SUPERHEATED STEAM.

The use of highly superheated steam is almost universal for power generation installations ashore and the advantages realised there and elsewhere in respect to economy has led to its being from time to time considered for the Naval Service.

As a matter of technical history it may be first said that superheaters were used in the Naval Service up to about 1872, at which time the rapidly increasing steam pressures led to steam temperatures which proved too high for the materials—in particular packings—available at that time to satisfactorily withstand. At a much later date they were fitted in some of the boilers of a reciprocating engined installation for a battleship and in more recent years they have been fitted in two cruisers and a number of torpedo boat destroyers in association with direct-driven turbine installations. In none of these installations did the superheat exceed about 100° F. and the corresponding steam temperature about 510° F.

The case for superheat rests mainly on the fuel economy attending its use. Considering a turbine installation, there is a gain in economy to be expected on theoretical grounds, due to the greater amount of heat available for conversion into work, but experience shows that the actual gain is sensibly greater than the theoretical gain. The difference is explained by the fact that the frictional resistance of superheated steam in the turbine blades, nozzles, &c., is markedly less than saturated or wet steam, observing that the frictional losses in a turbine average about 70 per cent. of the total turbine losses. This difference between the actual and the theoretical economy, however, decreases in any particular turbine as its output is reduced.

From experience in power plant practice, it is generally agreed that the water consumption at full power of turbines working between the usual commercial limits of pressure, which for first-class practice do not differ sensibly from Naval practice, is reduced by about 10 per cent. for 100° F. superheat, 17 per cent. for 200° F. superheat, and 23 per cent. for 300° F. superheat.

This reduced water consumption does not necessarily lead to an equivalent reduction in fuel expenditure since each pound of superheated steam requires more heat to generate it. But beside the turbines themselves, there are other sources of fuel economy incidental to the use of superheat, such, for example, as that following the reduced steam consumption for the condenser auxiliaries which accrues from the smaller amount of feed water and rejected heat which the pumps and condenser respectively have to deal with. The auxiliaries as well benefit by the use of superheated steam and on the whole it is generally considered that a degree of fuel economy nearly approaching that corresponding to the improved turbine efficiency should be realised in a well-designed installation.

In the mercantile marine for installations with reciprocating engines of small power a fuel economy of about 11 per cent. has been obtained on continued service for a superheat of about 200° F.

The use of superheated steam may also be attended with some saving in machinery weight in the turbine installations as a result of the reduced fuel consumption, since the boilers, turbines, condensers, and some of the auxiliary engines can be made smaller. Some of this saving is discounted by the increase of weight due to the superheaters and their appliances, but given a design in which all possible advantage is taken of the superheat a net saving in weight should accrue.

These advantages, needless to say, are highly attractive for warship machinery designs, but in considering the application it is necessary to consider to what extent this economy in fuel and any saving in machinery weight could be realised under the peculiar conditions obtaining there.

The requirements of all first-class machinery, whether afloat or ashore, run generally on parallel lines in respect to such matters as economy at full speed, reliability and durability, but in Naval designs, superimposed on these common requirements, is the need for good economy at all speeds and, in addition, the utmost flexibility combined with simplicity in handling and maintenance. Economy in weight and space is also as a rule of greater importance than elsewhere. It results, therefore, that the design conditions are on the whole more severe for Naval practice.

The machinery for power plant ashore and for the mercantile marine is generally run at full power and is designed to get the best results at that power, results at lower powers being of little importance.

The superheater has, therefore, been arranged in such a position in the path of the furnace gas that the required degree of superheat has been obtained at full power, and with this disposition but little superheat is obtained at low powers. Where the degree of superheat has been high and therefore necessitated the superheater being arranged nearer the furnace, very special safeguards have been considered necessary to prevent risk of damage under changing conditions of steaming. These safeguards lead to complication and loss of flexibility. Separately fired superheaters would overcome some of these objections, although the types so far proposed have always embodied some arrangement of water tubes in the vicinity of the furnace to screen the superheater tubes from the intense heat of the furnace; which leads to complication. The additional weight, space, and complication would probably render them out of the question for Naval designs.

A warship installation includes a varied collection of auxiliary machinery for fighting and maintenance in addition to those ancillary to the propelling machinery proper and the auxiliaries therefore require a much greater proportion of the steam generated by the boilers than in shore practice. It is probable that in the course of time the majority of the auxiliaries will be of a rotary type, but up to the present Naval designs have necessarily included many auxiliaries of the reciprocating type. Reciprocating auxiliary engines can be designed to run more or less satisfactorily with superheated steam, but it is always necessary to employ liberal internal lubrication with it, and in view of the type of boiler fitted in the Naval Service and the degree of forcing which weight and space considerations entail, it has not been considered desirable in those vessels provided with superheated steam to employ it on the reciprocating auxiliaries. This course discounts to some extent the economy to be anticipated from the use of superheated steam, and leads to further complication and additional weight. Turbine driven auxiliaries of small power are moreover less economical than reciprocating engines designed for parallel conditions.

Experience ashore shows, further, that the advantages of superheat are not fully realised unless very steady steaming conditions are obtained, and for this reason it is improbable that the same economy would be realised under the rapidly-changing steaming conditions which usually obtain in the Naval Service.

Turning to the durability aspect, there is ample experience to prove that the superheaters used on shore have proved durable and reliable, and in some installations steam temperatures as high as 800° F. are employed with satisfactory results. Certain precautions have, however, been considered necessary in some cases to safeguard standing conditions, such, for example, as separate safety valves on the superheaters themselves. Shore superheaters are, to some extent, safeguarded for standing conditions by the circulation of steam used by the auxiliaries, and the risk of damage is therefore increased when, as has hitherto been the case in the Naval Service, the auxiliaries use saturated steam. In some designs ashore it is considered necessary to raise steam with the superheaters flooded, but such a procedure would hamper the flexibility in the Naval Service.

As regards the main turbines, some designs are of course more inherently suited by their practical features to the application of superheated steam. In turbines, of the impulse type, for instance, the pressure and temperature of the steam can be sensibly reduced in the first nozzles before it comes in contact with the blading or casing.

Steam temperatures up to 650° F. have, however, been widely used ashore in all types of turbines, including designs similar to those now fitted in the Naval Service, which being of small fast-running type, are comparable with those used ashore for power generation purposes, except for the astern turbine.

The risk of damage arising from suddenly-applied temperature changes in the astern turbine has led to hesitation in recommending any marked advance in the degree of superheat hitherto used. But with the improvements in the blading materials now used and the comparatively small size of the turbines required for the geared installations, it appears that there is but little, if any, risk of damage in turbines of the impulse turbines, and that the practical difficulties experienced in the earlier designs of other types of turbines can be satisfactorily overcome by suitable precautions in respect to design and in particular to the clearances.

The choice of materials is somewhat more limited in the superheated steam installations. In particular the rapidly-reduced strength of the ordinarily-used non-ferrous alloys as they are exposed to higher temperatures, lead necessarily to their being discarded for use in connection with parts exposed to superheated steam, such as mountings and steam-pipe connections. The available materials remaining are the special bronzes and cast steel; in the past cast steel has proved difficult to obtain and somewhat uncertain in manufacture, but the improving methods for manufacturing in this country will probably remove this handicap for future Naval work. Cast iron is liable to deterioration if constantly exposed to high temperature steam, and it would be necessary to replace any parts exposed to superheated steam by cast steel.

To summarise the foregoing remarks, the introduction of superheat on an extended scale in the Service awaits the development of a reliable and durable superheater design which will allow of its advantages being realised at low speeds as well as at full speeds, without introducing elaborate safeguards.

The gain in fuel economy to be expected in the Naval Service will be less than that realised ashore owing partly to the impracticability of employing superheated steam in many of the auxiliary engines, and partly to the rapidly-changing requirements for steam. This disparity will be to some extent reduced as rotary auxiliaries become more generally employed, provided of course, that they are not less economical than the existing reciprocating types which they will replace.

Some saving in machinery weight will probably be realised.

The machinery would be somewhat more complicated, and would require more care in running and maintenance.

On the whole, the durability and reliability of the machinery would be somewhat reduced, the extent depending upon the safeguards fitted which would in turn affect the matter of complication.