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FRESH WATER EVAPORATORS.

PART I.—INFLUENCE OF METHODS OF OPERATION UPON MAINTENANCE AND ECONOMY.

The points to be considered as regards the production of fresh water from the sea in naval vessels are not by any means solely concerned with the amount of fuel so employed, as not only is the wear and tear of the evaporating plant a matter of importance, but also there arises the question of the number of man-hours required for maintaining the plant in proper condition. This latter consideration is becoming increasingly important in modern construction, in which the tendency is to restrict the storage capacity for fresh water and also to limit severely the dimensions (and therefore increase the forcing rate) of the evaporating plant; at the same time the natural demand for improved amenities operates to increase the requirements for fresh water both for washing and for culinary purposes; finally, the increasing demand for fighting personnel indirectly tends to reduce the numbers available for engine-room maintenance.

The tendency is then for increasing difficulty to be experienced in arranging for such services as the mechanical descaling of the evaporator coils, which entail the regular diversion of labour from other services. In any case, the operation is one that is better avoided, in so far as the damage to the coils leads to greater and greater difficulty in cleaning properly no less than to falling off in efficiency and undue wear and tear. These considerations led to the development of a method whereby the necessity for descaling of the coils has been *entirely avoided*, and to the further highly important advantage that the output rate of the evaporator can be maintained at a reasonably high level for as long a period as may be desired.

The purpose of this paper is to describe the mode of operation referred to, and also to give the results of careful tests, made under seagoing conditions with the object of comparing the fuel costs of various methods of operating evaporators.

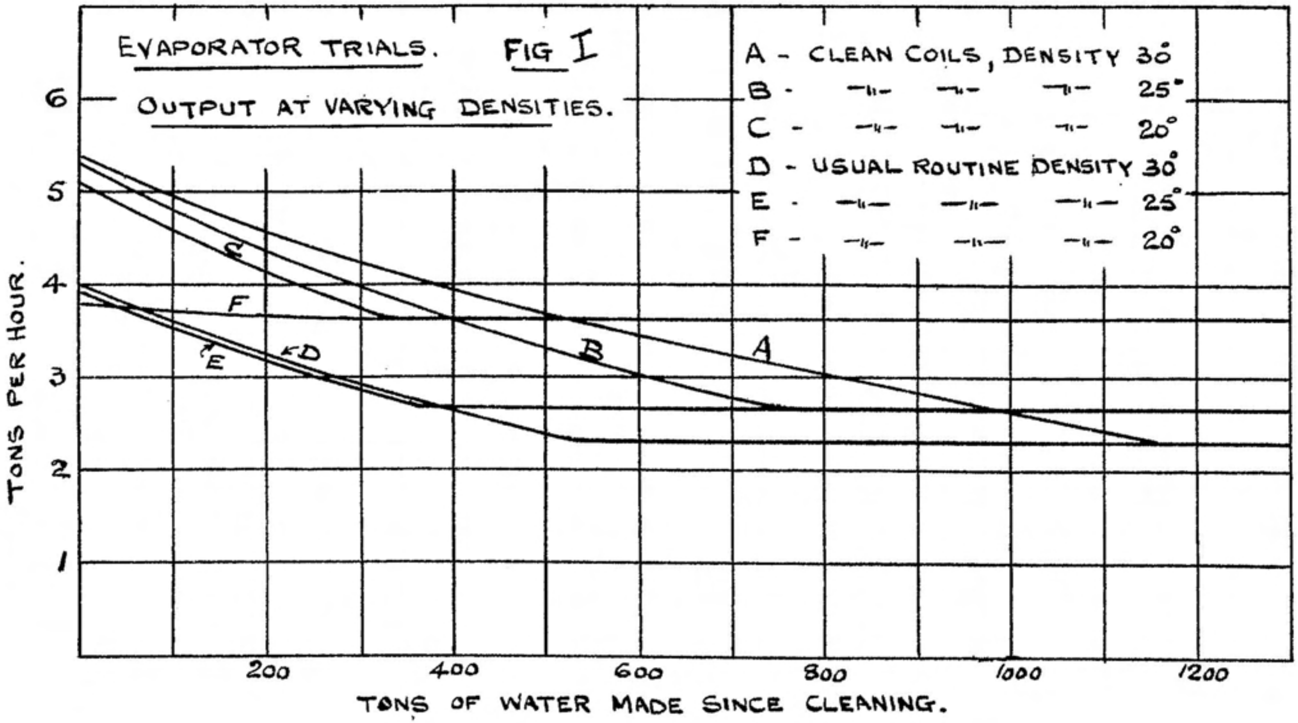
The Formation of Scale.—It will be remembered that solid matter is only thrown out of a solution if and when the saturation point of that solution is passed, either by the continuous addition of more and more saline constituent or by decrease of the liquid's capacity to retain matter in suspension. It is found that as the temperature of most solutions is increased, so also is their saturation density; this applies to all the normal constituents of sea water, with the sole exception of calcium sulphate ($CaSO_4$), which possesses an "inverted" solubility curve, *i.e.*, the saturation density *decreases* as the temperature rises above 140° F., the salt behaving in the usual manner, however, at temperatures below that point. The practical result of the foregoing is that deposition of $CaSO_4$ will usually occur in an evaporator upon any surface which is sufficiently hot to raise the temperature of the layer of brine in its immediate vicinity to a point such that the corresponding saturation density is below that prevailing locally. Deposition of the other constituents will not be experienced to any marked extent unless the working density is increased to a point above that at which evaporators are generally worked, the figure of 30° providing a reasonable margin in this respect.

As the layer of scale increases in thickness, so the temperature of its brine-washed surface falls (due to the heat resistance of the scale), till finally that temperature is just below saturation point —deposition then ceases. The output of the plant will be determined by the heat resistance of the scale in question, and will, of course, be less than the full output, other things being the same. It may be remarked in passing that as the output varies with the rate of heat transference from the coil steam to the brine, it evidently depends to some extent upon the temperature of the brine itself—that is, for a given steam temperature and given resistance of scale, the rate of heat transference will increase if the temperature of the brine actually in contact with the coils can be lowered. The fitting commonly known as an " apron plate " achieves this desirable end by separating the incoming " feed " from the hotter main body of brine, tending to keep a supply of the former against the heating surfaces. It will consequently be found in practice that if the space between the lower edge of the apron plate and the bottom of the evaporator shell becomes obstructed by detached scale, the output of the evaporator may fall off to a marked degree. The apron plate performs a second service, its use raising the output of the evaporator because the temperature of scale formation at the actual coil surface is higher (water density lower) than it would be if the density at that point was the same as that of the main body of the brine.

Two deductions can be made from the foregoing points, namely :—

(1) That if a given evaporator is operated at constant coil pressure and constant density, its output will gradually fall till it reaches a certain rate, which will not diminish as long as these conditions are maintained. This steady output may conveniently be called the " steady rate."

(2) That the absolute value of this steady rate will depend mainly upon the density of the brine and the temperature of the steam in the coils. It is evidently influenced by other factors in an actual case, where the rate of heat transmission necessarily varies from coil to coil (depending upon the amount of condensed water in them, etc. etc.) and where a higher shell vacuum may be practicable at low outputs than at greater ones, owing to considerations of priming, etc.



EVAPORATOR TRIALS. FIG I

OUTPUT AT VARYING DENSITIES.

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The validity of these deductions was tested by carrying out prolonged runs at different densities in each case, the coil steam pressures being, however, maintained constant. The results are shown graphically in Figs. I and II, from which it will be evident that the set can be operated at a particular output without descaling the coils at all, if the density of the brine is suitably selected.

Methods of Increasing the "Steady Rate."—The steady rate at any given density (coil steam pressure and coil-drain valve setting) can be increased by the use of some regular method of cracking the scale. The process actually in use during the tests referred to above merely entailed "blowing down" the evaporator once every 12 hours and then filling up with cold sea water as suddenly as possible, the steam being turned off the heated coils before the cold water was admitted.

Subsequently it was suggested that cracking might be facilitated if the coils were soaked in fresh water during the periods when it was necessary to lay an evaporating plant up for repairs to the pumps, valves, etc. This was done, the set subsequently being put into operation, when required, by starting with the brine suction and feed supply valves shut until the normal water level was attained; sea water was then fed in, and brining started when the correct density was reached. The next routine blow down was usually found to crack off most of the scale, and in view of the large quantity so dislodged the main doors of the evaporators were removed at this juncture as the loose deposit could not be cleared out sufficiently through the small cleaning doors provided. The initial output of the set after soaking and cracking was found to be somewhat less than it is with quite clean coils. The actual reduction is shown on Fig. I, the curves A B C being for clean coils and D E and F for coils treated in the above manner. The initial output of D E and F has been termed the "peak" output for convenience of reference.

It has not definitely been established whether soaking is of real value in loosening the scale, although there appears to be some improvement in this respect if coils lie in fresh water for at least 24 hours.

Working of "Steady Rate" Method.—The routine adopted in the ship where this method was used on service was as follows:—The two sets of evaporating plant were worked alternately, the "stand-by" unit being kept with its coils soaking in fresh water. The working evaporators were blown down and "cracked" once every 12 hours, the process involving a total loss of about one hour's output in every 24 hours.

With a view to obtaining the highest possible economy consistent with the avoidance of descaling by mechanical means, the reduction from the "peak" output to the desired "steady rate" was made by working for the necessary period at 30° density;

subsequent working was carried out at a density selected to suit the ship's immediate requirements for fresh water (Fig. II). It should be noted that once a set attains the steady output corresponding to a given density, a higher output can only be achieved by cracking the scale from the coils: merely decreasing the density without a prior cracking process will not raise the output, but will, of course, increase the fuel expended for the production of a given quantity of water.

The curve in Fig. II shows that there is a certain density corresponding to the highest possible minimum rate, and that the change in rate is very marked with small variations of density in the region of this optimum point. It is thus obvious that unless the density in the evaporators is very carefully maintained at the desired figure there will be marked variations in output when working in this region, which should therefore in general be avoided as far as possible. For reasons which will be given later the actual density used should be at least 20°.

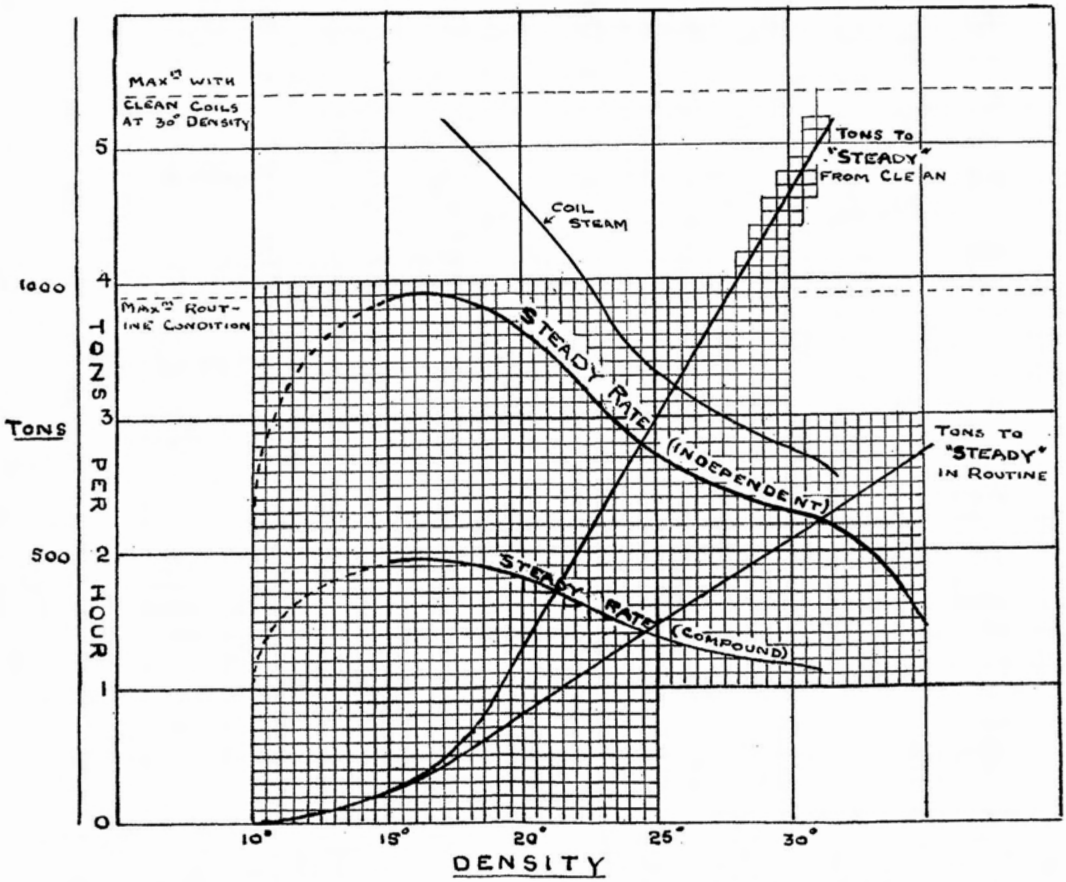
The coils were taken out of the evaporators only once per annum, mainly in order to remove scale from the apron plates, baffles, etc., and interior of the evaporators. Advantage was, however, taken of their removal to descale them entirely by heating over a forge; this can be done on board if the coil is covered with a steel sheet during the heating process.

Effect of Sea Water Temperature on Output.—The curves of Fig. I are based on tests carried out with sea water at a temperature of about 75° F. It was found later when making repeat trials with a sea temperature of about 48° F. that the " steady rate " at a given density had increased above the figures shown on Fig. I; this change is ascribed to the improved " cracking " effect resulting from the colder sea water, as the coils were evidently much freer from scale. This effect has not yet been fully explored but is of appreciable magnitude, the minimum rate at 30° density being raised from about 2·3 tons/hour at 75° F. to 3·0 tons/hour when the sea is at 48° F. It is reasonable to suppose that similar increases may be expected at lower densities.

Effect of Density on Economy.—Fig. III shows directly how the economy is affected by change of brine density; one curve gives the percentage reduction in output per pound of coil steam as compared with that at 30° density. The falling off in economy becomes very rapid at densities below 20°.

Effect of Coil Drain Valve opening upon Economy.—The steam connections to the evaporator coils are so arranged that the drainage all passes through the lowest coils and thus is cooled as far as possible by the incoming feed. The proportion of evaporation that takes place at the lower coils and similarly the temperature of the coil drainage is largely determined by the setting of the coil drain valve (assuming that a constant steam pressure is maintained

FIG: II.



STEADY RATES OF OUTPUT AND TONS OF WATER MADE UNTIL "STEADY" RATES ARE REACHED AT VARYING DENSITIES IN EVAPORATORS USING 18 lbs/□" L.S.

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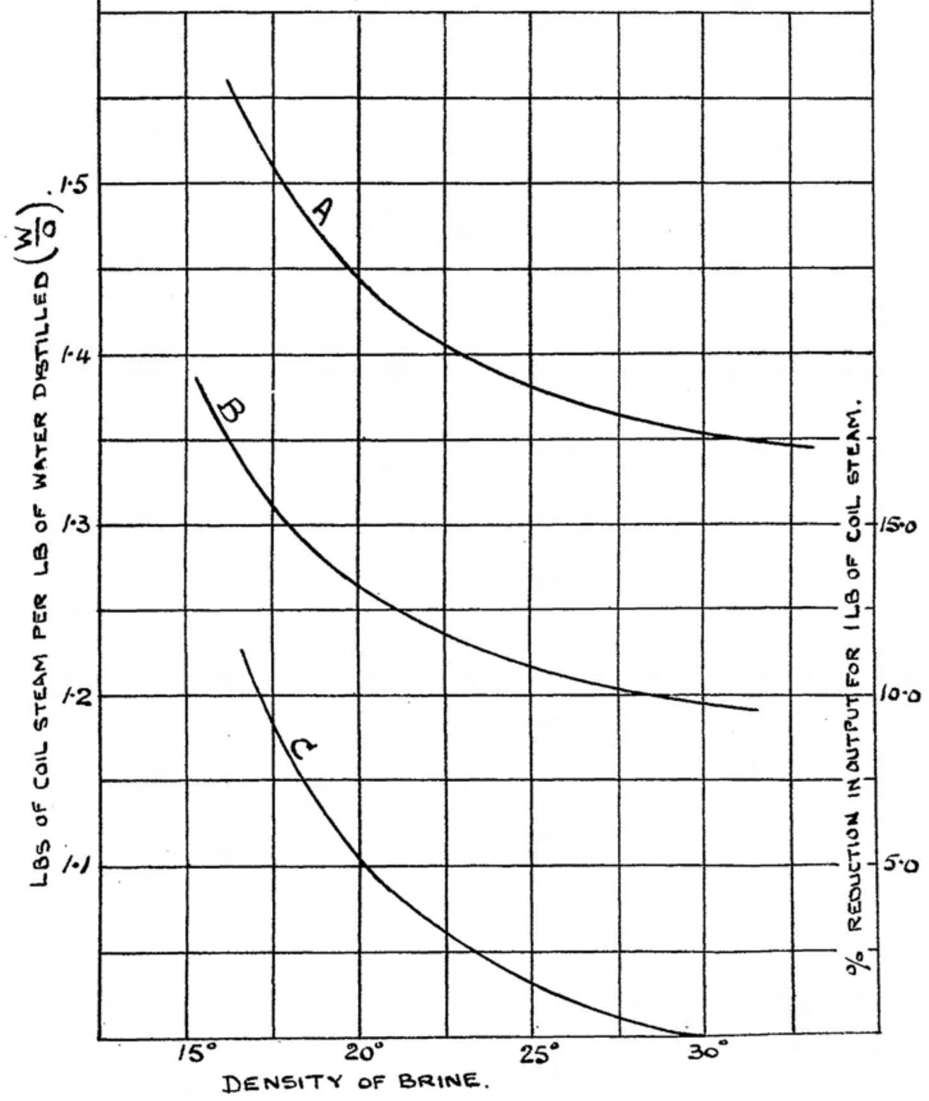
EFFECT OF DENSITY ON EVAPORATOR PERFORMANCE.

FIG: III

A - W/O, NO FEED HEATING.
B - W/O WITH FEED HEATING.
C - % REDUCTION IN OUTPUT PER LB OF COIL STEAM COMPARED WITH 30° DENSITY.



below the coil steam valve). In ships fitted with closed feed systems, it is important on this account that the temperature of the coil drain should be kept as low as possible, consistent with maintaining the desired output, as losses amounting to as much as 6 per cent. can be sustained by lack of attention to this point, when the coil drain is led to the feed tank. The fitting of a thermometer for this purpose is to be recommended, particularly if of the dial type—this can readily be made on board by adapting a pressure gauge to indicate the vapour pressure in a bulb filled with petrol and suitably arranged in the coil drain pipe.

Blowing Down and Cracking.—Tests were made to determine the best routine for blowing down and cracking, having in view the consequent loss of heat and operating time on the one hand and the improvement in hourly rate on the other. These tests are not yet completed, but it appears that at 30° density, under " steady rate " conditions, with sea at 50° F., the rate is improved by $\frac{5}{16}$ tons/hour at each cracking, depreciating a similar amount in the next 12 hours ; the average rate being 3·0 tons/hour. It may be deduced, on the assumption that 30 minutes working is wasted at each " blow down," that if this operation is carried out once every 12 hours the net output per diem is increased by about $\frac{3}{4}$-ton at the cost of the heat lost in two blow downs and in resetting the plant to work. Subject to confirmation of these results and to further tests under other conditions, it does not appear that blowing down and cracking is worth while.

PART II.—RELATIVE ECONOMY OF VARIOUS METHODS OF PRODUCING DISTILLED WATER.

Trials were carried out with a set of evaporators to demonstrate the relative efficiency of the following modes of operation :—

(*a*) Both working on live steam, 25 lbs. coil pressure.
(*b*) Working compound, 25 lbs. primary steam pressure.
(*c*) The evaporator working on live steam, 25 lbs. coil pressure ; vapour led through evaporator feed heater.
(*d*) One evaporator on closed exhaust and one on 25 lbs. live steam.

During the first three trials the closed exhaust steam was used for feed heating purposes, while in trial (*d*) the feed heater was shut off and all the exhaust taken through the coils of one evaporator. The coils were in the " steady rate " condition for 30° density, at which all these trials were run. The load on the boiler for extraneous services other than the evaporating plant, was kept as constant as possible throughout all tests ; measurements were made of the steam used by each individual auxiliary. It was possible from these and other tests to obtain data to enable Table I to be drawn up ; in this the only main variable is the steam consumption of the evaporating plant. The boiler efficiency has been assumed to be constant and equal to 80 per cent. for the purpose of making these figures strictly comparative; it having been found that such an efficiency can be regularly attained over the usual harbour range of output.

Curves are given on Fig. IV to show the effect of coil pressure on the output and efficiency of a set of evaporators, worked at 30° density (in the "steady rate" condition: sea at 50° F.). No difference could be observed in the output when using live steam or closed exhaust in the coils. As regards "compound" working, the rate is in general too low to meet ordinary ships 'requirements, unless the coils are quite clean—hence it is impracticable to make full use of the economy of this method. In this connection, it will be noted that the consumption of coil steam per unit weight of water distilled is not in practice by any means a complete criterion of the cost of producing fresh water. This apparent anomaly is due to the effects of feed temperature and of the changing ratio of $\frac{\text{superheated}}{\text{total}}$ steam; these combine to alter the evaporation of the boiler, as judged in lbs. of water per lb. of oil fuel.

As a general conclusion, it may be stated that if evaporators are worked at a density of about 20° for an indefinite length of time without scaling coils at all, a steady rate of water output will be achieved which will be about three-quarters of the normal maximum output with clean coils, and the amount of steam required per lb. of water made will only be some five or ten per cent. more than that required with clean coils.

Under these conditions the output is ample for normal ship requirements and the slight loss of efficiency is outweighed by the saving of the labour involved in coil scaling.

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TABLE I.

EVAPORATOR CONDITIONS.	COIL PRESSURE LBS/IN²	COIL STEAM TONS/HOUR	FUEL CONSUMPTION.		FRESH WATER TONS/HOUR	$\frac{\text{LBS WATER}}{\text{LBS STEAM}}$	$\frac{\text{LBS WATER}}{\text{LBS FUEL}}$
			LBS/HOUR	TONS/DAY			
2 EVAP^RS^ ON L.S.	BOTH 25	3·7	624	6·7	3·0	·817	10·75
—"— —"—	" 15	2·85	501	5·4	2·46	·86	11·0
—"— —"—	" 10	2·34	414	4·4	2·07	·88	11·2
1 ON L.S ; 1 ON C.E	25 & 5	1·85 + ·83	334	3·6	2·25	·844	15·1
1 SET COMPOUND	25 PRIMARY	1·4	271	2·9	1·56	1·114	12·9

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EVAPORATOR TRIALS FIGURE IV

EVAPORATOR FEED IN USE THROUGHOUT. (EXCEPT COMPOUND)
COIL DRAIN TO HEATER CONDENSER; 1¼ TURNS OPEN.

LBS OF WATER MADE PER LB OF COIL STEAM
- A. BOTH ON LIVE STEAM.
- B. ONE ON L.S & ONE ON C.E

WATER MADE
- C. ONE EVAP^R ON 25 LBS/IN^2 L.S. & ONE ON C.E. AT THE PRESS: SHOWN
- D. BOTH ON L.S. AT THE PRESSURE SHOWN.

E. COIL STEAM (COIL DRAIN 1¼ TURNS OPEN.)

DENSITY 30°; "STEADY RATES" WITH CRACKING TWICE DAILY. (SEA AT 50°F).