## TRIALS OF EXPERIMENTAL SUPERHEATER BOILER.

With the designs of superheaters hitherto fitted in H.M. Service as a result of the position of the superheater in relation to the generating surface, the superheat at full power is only about 100° F. at full power, and moreover the superheat falls off rapidly as the output of the boiler is reduced. Under the conditions obtaining in the Naval Service, fuel economy at low powers as well as at high power assumes considerable importance, and efforts have been accordingly directed to evolving a design for a superheater boiler which, while providing for an increased superheat at full power would also yield a sensible degree of superheat at low outputs. General experience has indicated that degrees of superheat appreciably exceeding 100° F. can be safely employed in the designs of turbine installations now developed.

It was decided that the superheat of the projected design at full power should not exceed about 250° F., and with this restriction the object was to attain as high a superheat as possible at the lower outputs of the boiler.

An examination of available trial data of small tube boilers, including somewhat scanty records of gas temperatures at different parts of the heating circuit, and a consideration of the heat transfer at different parts of the circuit indicated the probability that a sensibly constant superheat at varying outputs of the boiler might be obtained by fitting a superheater immediately after the third row (from furnace) of generating tubes. It was appreciated that with such a disposition the degree of superheat under certain conditions would probably be high, but seeing that the superheater would be shielded in the main from radiant heat, it was judged safe to try the arrangement with the object of gaining preliminary data, particularly as regards temperatures.

Having in view the test-shop facilities available, and for reasons of economy it was necessary to carry out the trial on the smallest scale possible, consistent with obtaining reliable data for future design purposes, and a partly completed small-tube Yarrow boiler originally commenced for use in a mine-sweeper was chosen for the experiment. This design was intended for 3,500 sq. ft. of heating surface and was fitted for 17 rows (athwart) of tubes each side; a small tube Yarrow boiler as ordinarily fitted in modern war vessels has 18 rows of tubes, and the efficiency of the boiler as obtained on these trials and referred to hereafter, making due allowance for the influence of the superheaters, is consequently less than would be obtained in an actual installation, as a result of the high funnel gas temperatures which attend the shorter gas circuit.

The arrangement of the boiler and superheater as first fitted is shown in Fig. 1. The superheaters are arranged symmetrically, and consist of horizontally disposed rows of " U " tubes extending from front to back of the boiler and connected at the front to rectangular steel headers to which the steam pipes from the boiler steam collector and to the boiler stop valve are connected. The path of the steam is indicated on the figure from which it will be seen that all the steam generated in the boiler passes through the superheater tubes on its way to the boiler stop valve. As thus fitted, the generating tube surface was 2,745 sq. ft., the superheater surface 382 sq. ft., and the combustion chamber volume 368 cu. ft. The boiler was oil-fired, six Admiralty pattern burners of 650 lbs. per hour output being fitted.

The results shown in Table I. were obtained during a series of short trials intended to give preliminary data respecting the temperatures.

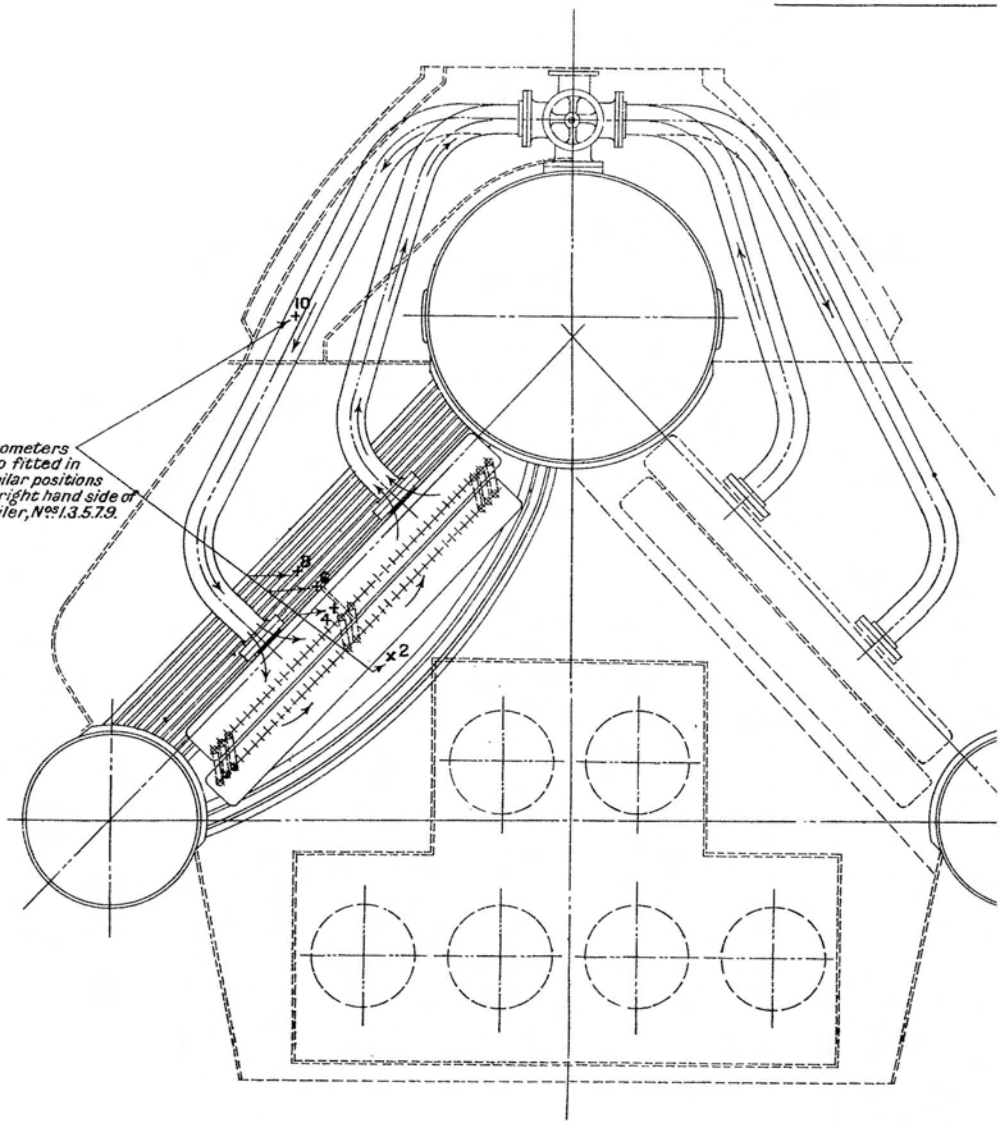
TABLE I.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Test No. - - - | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Oil burned per hour, lbs. | 450 | 900 | 1300 | 1950 | 2600 | 3250 | 3900 |
| Oil burned per sq. ft. heating surface per hour. | ·143 | ·286 | ·413 | ·62 | ·826 | 1·03 | 1·24 |
| Steam temperature °F. | 560 | 620 | 670 | 700 | 720 | 725 | 740 |
| Superheat - - °F. | 157 | 217 | 267 | 297 | 317 | 322 | 337 |
| Gas temperatures - | | | | | | | |
| Furnace side of Superheater. °F. | 687 | 912 | 1091 | 1354 | 1555 | 1602 | 1627 |
| Uptake ditto - °F. | 617 | 761 | 957 | 1127 | 1332 | 1363 | 1387 |
| Uptake temperature °F. | 459 | 482 | 530 | 663 | 802 | 927 | 1002 |

These results confirmed in a measure the deductions made, and, further, yielded valuable information as to the temperature changes in the gas circuit and the heat transference at the various stages, but showed that the position of the superheater was not a practicable one for everyday use in view of the high steam temperatures obtained when lighting up or standing by. It is of interest, however, to note that an examination of sample superheater tubes cut out after these trials showed that the metal had suffered no deterioration, although they had been worked at temperatures certainly exceeding 740° F.

Retaining the superheater in the same position, another row of generator tubes was next fitted betwen the superheater and the furnace, making four rows instead of three rows as in the preliminary trials. The generating tube surface was thus increased to 2,974 sq. ft., other things remaining the same. A series of efficiency and temperature trials was carried out in the test shop with this arrangement, with the results shown on Table II. Shale oil was used throughout. The superheat obtained is plotted on an output base in Fig. 2 from which it will be seen that a fairly high degree of superheat is obtained at low outputs of the boiler which would lead to a marked

EXPERIMENTAL




FIGU

GENERAL

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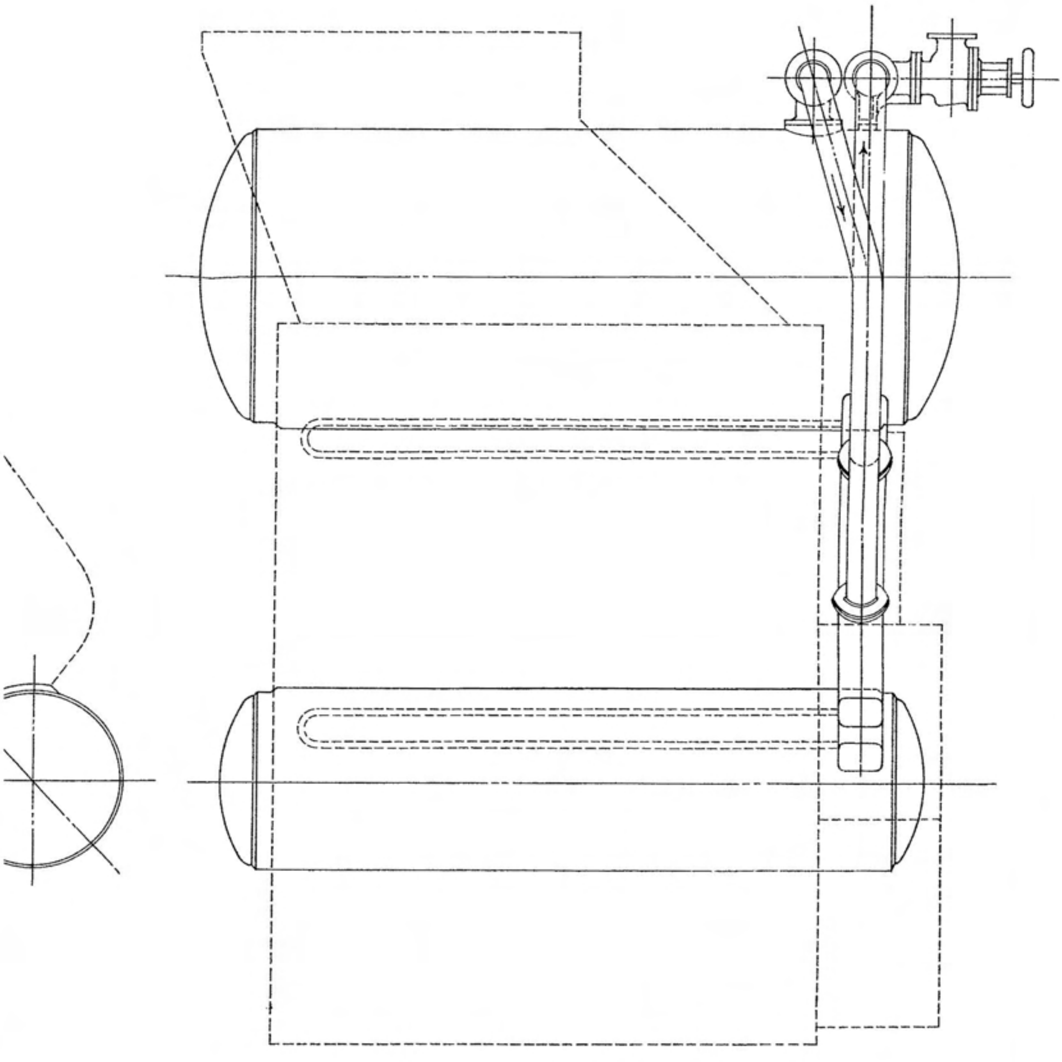
SUPERHEATER BOILER.



RE I.

ARRANGEMENT.

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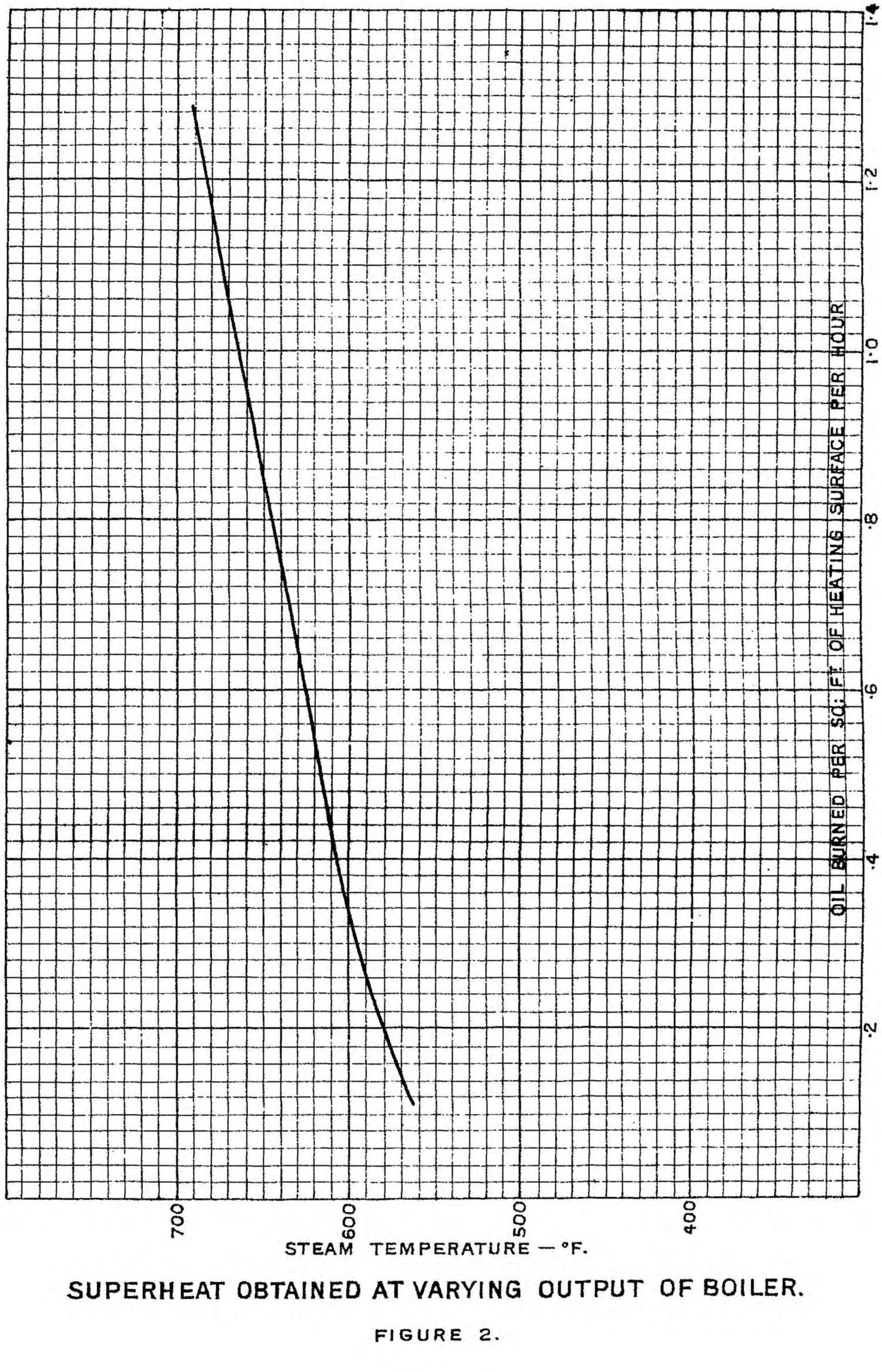


SUPERHEAT OBTAINED AT VARYING OUTPUT OF BOILER.

FIGURE 2.

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reduction in fuel consumption in a Service installation at cruising speeds.

Samples of the superheater tubes were also cut out for examination after these trials and no signs of damage or deterioration were observed.

The recording arrangements of the trial were designed to ensure accuracy in all the essential details and were briefly as follows :—

*Water Measurements.*—The feed tank was fitted with a water gauge and carefully graduated, arrangements being made for filling it as required from two calibrated tanks arranged above it. The steam was finally discharged to the atmosphere and the evaporation was measured by the feed-water supplied. The height of the water in the boiler gauge glass was noted at the beginning and end of each trial and any variation allowed for in the calculations. The boiler was worked at the desired output until steady conditions had been reached before any records were taken.

*Oil Measurement.*—The oil supply tank was calibrated and fitted with a gauge, and a measuring tank was arranged on a weighing machine above the supply tank from which weighed quantities of oil could be run to the supply tank. The height of the oil in the air vessel on the oil pump discharge was kept constant during the trials.

*Steam Measurements.*—The temperature of the steam was measured by mercury thermometers at the positions where it left the generator and where it entered and left the superheaters. A throttling calorimeter was fitted on the saturated steam discharge from the boiler in order to measure the wetness of the steam passing to the superheater. The steam calorimeter readings showed that the steam leaving the steam drum before entering the superheater was practically dry at all powers.

The pressure in the boiler was kept constant during the trials by regulating the opening of the boiler stop valve to the atmosphere.

*Gas Measurements.*—The gas temperatures were measured by nickel-iron thermo couples arranged on a flexible lead to pass through the nests of tubes from the front of the boiler in such a way that the junction of each thermo couple could be moved to any position in the tube nest on a line from the front to the back of the boiler. During each trial the readings for each pyrometer were taken at three positions, these three readings being taken within 30 seconds of one another. All temperature observations were repeated at intervals of 15 minutes :—

(1) At one-sixth of the length of the boiler from the front casing.

(2) At the centre of the length of the boiler.

(3) At five-sixths of the length of the boiler from the front casing.

Separate thermo couples were fitted on each side of each superheater, and at positions three rows and six rows away from the superheater on each side towards the uptake and in the uptake on each side of the boiler, as indicated in Fig. 1.

The uptake gas temperatures were also measured by a mercury nitrogen thermometer fitted in the uptake and the readings of the electrical pyrometers were checked against it.

An Orsat apparatus was used for the analysis of the funnel gas. The air supply was regulated to give a just discernable discharge at the funnel.

The gas temperatures given in Table II. represent average results, but some variation was observed between the temperatures taken at the three positions along the length of the boiler. On each of the low-power trials the temperature of the gases in the nests of tubes was much higher towards the back of the boiler than in the centre or front, and as the output of the boiler was increased the temperatures became more nearly equal at the back and centre, but the temperature towards the front of the boiler remained lower than at the centre and back at all powers.

This was confirmed by observations of the conditions in the furnace, where it was noticed that the flame and hot gases from the sprayers pass mainly through the back portions of the tube nests at low powers, and indicates that at low powers most of the heat is transmitted to the fire row tubes and the tubes towards the back of the boiler.

# TABLE II.

## TRIAL OF SUPERHEATER BOILER.

| No. of Trial | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Steam press boiler - - lbs. per sq. inch | 240 | 240 | 240 | 240 | 240 | 240 |
| „ „ superheater - „ „ | 240 | 240 | 240 | 240 | 240 | 231 |
| Final steam temperature - - - - ° F. | 564 | 580·5 | 605·6 | 632·4 | 663·1 | 686·4 |
| Superheat - - - - - - ° F. | 161·2 | 177·7 | 202·8 | 229·6 | 260·3 | 283·6 |
| Water evaporated per hour - - - lbs. | 4,133 | 7,940 | 16,180 | 23,625 | 31,745 | 38,150 |
| Feed temperature - - - - - - °F. | 52 | 49 | 50 | 50 | 47 | 50 |
| Factor of Evaporation - - - - - - | 1·320 | 1·331 | 1·345 | 1·358 | 1·375 | 1·383 |
| Equivalent water per hour from and at 212° F. - - - - - - - lbs. | 5,456 | 10,568 | 21,762 | 32,082 | 43,649 | 52,761 |
| Oil burned per hour per sq. ft. of total heating surface - - - - - - - - lbs. | ·11 | ·214 | ·437 | ·684 | ·991 | 1·283 |
| Oil burned per hour per cub. ft., combustion chamber volume - - - - - - lbs. | 1·012 | 1·955 | 3·986 | 6·244 | 9·044 | 11·704 |
| Water from and at 212° F. evaporated per lb. oil - - - - - - - - - lbs. | 14·64 | 14·66 | 14·82 | 13·96 | 13·11 | 12·25 |
| Water from and at 212° F. evaporated per sq. ft. heating surface - - - - lbs. | 1·625 | 3·00 | 6·48 | 9·56 | 13·00 | 15·72 |
| Overall efficiency - - - - per cent. | 77·48 | 77·82 | 78·44 | 74·0 | 69·65 | 65·09 |
| Air pressure - - - - ins. of water | ·15 | ·19 | ·37 | ·81 | 1·7 | 3·0 |
| Duration of trial - - - - hours | 1 | 2 | 2 | 2 | 2 | 2 |
| Gas Temperatures :— | | | | | | |
| Furnace side of superheater (average of six positions. ° F) | 700 | 907 | 1,280 | 1,364 | 1,560 | 1,594 |
| Uptake side of superheater (average of six positions. ° F) | 640 | 756 | 1,026 | 1,079 | 1,295 | 1,326 |
| Uptake temperature - (average of six positions. ° F) | 453 | 516 | 672 | 816 | 963 | 1,030 |
| Gas Analysis :— | | | | | | |
| $CO_2$ - - - - - - per cent. | 10·12 | 10·44 | 11·7 | 10·9 | 10·75 | 10·76 |
| CO - - - - - - - „ | 0·2 | ·05 | ·18 | ·2 | ·18 | ·25 |
| O - - - - - - - „ | 6·6 | 5·9 | 5·2 | 5·9 | 6·15 | 6·05 |
| Excess air - - - - - „ | 43 | 36 | 31 | 37 | 39 | 38 |