the brine. Ferric chloride is being used for this purpose very successfully in some merchant liners and in a number of shore installations. It is either injected into the feed as a solution in the same way as evaporator compound, or it can be produced electrolytically in a cell in the feed line to the shell. Unfortunately, ferric chloride is difficult to handle, requiring special containers for storing and special alloy equipment for injecting. It is not the present intention, therefore, to introduce acid injection in the Service for normal steam evaporators.

The second alternative for disposing of the scale as it is formed has been pursued vigorously and a number of successful trials have been completed with a scale-shedding heating element fitted in place of coils.

Flexing Heating Element

FIG. 2 shows a typical element. It is constructed of 18–20 gauge monel metal plate and is designed to operate with a steam pressure of up to 10 lb/sq in and a shell vacuum of 20 inches, although the smaller the pressure difference between the inside and outside of the element, the more efficient the scale shedding is likely to be. Steam is led into the top of the element and the drain is at the bottom. To describe it as a flexing heating element is somewhat misleading as one gets the impression that the element behaves like a concertina, whereas, in fact, it is a fairly rigid structure. The shedding of the scale is probably due to a combination of local panting of the flat side of the fins, caused by the formation and collapse of bubbles of steam when comparatively cold brine comes into contact with the hot surface, and the rapid change of temperature at the element surface. It will be appreciated that, as the pressure difference between the inside and outside of the element increases, the flat sides will become more rigid and resist the effort to flex them. Trials have demonstrated that the element will tend to shed its scale when the thickness has built up to as little as 0·015 to 0·020 inches. As the rate of scale build-up varies in different parts of the element, there is always a considerable area of clean surface available. Although scale shedding is continuous, it is as well to carry out the usual blowing down routine every four or five days. Present indications are that this element, without using evaporator compound, will give an equivalent heat transfer rate greater than twice that obtained with orthodox coils using compound, and that this higher heat transfer rate will be maintained over a more or less indefinite period.

With the new element, the need for orifice control of steam is to a large extent removed because, provided the element can be supplied with steam at constant pressure, the heat transfer rate remains substantially constant and, therefore, the element drain valve need only be very infrequently adjusted.

Trials on the flexing heating element showed that it was equally efficient in dealing with calcium carbonate or magnesium hydroxide scales. Calcium

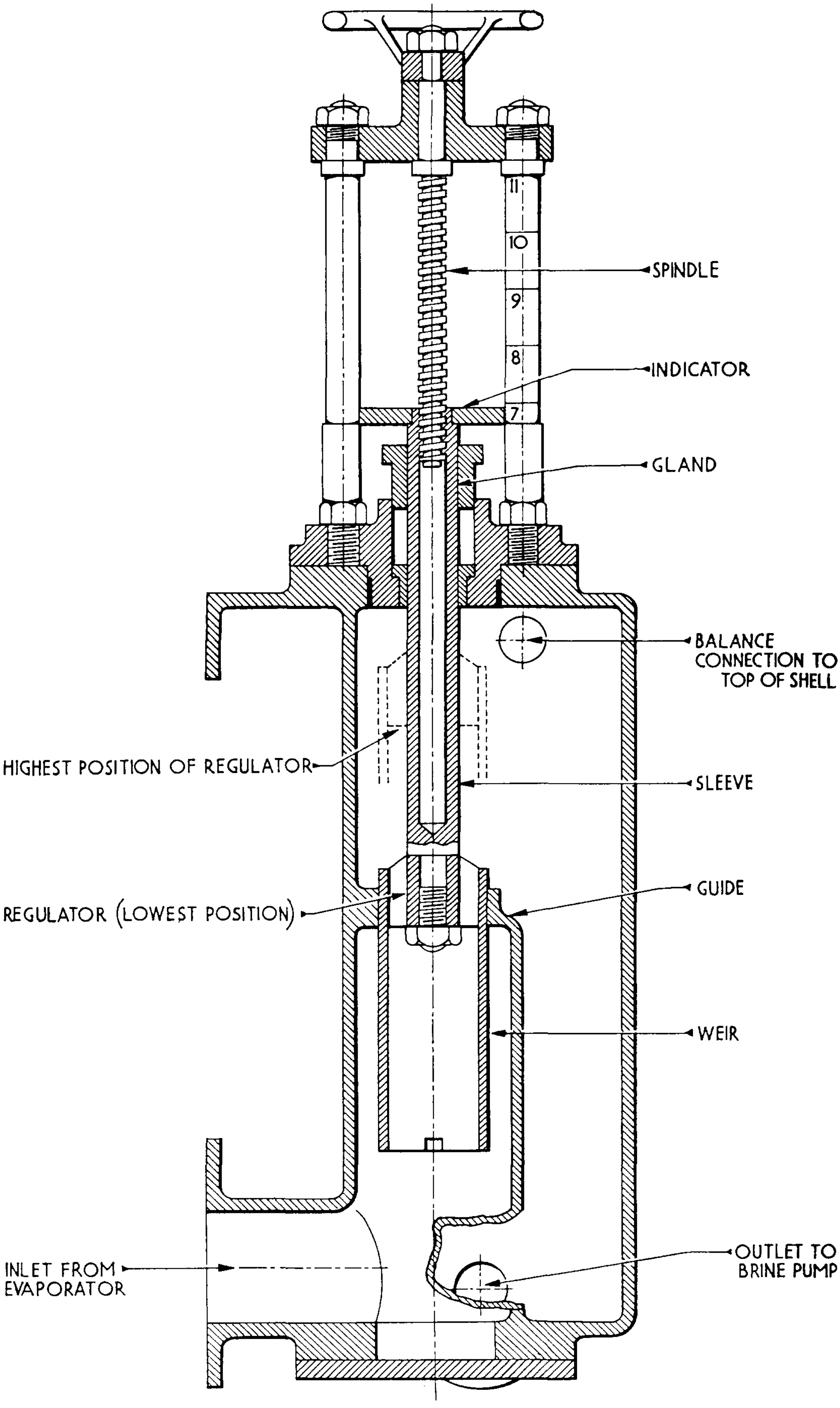

FIG. 3—EXTERNAL OVERFLOW WEIR

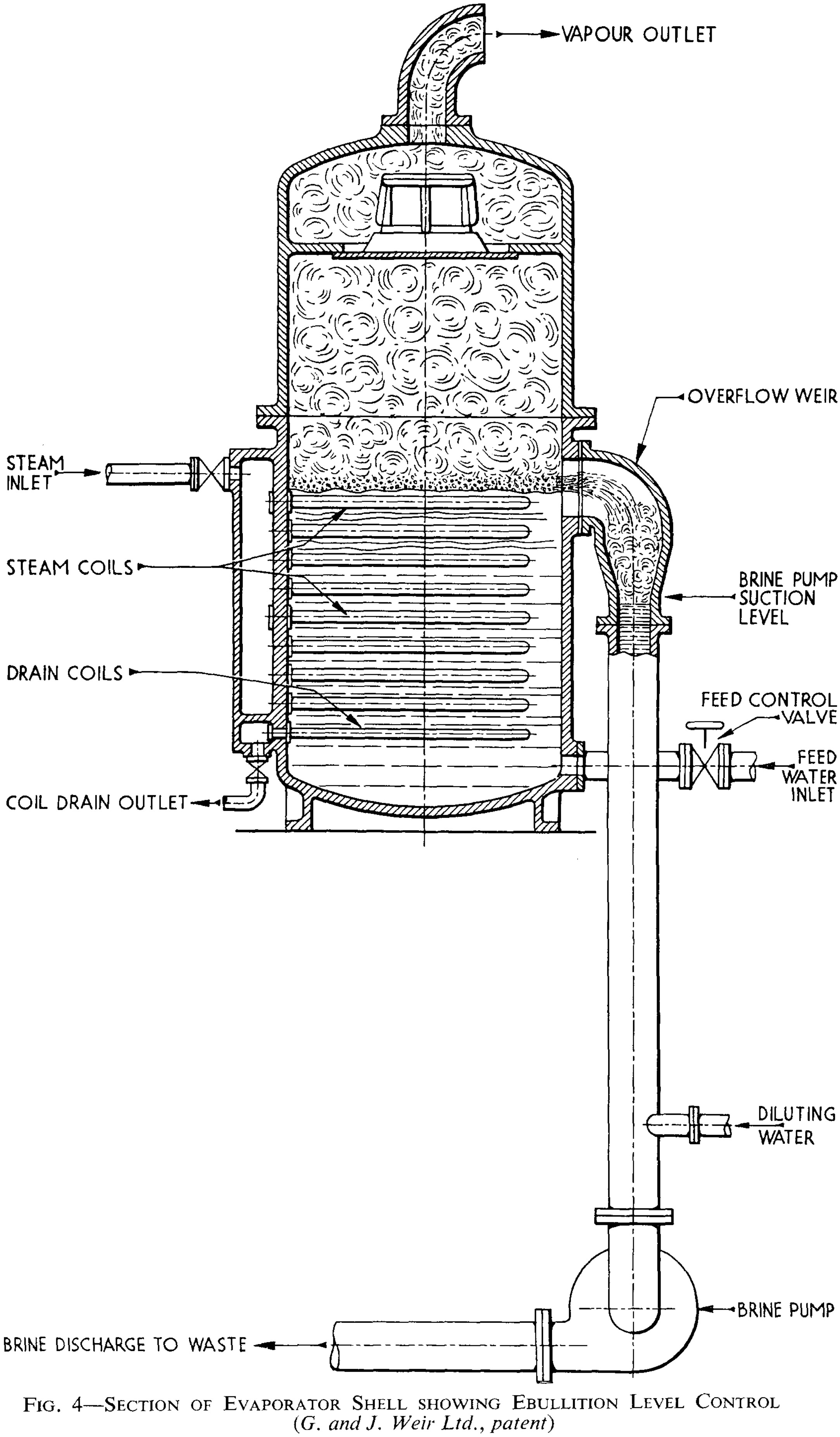

FIG. 4—SECTION OF EVAPORATOR SHELL SHOWING EBULLITION LEVEL CONTROL
(*G. and J. Weir Ltd., patent*)

sulphate will be avoided by ensuring a fairly low steam temperature and the correct brine density.

BRINE SYSTEMS

The flexing heating element should overcome its own scale problem, but there remains the difficulty of scale in the brine system, both that deposited on the surface of the pipes and, more important, the loose scale from the coils or heating element. The external overflow weir fitted to the new frigate plants (FIG. 3) is an improvement on the normal float controller on the feed inlet, and is simpler and less erratic in operation. If it were used in conjunction with the flexing heating element, however, the large quantity of scale being shed continuously would almost certainly choke the weir inlet, which is led from the bottom of the shell. Brine has always in the past been taken from the bottom of the shell, on the assumption that brine density was higher at the bottom. In actual fact the density of the brine varies very little throughout its mass. A new weir has been developed and tried in service. It consists of what amounts to a reversed ' letterbox ' fitted on the side of the shell at the brine level. (See FIG. 4). The brine merely tumbles over the weir into the suction side of the brine pump, diluting water being provided between the weir and the pump. The weir is not adjustable for height, but, as it is fixed at the ebullition level, the actual amount of brine in the shell will vary with the forcing rate. At high forcing rates the ebullition level remains fixed, but as the ' denseness ' of the brine will be less, the level, as measured by an external gauge glass, would fall. The effect is, therefore similar to that obtained with an external feed regulator except that, in the case of the weir, the reaction to a change in forcing rate is quicker and the risk of priming less.

Materials

One of the aims of the new look plant is lightness in weight combined with a small block size. In the past, plants have been composed of a riveted and sweated sheet-brass shell with a cast gunmetal door, a cast dome and shell base, and the distiller and other heat exchangers have been of similar construction. The most logical step would be to make the whole plant of welded non-ferrous materials. In America, where monel metal is readily available at reasonable cost, extensive use is made of this material in the manufacture of evaporating plants. Monel metal can be easily fabricated but, in this country, is too expensive for general use. The two obvious alternatives are welded copper and welded R.N.B. sheet, the choice depending upon the ability to obtain a mechanically sound weld and upon the ability of the welding material to stand up to immersion in hot brine and sea water without corrosion. Unfortunately, some of the most satisfactory welding rods, from the mechanical strength point of view, produce a weld which is attacked in preference to the parent metal. Before a choice of material can be made, it is necessary, therefore, to try out a number of different welds under service conditions.

Economy—Compound or Single Effect ?

In the past, most engineer officers have been highly suspicious of compound operation, mainly because they could get a higher output from single effect operation, but also because operation in compound required greater skill on the part of the watchkeeper. Nevertheless, compound operation is more economical. A single effect plant will give an output of one pound of made water per pound of coil steam (approximately) whereas, by compounding, 1·7 pounds of made water per pound of steam can be obtained. Even when exhaust steam is used this is an important consideration, because, in future ships, there is unlikely to be sufficient spare exhaust to run all the distilling plants together in single effect

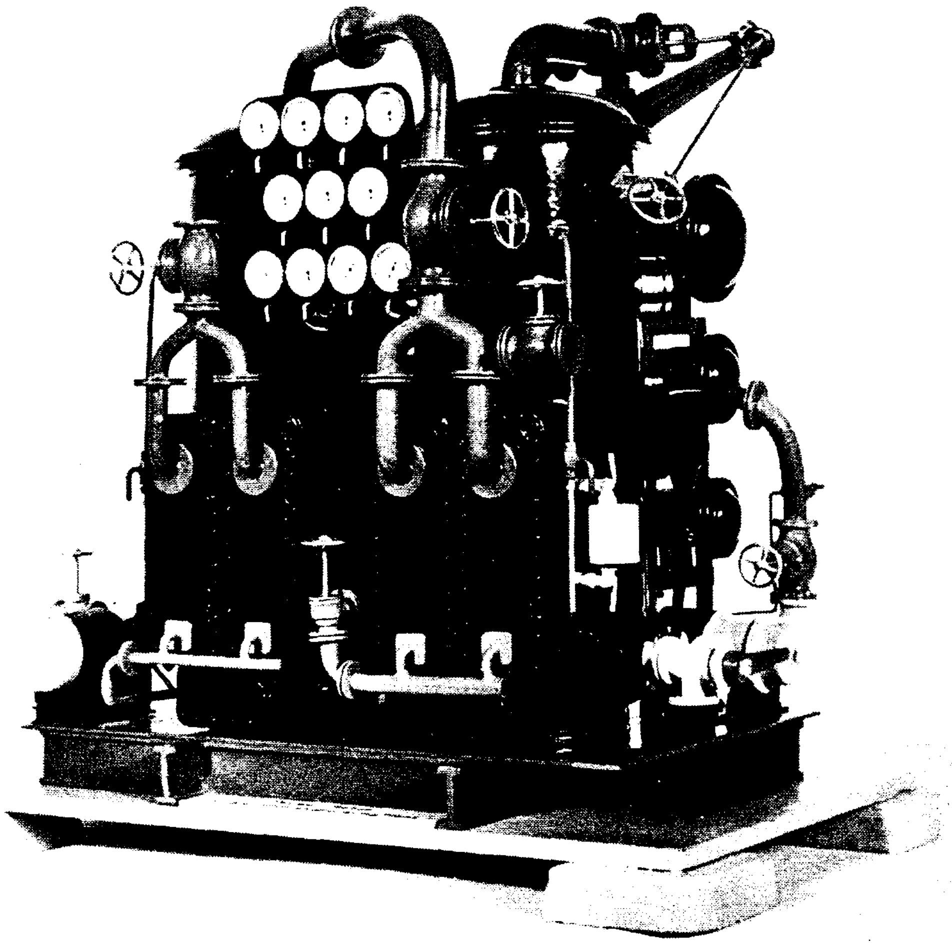

FIG. 5—MODEL OF PROTOTYPE DOUBLE EFFECT DISTILLING PLANT

operation. Even if compounded plants are fitted it will, of course, be necessary to provide some method of supplementing the supply of exhaust steam during manœuvring, when the demand by the feed heaters fluctuates rapidly.

A two shell plant designed for compound operation need not be very much larger than that designed for single effect. A small increase is, however, inevitable because both shells will be operating with a smaller temperature difference between the heating element and the brine, and the elements will therefore need to be larger to give the required vapour release from each shell. On the other hand, the distiller can be made smaller in a compound plant, because it is only dealing with the vapour from one shell. It is essential, however, if the advantages of compound working are to be achieved without an increase in weight and space, that the plant should be designed for compound working only, and not for both compound and single effect.

So far as single shell plants fitted in small ships are concerned, if these are replaced by two shell plants, either with completely separate shells or both shells combined in a single casing, there is bound to be some increase in size. This increase should be very small and can be more than compensated for, in comparison with old designs, by adopting fabricated construction and design improvements.

THE 'NEW LOOK' DISTILLING PLANT

What has already been said, and a great deal more which would be of only limited interest to the reader, has led to a 'new look' in distilling plants.

Details of the New Plant

The prototype plant (FIG. 5) is now installed at the Admiralty Distilling Experimental Station, Portland, for extended trials, run as nearly as possible in the seagoing condition. It is designed for a continuous output of 25 tons per day, similar to the frigate plant. It is expected that trials will show that it is, in fact, underrated.

The plant is designed for compound working only, the heating element pressure on the first effect of 10 lb/sq in gauge being obtained from the exhaust range, which will be maintained at a constant pressure of 10 lb/sq in $\pm$ 1 by a system which bleeds off excessive pressure to the main condenser and supplements from a suitable source when insufficient exhaust is available. The first effect shell pressure will be 11 lb/sq in absolute (8 inches vacuum) and the second effect shell will operate at 20 inches vacuum. The prototype is designed for either series or parallel brining, although the production models, for the sake of simplicity, will probably be provided with series brining only, thus concentrating most of the scale in the first effect. Two flexing heating elements are fitted in each shell and are attached to the two doors, and rest on runners for easy removal. The fact that the steam and drain leads have to be disconnected to withdraw the elements is considered acceptable, as the operation should be necessary at very infrequent intervals. It is intended to change the angle of the flanges to simplify breaking and making of these joints. Each shell is provided with the fixed overflow weir which has already been tried out at sea. The baffles have been improved by fitting a secondary flow reversal baffle below the main baffle, which arrangement gives stability and allows the height of the shells to be reduced.

In the prototype the pumps are grouped around the plant, but in the production models they will be mounted in delta formation. Rotary seals are fitted in place of the normal gland packing and will be tested over several thousand hours running before being put into service. Even if they are introduced, it will be quite easy to change back to ordinary packing, if necessary.

A steam connection is provided on the second effect for blowing down only. Valves are provided on the exhaust line to the first effect heating element, on the vapour lead to the second effect heating element, and in the second effect vapour lead to the distiller, but it is intended that, once the plant is running, all these valves will remain wide open. Heating element drain valves are provided with a fine adjustment and should require little attention. A restricting orifice will also be fitted in the coil drain. The second effect coil drain is led to a flash tank, where it mixes with the made water from the distiller, before passing to the suction side of the fresh water pump. Vapour released in the tank passes back to the top of the distiller. The normal arrangement of brine cooler feed heater and distillate after-cooler is provided. No chemical injection equipment is provided.

The shells, distiller and other heat exchangers are all welded, one shell is welded R.N.B., the remainder welded copper, using a number of different types of welding rod.

It is intended to continue running the prototype at Portland for several thousand hours to establish the effectiveness of the flexing heating elements and possibly to try elements of different designs and materials. It is also hoped to confirm that the plant can be run without a permanent watchkeeper; to establish the most suitable material and welding rods for the manufacture of the shells etc. and to decide between series and parallel brining.

It is interesting to note that the new plant is smaller than the frigate design, even though it is a compound plant, the weights being about the same.

Accessories

The new plant has been designed for economical and trouble free running but, if there is to be no permanent watchkeeper, some additional safeguards will be needed. When the plant is fitted in a ship, automatic dumping valves will be provided to discharge the made water overboard if the salinity of made water exceeds acceptable limits, both local and distant reading salinometers will be fitted and a continuously reading brine density meter will be provided.

CONCLUSION

The author has suffered from distilling plants in battleships, cruisers and destroyers. Usually the things have been made to work fairly well after much blood and sweat on somebody's part, and not a few unofficial A.'s and A.'s. It is hoped that the new plant, which was designed and manufactured by Messrs. G. & J. Weir, and any subsequent plants of a similar type, manufactured by other firms, will really deliver the goods.

The author acknowledges with thanks the assistance provided by Messrs. G. & J. Weir Limited, in the supply of the photographs used to illustrate the article.