SEA-WATER DISTILLATION

SOME INTERESTING MARINE APPLICATIONS

BY

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Introduction

The intention of this arcticle is to describe a few interesting examples of marine distillation rather than to attempt to cover the whole field. Although the authors have attempted to relate these examples to the commercial plants from which they were evolved, they all have a strong naval bias. An opportunity has been taken to describe a part and, because it applied to low temperature generally, the most significent part of the bacterial contamination experiments recently completed.

The authors express their thanks to the manufacturers of the plants illustrated and discussed in this article for their kind permission to do so and to the officer in charge of the Admiralty Distilling Experimental Station, Portland, Mr. R. N. Jackson, and to Surgeon Commander D. Walters, R.N. and Mr. W. D. Drake of the Institute of Naval Medicine for their advice. Official naval policy is not necessarily reflected in any opinions expressed by the authors.

Background Constraints, Possibilities and Costs

The object of distilling at sea is to provide water for engines and crew. Although the consumption by the crew is usually much the greater, priority of demand for obvious reasons lies with the engines in both quality and quantity. The design and number of plants fitted is influenced by size and employment of the vessel, the heat source and quality of distillate required. The choice of materials used will be influenced by the plant siting within the vessel for on this depends the possibility of replacing large components without recourse to major 'surgery'. The tankage of both feed and potable water, the voyage time and its predictability will determine the degree of redundancy that should be included. These factors, in addition to the availability and quality of water at the terminals of the passage, will enable an optimum distilling time to be practised.

For any one particular ship, the duties and qualities outlined above must be known. In addition it is useful to know from which seas the plant is intended to distil as the salinity will have some effect on scale life and therefore on the frequency of maintenance.

The weight and space problem can be minimized at the expense of performance and accessibility, but in the past rarely seems to have led to simplicity, probably because the desire to save space encouraged ship designers to install plants that were essentially a group of components mounted on the ship's structure, the inter-connecting piping being determined by the convenience of erection rather than the hydrodynamics of their function. Not until the advent of package evaporators did the simple and virtually self-regulating plant become readily available.

There is frequently a requirement to run a plant either on auxiliary exhaust steam or on live steam, so that either of these two convenient heat sources may be used according to the ship's machinery state. Naval installations, in order to make water constantly available, carry a good deal of redundancy and are designed to work under extreme conditions, including 20° heel either side and full output in both arctic and tropical conditions. The most extreme conditions of ship movement are probably to be found in trawlers where the distiller is frequently mounted right forward so that not only does it receive its full share of heel and trim variations but is also subject to considerable vertical accelerations in rough weather. This makes disentraining droplets from the vapour more difficult as the splashing induced by the plant's movements readily bridges the separation between the boiling surface and the disentraining devices of a small plant. Happily the duty in such applications is for water of potable rather than boiler feed quality.

The water requirements of some vessels can well be met by tank storage. A case for not fitting a distillation plant depends on the range of duties specified for the vessel and the degree of confidence the owner has that the range of duty will never be exceeded.

For small auxiliary vessels such as tugs and minesweepers, the smaller yachts and fishing vessels, there appears no good case for installing anything more complicated than a water tank as water is cheap enough in harbour and endurance is not required. In any case, for the non-steam ship until comparatively recently, water distillation equipment was very costly. Even the trawlers fishing the then distant waters around Iceland up to the early '60s relied on tanks only.

Whether the commercial necessity to run trawlers further afield and for longer voyages provided the stimulus to small waste heat evaporator development or whether the evaporators' emergence provided the means of fulfilling a long cherished trawler dream is conjectural. What is certain is that the combination was successful and the other small vessels hitherto reliant on tankage were able to benefit from the small waste heat evaporators which emerged. The appetite for this means of desalting sea water was further enhanced by the general change from steam to diesel propulsion which was by this time well established.

In craft not traditionally fitted with distillers but now so equipped, the use of water appears to be addictive and the situation in small craft has increased in water-making terms from an attractive extra to a necessity as the crew have accustomed themselves to the amenity. This tendency of consumption to escalate is true to some degree in all ships. For instance, the change from salt water showers to fresh invites and achieves a large increase in the number of showers taken. In trawlers, both the process carried out on board and crew consumption have adapted to the new-found plenty. In naval ships, particularly in the tropics, there is a marked tendency for the demand to absorb the available supply which is designed on the basis of 30 gallons per man per day, augmented by whatever is fitted in the way of standby plant.

The running pattern of ships varies between the very organized predictable trade of a liner, where commercial considerations justify careful calculation of demand so that distillers are run to a minimum extent, to the unpredictable defence role of a naval ship which may well find itself distilling in-shore dependent entirely upon its own resources for quite long periods. These extremes of situation illustrate the need to approach reliability of supply in different ways. For the accurately predictable running pattern, comparatively small spare plant capacity plus generous tankage is likely to be more appropriate while the unpredictable naval condition needs to be met in full with one plant entirely out of action. In small ships this usually leads to 100 per cent. redundancy on basic allowance which offers considerable scope for a high consumption when both plants are available.

In ships using other than steam propulsion, the water problem is a bit different because the immediacy of the demand is reduced and so carrying redundant plant is less easy to justify as increased tankage and spares can give sufficient leeway to cover the inconvenience caused by mechanical breakdown. The purity of the water too can be relaxed somewhat. A requirement for distilled water for naval boilers is that the conductivity should not exceed 4·5 micromhos or that it be clear by a silver nitrate test. In practice, steady running at about 3 micromhos conductivity is achieved. The degree of relaxation from this standard is not enormous for an increase beyond about 20 micromhos indicates either a plant fault or incorrect operation.

There is a strong economic incentive to use waste heat for distillation. Steam ships can use auxiliary exhaust as the heating medium, diesel-engined ships can use the heat rejected in the engine coolant whereas in the case of gas turbines some means of heating a boiler in the engine exhaust has to be devised. The drawback to these last two means of providing heat to the distiller is that they are geared to main engine usage and power level. Where these are predictable, steady, and form a coherent pattern against demand, they are potentially attractive.

In the case of naval vessels, the use of main engines bears no relation to crew needs, although in steam ships, it is comparatively easy to supply exhaust steam-heated evaporators with live steam or, alternatively, supplement the exhaust steam range to maintain a constant pressure.

The engine coolant waste heat approach in diesel propelled merchant cargo ships is capable of providing a greater quantity of water than the crew requires while at sea because only a fraction of the engine coolant is used for distilling. This means that full water demand can readily be met over a wider power range than is normally used. In some naval vessels, the diesel generator running pattern and waste heat rejection bear a passable relation to water demand. The electrical load in harbour is fairly high as a rule and it can be shown that a frigate's generators and evaporators could be arranged in such a way that the ship's water requirements could be met in all normal circumstances from the waste heat of the diesel engines. Extraordinary requirements could be met by providing electrical immersion heaters into the engine coolant circuit to raise artificially the heat available. The disadvantage of this proposal is that it is, if anything, more bulky and only slightly less expensive to install than its steam (auxiliary boiler) heated equivalent. On a through cost basis it is, of course, much cheaper.

TABLE I—*Comparison of methods of making potable water*

Plant	*Cost*
7 tons/hr. steam-heated two-stage flash plant	1·07 £/ton
2 tons/hr. steam-heated two-stage flash plant	1·41 £/ton (1·08)
2 tons/hr. waste-heated two-stage flash plant	0·625 £/ton (0·344)
2 tons/hr. reverse osmosis plant	0·55 £/ton (0·35)

To compare the various means of making potable water (TABLE I), a frigate-sized vessel is taken as an example and the costs of meeting the water demand of 2 tons per hour are costed over 20 years. Reverse osmosis, although outside the scope of this article, is included as it is now sufficiently explored to show that it is a probable contender for potable water production in the late '70s. A similar calculation for a larger naval vessel using a 7 ton/hr. plant heated by steam from an auxiliary boiler demonstrates the reduction of costs with increased size.

In each case the electrical power is costed as an equivalent quantity of fuel. Two plants are provided only one of which runs at any one time. The ship spends half its life at sea and each conventional plant consumes spare parts worth one third of its initial cost. In the case of the reverse osmosis plant, new first stage modules are supplied every two years and second stage modules every three years.

A further figure shown in brackets is the cost that would obtain if the distilling plants are built to commercial rather than naval requirements. In the case of the reverse osmosis plant (which because of its modular construction can much more readily handle the redundancy requirement within the confines of a single plant) a figure is also shown. Within the assumptions upon which these figures are based, it is interesting that reverse osmosis appears comparable in cost to waste heat distillation. This would not hold true for the case of a diesel-propelled cargo ship because the capital costs of a single-stage evaporator (which would be used in this case) is different as is also the usage rate and spares consumption.

A Two-Stage Naval Flash Evaporator

The former naval practice of specifying an evaporator which was then built as a collection of components and connected up on board meant that every class of ship had a different evaporator and quite often in a single class there would be substantial variations. Although any one design would incorporate all the desirable features of the sea-water evaporator as seen at the time, none went through any development programme. Indeed, the testing for acceptance of these plants in a shop rig often bore little more than a perfunctory relationship to the ship fit as far as the relative positions of the pumps were concerned.

The attractions of developing a range of standard plants to be used throughout the future Fleet were strong for reliability, ease of handling, maintenance and spares provision, but tended to the opposite for space and ease of fitting into a ship's machinery box.

Trials at the Admiralty Distilling Experimental Station in the early '60s had shown that small packaged flash evaporators held great promise for satisfying the naval requirement much more comprehensively than it had been in the past. As a result of these trials a number of ships have been fitted with flash plants, which were however tailored to fit the ship rather than being self-contained units.

The decision to build and develop a range of flash evaporators was made and the specifications for a 2 tons/hr. and a 1 ton/hr. plant were drawn up in 1966. These were to be packaged plants containing all equipments and controls with the exception of the pump motor starters. They were to have two stages and a coefficient of performance of 1·5, i.e. the output in made water should be 1·5 lb. per 1000 B.T.U.s input which is very nearly the same as saying the output is 1·5 times the steam rate. The choice of flash plants and the selection of two stages rather than three or four depends on selecting the optimum condition of weight, space and simplicity against steam consumption. The good scale life and inherent stability of flash evaporators had already been satisfactorily demonstrated but the choice could conceivably have been for more stages. However, size considerations make two stages look better than three and not much larger than the conventional double-effect submerged-element plants already fitted in a number of vessels.

Specifications for the 2 tons/hr. and 1 ton/hr. plants included a number of hitherto unusual design features which are worth mentioning:

(*a*) That the plant should operate at acceptable purity down to 60 per cent. of its full output.

(*b*) That the feed temperature was not to exceed 79·5°C.

(*c*) That the scale life without recourse to chemical treatment should not be less than 2000 hours in normal circumstances.

(*d*) That the plant should work satisfactorily when heeled at 20° in any direction.

(*e*) That the control requirements should include automatic shutdown in the event of:

  (*i*) High brine level in the second stage.
  (*ii*) High steam pressure in the final feed heater.
  (*iii*) Failure of any pump.

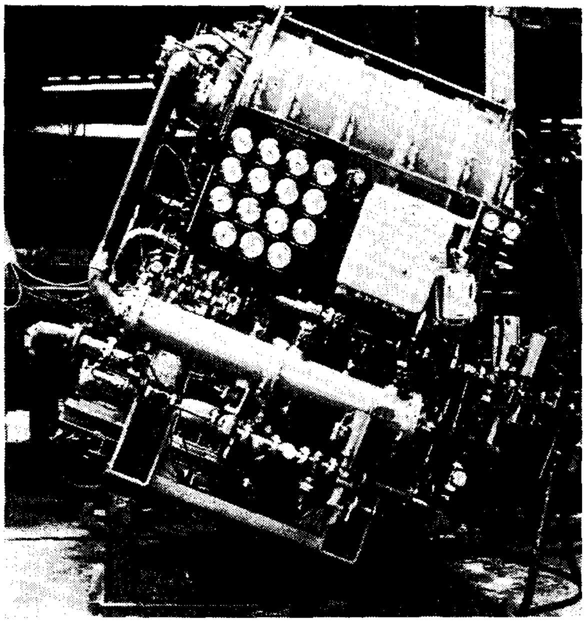

FIG. 1—PROTOTYPE TWO-STAGE FLASH PLANT OPERATING AT MAXIMUM HEEL ANGLE

FIG. 1 shows the prototype two-stage flash plant operating at the prescribed angle of maximum heel. FIG. 2 shows a line diagram of the system, and FIG. 3 compares the commercial and naval equivalent plants.

A number of invitations to tender were made and the most promising design was selected on the basis of cost and technical adequacy. The 2 ton/hr. plant finally selected had many basic qualities very similar to a successfully working commercial plant which was produced a few years earlier.

The control of this plant is managed by selecting a constant steam supply with the aid of a throttle valve and orifice. The feed flow is then regulated to maintain a top temperature of 79°C; this can be done either by temperature control valve or manually. In the manual case, adjustment to compensate for changes in sea-water temperature will be necessary from time to time; this makes automatic control look attractive. In the first instance, the prototype was fitted with a pneumatically-operated feed flow control but this was later abandoned.

The protoype was duly ordered and produced and began shop trials in March 1969. Initially trouble was experienced with balancing the extraction of incondensable gases between the two stages. This was overcome by a modification to the off-take pipe and trials in both the horizontal and heel conditions were completed before the plant was despatched to the Admiralty Distilling Experimental Station.

The programme of trials at Portland was primarily intended to test the plant against its specification, describe its behaviour and, where necessary, recommend modifications to improve its qualities. Specifically, this concerns:

(*a*) Starting and running procedures and characteristics.

(*b*) Scale life at ambient temperature and under simulated tropical conditions.

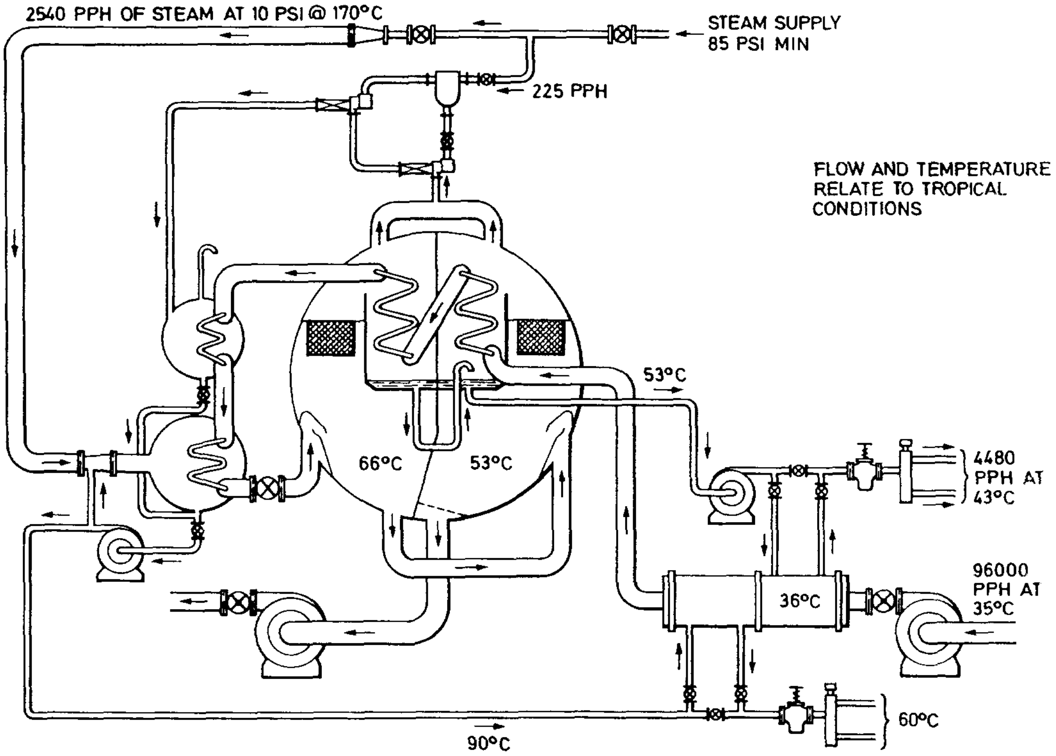

FIG. 2—FLOW DIAGRAM OF THE NAVAL TWO-STAGE FLASH PLANT

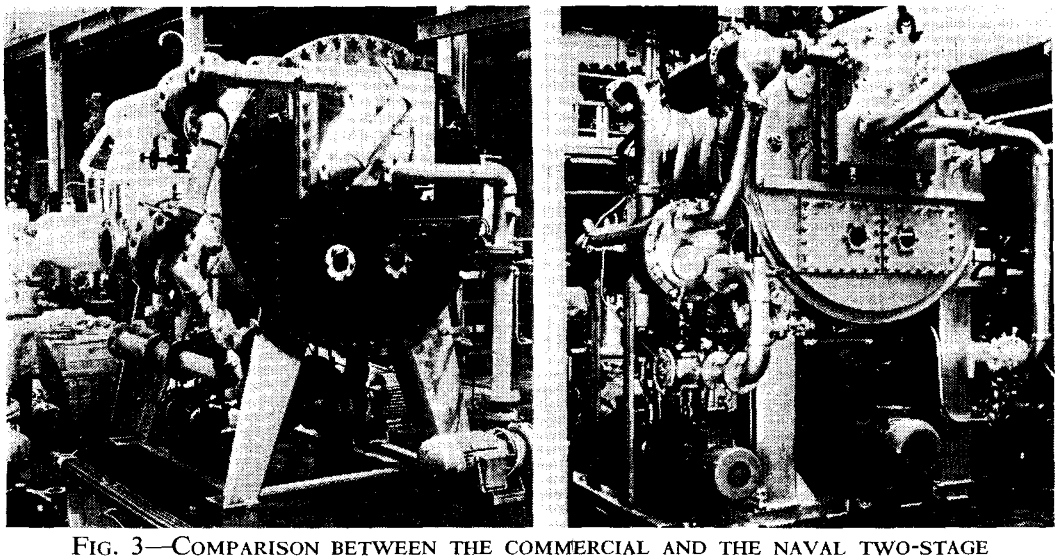

FIG. 3—COMPARISON BETWEEN THE COMMERCIAL AND THE NAVAL TWO-STAGE FLASH PLANT

(*c*) Determination of the performance envelope (see FIG. 4).

(*d*) Development of automatic controls.

(*e*) Evaluation of recommended maintenance procedures and component reliability where this gives concern.

(*f*) Verify and, where necessary, re-write the handbook.

At Portland it is possible to simulate sea conditions varying from an ambient of 70°C in winter and 14°C in summer at about 35,000 p.p.m. sea salt to 35°C at about 40,000 p.p.m. sea salt by re-circulation; the latter is probably as severe a condition as any naval ship is likely to encounter. The quality of the sea-water is for a variety of geographical reasons free from normal coastal pollution or river dilution.

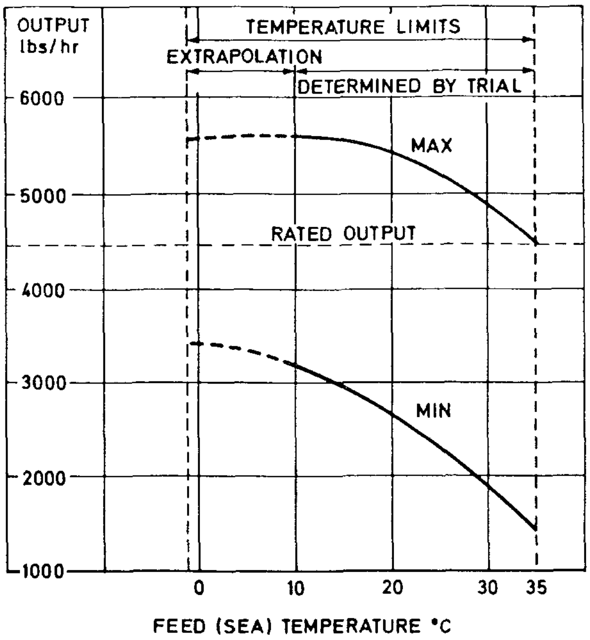

FIG. 4—PLOT OF PERFORMANCE ENVELOPE OF TWO-STAGE FLASH PLANT

The plant was run initially on a pneumatically-controlled feed control valve; this behaved satisfactorily until the butterfly disc had eroded so badly that flow was greater than required with the valve tight shut. At this point pneumatic control was abandoned because it had become apparent that some other sort of control would be better for the first ship application. Double-beat valves working directly from a wax-filled thermostat were tried and performed satisfactorily from a control point of view but being only obtainable in LG2 gun-metal they also eroded very quickly.

There was always some reservation about this form of direct control because it was felt that the driving force available from a wax-filled element could become inadequate should the valve stem and guide become stiff with deposited scale. In fact, this appeared to happen once or twice but, as the life of the valve was so short, nothing was absolutely determined. For the first production plant it was decided to use hand-adjusted diaphragm valves which are known to have a life of about 4000 hours under these conditions. For later plants development work would continue on a valve with monel lid and seat and to be servo-operated using feed pump pressure for servo power.

When the decision was made to use hand-controlled valves on the first production plants, the principal considerations were as follows:

(*a*) As the butterfly control valve had eroded away rather rapidly, an alternative form of motorized valve would be required if pneumatic controls were to be used.

(*b*) Pneumatics are awkward to accommodate and expensive, particularly if future ships are not going to make wide use of pneumatic systems.

(*c*) The penalty of not having an automatic control of feed flow is minimal. Adjustments need not be more often than can be made by a watchkeeper visiting the machine once a watch. Even if a large variation in sea temperature occurs during the watch resulting in a rise of the final feed water temperature for a few hours, the scale life will not have been shortened appreciably; conversely, if the temperature goes down for a few hours, only a little output will be lost.

The performance envelope evaluation (FIG. 4) consists of running the plant at various temperatures between the ambient and simulated tropical condition to its maximum and minimum output compatible with acceptable salinity.

The maintenance evaluation is carried out by doing a schedule of routine maintenance devised from experience with similar plants, removing the most awkward pump and renewing a pump seal and impeller under the vigilance of stop-watches and time-elapsed cameras. The evidence provides a basis for modifying both the schedule and details of plant design. By the time the 'maintenance evaluation' is carried out, a good deal is already known about maintaining the evaporator as maintenance is a continuing requirement during trials. However, the value of getting an independent opinion on the maintenance schedules and some details of plant design is extremely valuable.

At the time of writing (early 1973) the plant has run for about 11,000 hours. Some work remains in proving modifications that are desirable although not essential and which could well be introduced in a few years' time. The trials injected a number of modifications into the original design; these include:

(*a*) Improvement of the acid cleaning facilities.

(*b*) Additional flow-sight glasses and detail modifications of pipework.

(*c*) Some improvement to the internal spray control deflectors.

The trials have also confirmed that the scale life is likely to be about 4000 hours in temperate and 2000 hours in tropical waters, and that the plant is stable and reliable over a wide range of running conditions. The experience gained has been liberally used in writing the handbook.

The differences between the original commercial plant and the naval evaporator are shown in TABLE II.

TABLE II—*Comparison between commercial and naval flash evaporator plant*

	Naval Plant	*Commercial Plant*
Materials:		
Shell	90/10 and 70/30 Cu-Ni	Mild-steel (coated)
Tubes	70/30 Cu-Ni	90/10 Cu-Ni
Water boxes (covers)	Gunmetal	Cast iron
Construction	MOD(N) Grade 1 shock More robust More compact	Lloyds, ABS, etc.
Pumps	Separate pump and motor with flexible coupling. 1750 r.p.m.	Motor pumps with extended armature shaft and no coupling. 3400 r.p.m.
Salinometer	6 points	1 or 2 points
Interchangeability	Complete, with close tolerance on all terminal connections	Normal commercial
Additional fittings on naval plant: Distillate cooler with bypass system Drains cooler with bypass system Ejector condenser drains system Drains pump Drains discharge diverting valve Note: Distillate and drains are normally accepted direct into the ship system in Merchant Navy vessels. Safety shut down control and remote indication Instrumentation Back pressure valves for stable pump operation		

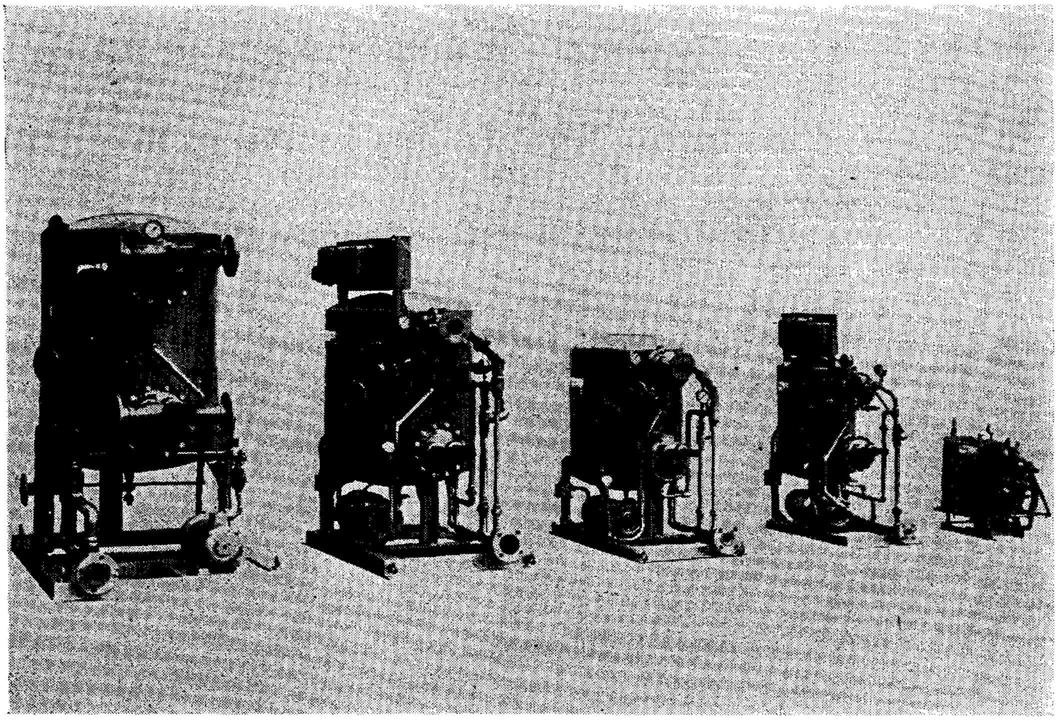

FIG. 5—FAMILY OF LOW-PRESSURE WASTE-HEAT EVAPORATORS

A Family of Small Waste-Heat Evaporators

FIG. 5 shows a family of low-pressure waste-heat evaporators with an output range from 200 to 2400 imperial gallons per day.

In the early sixties the low pressure waste heat type of evaporator, which had been successfully used in motor ships since the Second World War, appeared in smaller sizes suitable for the many motor vessels which were being put into service.

In about 1963 they were adopted as standard for the new generation of Distant Water Trawlers which were destined to work fishing grounds which required them to remain at sea 50 per cent. longer than before—voyages of three months being not uncommon. They thus needed both more fuel and more water and to accommodate the one it was necessary to reduce the volume occupied by the other. Desalination provided the essential solution by reducing water tankage to a minimum.

These new trawlers were all diesel or diesel electric driven and so there was an abundance of the low grade waste heat in the engine jacket cooling water for an evaporator.

At the same time the crews 'discovered' the advantages of fresh water showers and general supplies of relatively plentiful fresh water. Indeed, the longer voyage times made this amenity a must. Today, during the time at sea this class of ship is completely dependent on made water for supplies of fresh water for domestics, galley, showers, engine-cooling, battery-topping and, particularly, for fish processing.

In cruising yachts, the need for less dependence on shore supplies of, at times, expensive and dubious quality fresh water was felt and here again, as these ships were now motor driven, this type of evaporator was a natural choice. Yachts of 50 ft. and upwards are commonly now fitted with plants producing from 200 gallons to 1200 gallons per day using waste heat from main engines or generators. Ocean tugs, too, have found advantage in installing small evaporators to support their water needs during long sea trips.

In the small sizes of plant in this class of evaporator, it was usual to have shells of corrosion resistant material—initially, monel and lower nickel content cupro-nickel. More recently aluminium-silicon-bronze has been used. With argon-arc welded fabrication, the shells are light weight and completely proof against corrosion wastage while yet being rugged to withstand the rigours of the engine-room. Matching materials, all non-ferrous, are used for the tubular heat exchangers, pipework and fittings. Plastic evaporators were successfully developed but for the small sizes, non-ferrous metal construction is a better economic proposition.

As with flash evaporators described above, these deep-vacuum waste-heat units, boiling the raw sea-water at 40°C, will give long operating runs before cleaning is necessary—up to 1500 hours depending on the operating conditions. Cleaning is done using a liquid chemical which fills the shell and dissolves all scale from heating surfaces and the inside of the shell and pipework in 24 hours or so. Thus on average the plant needs to be cleaned only three times a year—a marked contrast to the practice necessary to keep the old style submerged coil evaporators in good fettle.

It seemed that this type of plant, being successfully used in commercial form, had a potential use in the Royal Navy. There was a need to provide water in minesweepers if this could be conveniently arranged and it was thought too, although this was later abandoned, that this means of making water might be better than existing plants in conventional submarines.

A plant was built to naval requirements in its principal components, although the peripherals—motors, starters, salinometers and dump valves—were left commercial to keep the cost and delivery reasonable.

This plant was run at the Admiralty Distilling Experimental Station on a rig providing hot water at temperatures and flows to simulate the diesel engine coolant range of interest and this gave a good indication of the plants behaviour, product purity and scale life. It was also used to investigate bacterial contamination.

Initial runs showed rather a short scale life (about 300–400 hours at 'modest' 74°C hot water inlet) and a marked tendency to prime at shell vapour temperatures below 47°C. At this point it was discovered that the internal brine pipe was an inch too high and the fabrication of the brine pipe caused a partial blockage. This was put right and a second brine pipe fitted near the centre of the plant. These modifications allowed the vapour temperature to be reduced to 40°C before carry-over occurred. Further lowering of the brine duct permitted stability at even lower vapour temperatures.

Further modifications to the plant were made to allow a single ejector to deal with both the brine and the incondensable gases (in line with current commercial practice) and to allow the cooling water flow to be varied over a wider range. The result of these modifications was an ability to run with a vapour temperature as low as 40°C and a product conductivity of between 2 and 2·8 micromhos. The scale life was further improved by fitting a more powerful ejector which reduced the vapour temperature to 38°C.

It appears that scale life is very much increased by using lower temperature heating water and accepting lower outputs while maintaining minimum shell temperatures. Clearly, the temperature of hot water and the size of demand for distillate may necessitate running in a manner which will require some feed treatment if further extension of scale life is to be achieved.

During the course of this trials programme at ADES, a larger edition of this plant was built into a package and supplied to the survey vessels

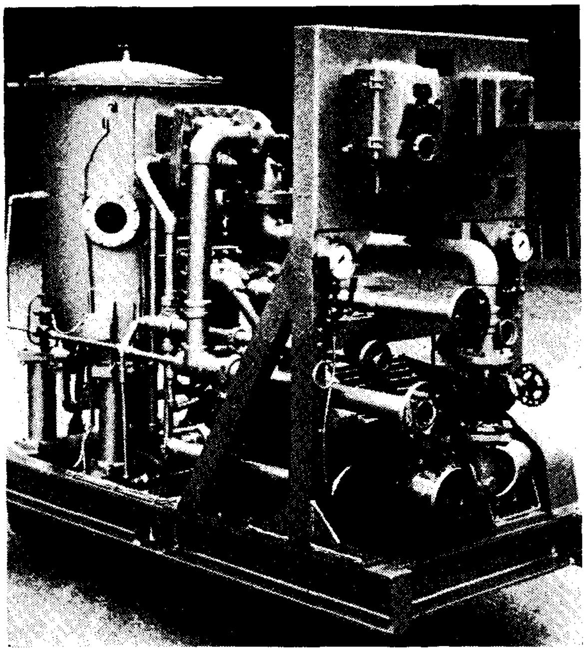

FIG. 6(a)—800 GALLONS PER DAY NAVAL WASTE-HEAT EVAPORATOR

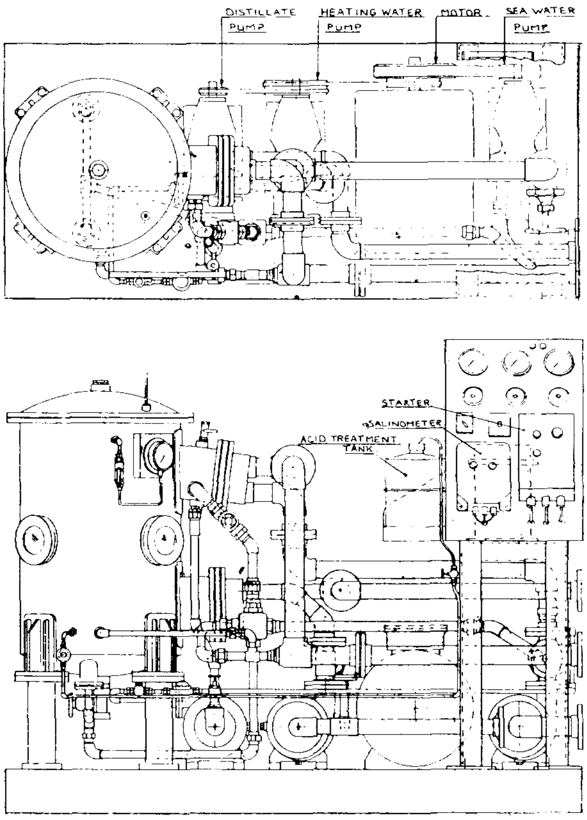

FIG. 6(b)—800 GALLONS PER DAY NAVAL WASTE-HEAT EVAPORATOR

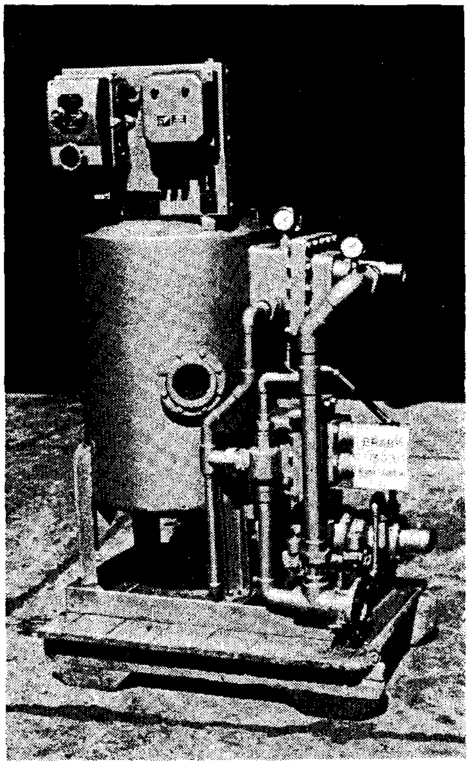

FIG. 7—1300 GALLONS PER DAY COMMERCIAL WASTE-HEAT EVAPORATOR

Hecate, Hecla and *Hydra*. In this application, diesel engine coolant waste heat was not available but low grade steam heat was and so each plant was fitted with a circulating pump, header tank and thermostatically controlled calorifier. The plants had separate ejectors which caused a few teething troubles; these were replaced with single ejectors after which the plants settled down quite well.

As a result of both prototype and ship experience, an 800 gallon per day package prototype was specified. The resultant design was put to work at the ADES, where the plant was proved and a number of improvements introduced.

A novel feature of this plant is the employment of a single motor using flat belts to drive all three pumps. This appears to be a simple, reliable, and attractive system for small plants.

The 800 gallons per day plant is shown in FIGS. 6(a) and (b), and FIG. 7 shows the comparable commercial plant. The naval specification demanded a rated output of 800 gallons per day in sea-water of temperature up to 90°F and with hot water supply at 145°F maximum. For normal commercial operation the sea temperature is taken as 75°F and the hot water supply as 160°F. For these conditions the commercial rating is 1300 gallons per day.

Distillate Contamination in Waste-Heat Evaporators

The question of bacterial contamination, which is a problem common to all evaporators, was explored in detail because of the potential that waste heat plants have for small vessels which do a good deal of their work near the shore. Steam-heated evaporators can be and customarily are set to run at higher temperatures when a danger of contamination is thought to exist but this is not possible with waste-heat plants.

The naval practice in steam plants has been to maintain a shell vacuum of not greater than 20 inches of mercury when distilling inshore and a long, and apparently uninterrupted, trouble-free experience would appear to show that this is a sound practice. The other rather obvious contamination problem with waste-heat evaporators occurs when a heating element tube leaks. The contamination of the boiling brine could lead to carry over of dissolved corrosion inhibitors from the diesel generator coolant if the evaporator was running badly or priming and would lead to the distillation of some ethylene glycol if an anti-freeze solution was in use.

Experiments were designed to investigate both the bacterial and toxic hazards and were run over a fairly wide range of operating conditions. These included distillate purity from the normal to the priming condition and, after some modifications to the plant, temperatures down to 35°C. Essentially, the evaporator was set to work and when running steadily the feed suction was inoculated at a known rate with a culture of *Escherichia coli* bacteria. Samples and temperatures were then taken at interesting points round the system and the samples returned to the Institute of Naval Medicine for analysis.

FIG. 8 shows a diagrammatic arrangement of the system used for the experiment. The sampling and thermometer points are marked S1, S2, etc.

Runs were repeated using *Streptococcus faecalis* which again is found widely in sewage but has a higher temperature death point than *E. coli* and

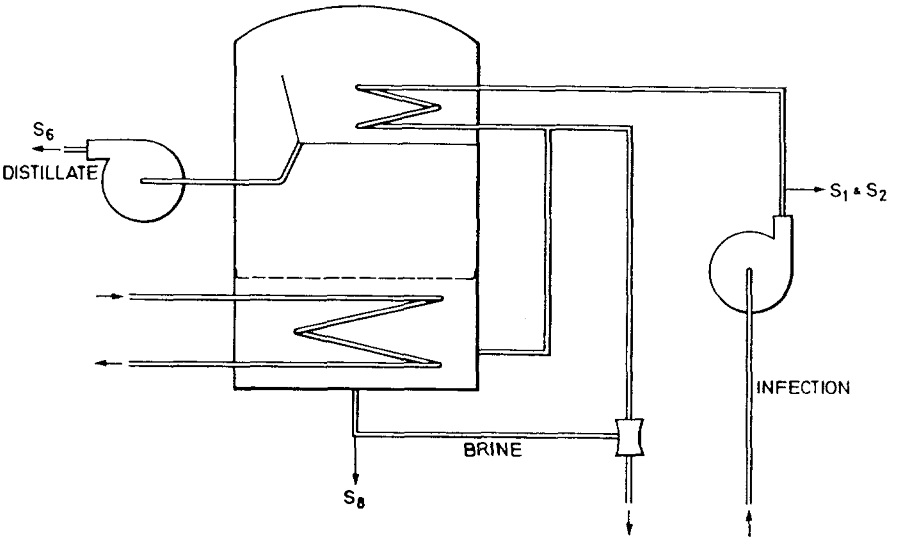

FIG. 8—DIAGRAMMATIC ARRANGEMENT OF SYSTEM FOR BACTERIAL CONTAMINATION EXPERIMENT

is therefore a more exacting test vehicle in this instance. The trials consistently and very unexpectedly showed that the bacteria were dying at very much lower temperatures than had previously been thought possible and it was concluded that the sterilizers currently fitted to waste-heat plants which comprised a heater designed to raise the distillate temperature to 160°F, were, because they were followed by a distillate cooler, worse than useless in that the major hazard clearly arises from leaks in low temperature coolers. The apparent susceptibility of seaborne pathogens to boiling was not altogether understood and it was speculated optimistically how wide the application of this phenomenon might be. However, laboratory experiments later revealed that a significant salt strength was necessary in addition to boiling.

In the laboratory the cultures were prepared in a preserving balanced electrolyte solution (Ringers) at a suitable concentration for injecting into the feed water supply of the evaporator. They were then transported at low temperature in an insulated container to the evaporator on trial and used the same day. The concentrations used approximated to those expected in sewage which is about ten times that predicted for sewage effluent. Samples from the trial runs were then returned at the end of the day and were cultured and counted to yield a figure of organisms per millilitre.

Separate tests were undertaken to assess the viability of the two test organisms in sea-water and under transport conditions. This was necessary to show that the bacteria were not disappearing for reasons other than the treatment they received in the evaporator.

A still equipped to allow samples of brine to be removed for test was used to simulate conditions that exist in the evaporator. With this apparatus, the separate effects of vacuum, heat and the two together were investigated.

The surprisingly low temperatures at which the test organisms disappeared was further investigated with relation to the brine strength. These tests showed that we can expect sewage born bacteria to die at low temperatures under boiling conditions with salt strengths down to 4 per cent. but below this their viability increased until at 1 per cent. some organisms were still alive after one hour.

Typical Infection Readings at points around the circuit shown in FIG. 8 are given in TABLE III.

TABLE III—*Set of typical infection readings*

Raw Sea-water		*Infected Sea-water*		*Heating Water*		*Distillate*		*Brine*	
S1		S2		In	Out	S6		S8	
Temp. °C	Infection Org./ml	Temp. °C	Infection Org./ml	Temp. °C	Temp. °C	Temp. °C	Infection Org./ml	Temp. °C	Infection Org./ml
16·5	420	16·5	11,500	69·5	58·5	35·5	Nil	41·0	Nil

To estimate the effect of a leaking heating coil contaminating the evaporator brine with ethylene glycol, a direct injection of glycol solution was made into the test plant and samples of the distillate and brine taken. Testing the samples proved something of a problem which the Institute of Naval Medicine ingeniously solved by oxidizing the glycol to formalin with periodic acid and estimating the formalin. The rate of injection was arbitrarily fixed, but this is not regarded as significant because leakage, when it occurs, will be at a very much smaller rate than the normal feed rate and will last only so long as the engine coolant header tank allows. It was found that, provided the product salinity remained below 10 micromhos, the ethylene glycol contamination of the product remained below the permissible level which is regarded as 30 p.p.m. However, had toxic compounds been present in addition even in very minute quantities, they could easily contaminate the product and present a very hazardous situation.

The conclusions drawn from these trials are:

(*a*) The rapid disposal of pathogenic bacteria entering a low temperature evaporator shell depends on the strength of the brine, its temperature, and on the activity of boiling. In boiling brine of 4 per cent. salt or greater, sea-borne pathogens will disappear at temperatures down to 40°C.

(*b*) The principal hazard when distilling in potentially polluted sea-water is from leaks in the distillate cooler or condenser. The risk will be very small if distillate conductivity is held below 10 micromhos.

(*c*) When distilling in fresh water, chlorination or some similar process is necessary for complete assurance of sterility.

(*d*) Diesel engine coolant additives including ethylene glycol are a hazard which can be contained by limiting the constituents to approved specifications of low toxicity and maintaining a distillate conductivity of less than 10 micromhos. This last is no protection when distilling in fresh water as there would be no conductivity indicator carried over with the glycol and so it would be advisable in these circumstances to forego the use of coolant additives.

The conclusions concerning the bacterial sterility apply equally to any submerged boiling surface plant.