SELECTABLE SUPERHEAT

BY

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Introduction

Familiarity is said to breed contempt, and it is certainly true that often as one becomes familiar with any engineering device, the more transparently simple it appears. This article discusses only a few of the design considerations applicable to the damper control of superheated steam temperature, but it is hoped that it will show that even the simplest device may have more to it than meets the eye.

Superheater Characteristics

It is an easy matter for anyone requiring a boiler to specify that the steam temperature must lie within certain limits at certain rates of evaporation. Meeting the specification is, regrettably, far less simple, and even the most experienced boiler designer breathes a discreetly concealed sigh of relief on finding that he has met the requirements of a customer.

The achievement of the required characteristic in a superheater depends upon many factors, but notably upon the balance between the radiant and convective heat falling on the furnace and superheater tubes. It can be considerably influenced by other features such as stratification of the gas in layers of different temperatures or unequal flow of steam within the superheater tubes, to mention but two. Reputable firms have been known to exercise ingenuity in making their designs flexible enough to permit ready modification in the event of the actual superheater characteristic falling outside the specification.

In arriving at his desired characteristic, the customer may find that he requires a constantly high temperature at the ahead turbines to give him a high economy, while he also needs the ability to reduce the steam temperature when the astern turbines are in use. Further, he will perhaps also require that the constant temperature is to be selectable between certain limits. The boiler designer may, therefore, be presented with a specification which renders control of the superheater outlet temperature imperative.

The Babcock and Wilcox Selectable Superheat Boiler

Several different methods have been used for achieving control of steam temperature, among which is the two-furnace arrangement used in the boilers fitted in the *Weapon* and *Daring* Classes. The boilers used in the *Whitby* and *Blackwood* Classes, however, and now in the Guided Missile destroyers and G.P. frigates, are of the Babcock and Wilcox Selectable Superheat type. FIG. 1 shows the principle, in which the gases flow through two parallel paths from the furnace, one of which contains the superheater. The flow is proportioned between the two paths by dampers fitted between the generator tubes and the economizer.

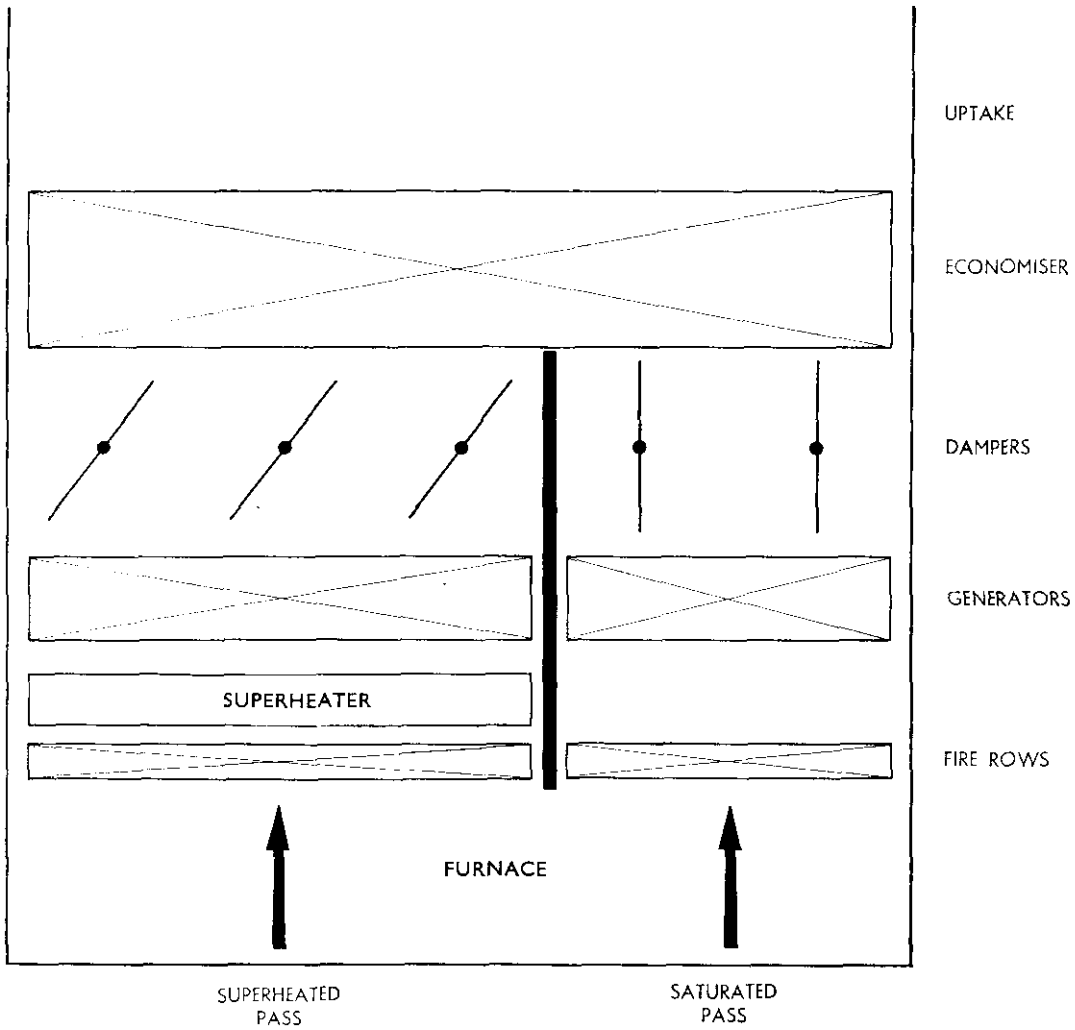

FIG. 1—PRINCIPLE OF BABCOCK AND WILCOX SELECTABLE SUPERHEAT BOILER

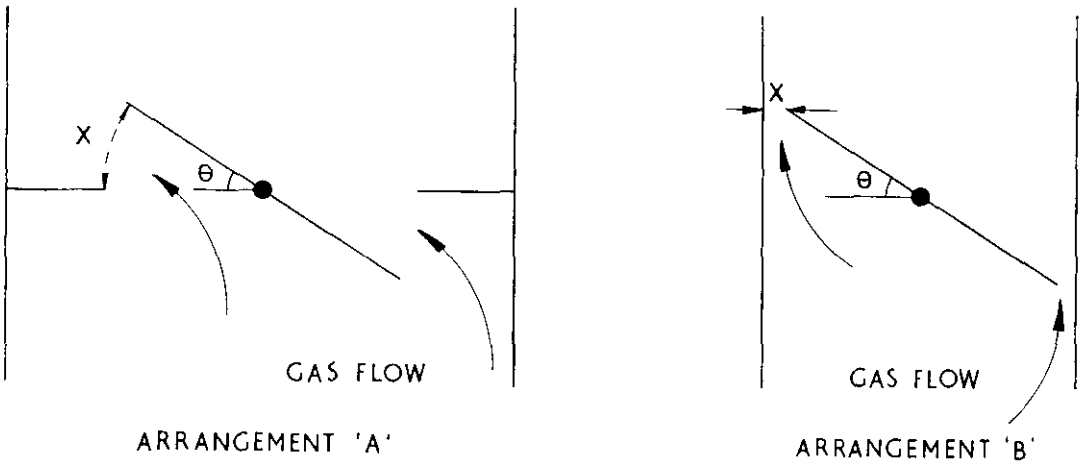

FIG. 2—DIFFERENT DAMPER ARRANGEMENTS

Damper Characteristics

FIG. 2 shows two identical dampers fitted in different trunkings. On each drawing, the area for gas flow is proportional to the length of line 'X'. In arrangement 'A', the area for gas flow is proportional to sine θ, while in arrangement 'B' it is proportional to 1-cos θ. It will be seen that although

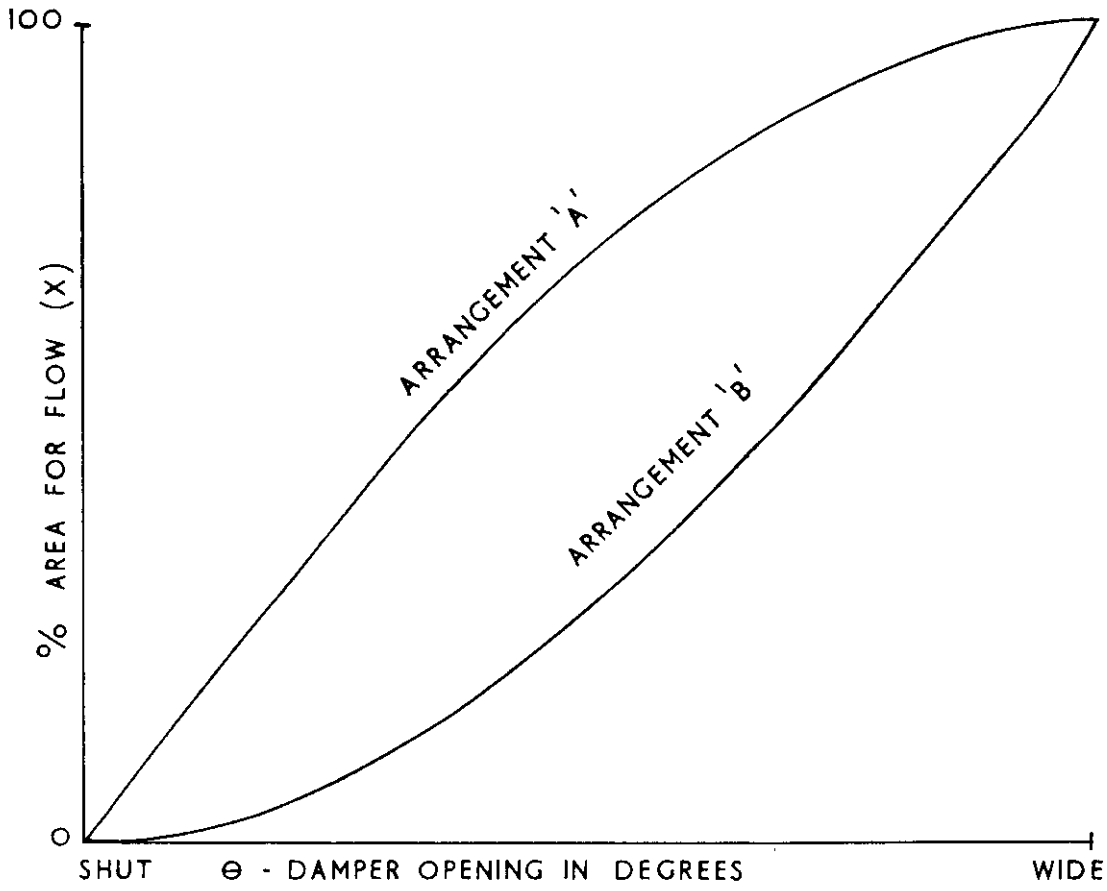

FIG. 3—CHARACTERISTICS OF DAMPERS SHOWN IN FIG. 2

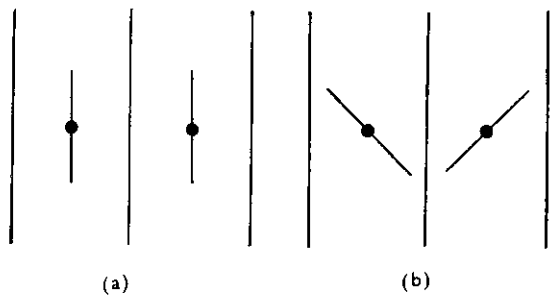

FIG. 4—IDENTICAL GAS DISTRIBUTION WITH DIFFERENT DAMPER POSITIONS

both dampers have been opened through the same angle, the areas for flow are quite different in the two cases. This is illustrated in FIG. 3, and it will be seen that, near either the shut or wide positions, the same change in damper angle will produce very different changes in area for flow in the two arrangements. This will have its effect on the control of steam temperature, and, for example, the damper in arrangement ' B ' would have little influence on steam temperature below a quarter open, were it controlling the flow of gas through a superheater. There is scope for producing any required damper characteristic in altering the casting shape where the dampers seat. A similar effect can be obtained by adding ' flights ' to the damper edges to alter the flow area for any given damper opening.

Damper Ganging

FIGS. 4(a) and 4 (b) show two different damper settings which will nevertheless give the same gas distribution between the two passes in each figure because the ratios of the areas for flow past the two dampers in each example are equal. Any required gas distribution can be produced by an infinite number of combinations of damper positions, but the draught losses through the dampers will not be the same in each case. These draught losses are parasitic, in that

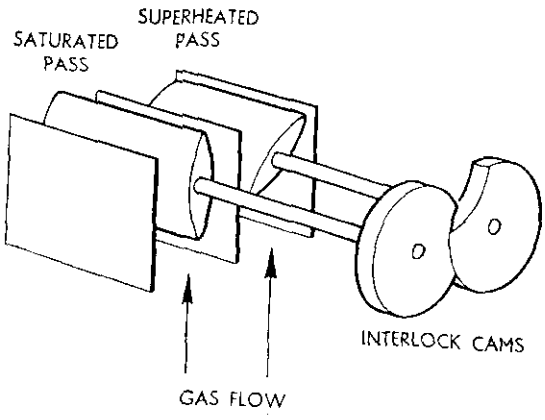

FIG. 5—PRINCIPLE OF THE DAMPER INTERLOCKS IN 'WHITBY' CLASS

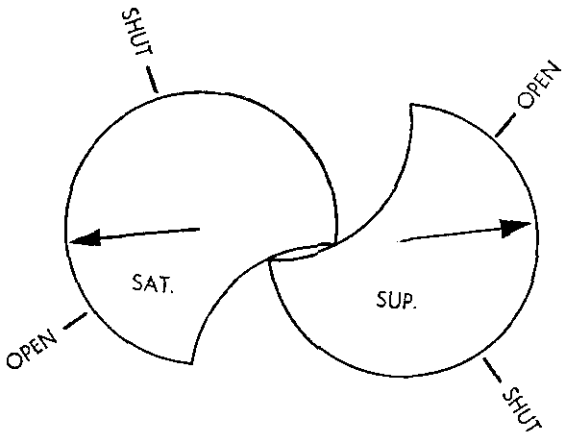

FIG. 6—POSSIBLE WRONG POSITION OF 'WHITBY' CLASS INTERLOCK

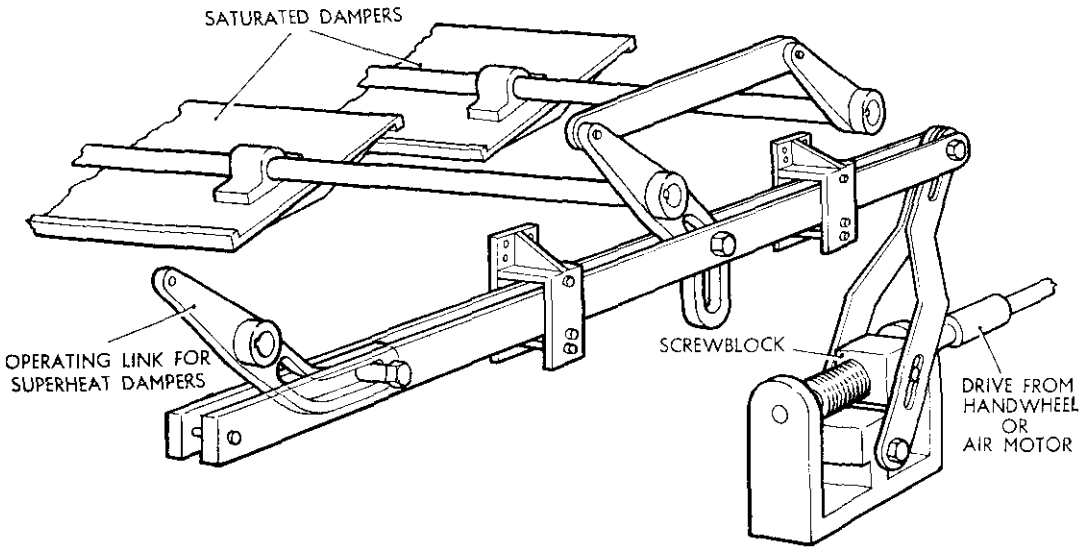

FIG. 7—ORIGINAL DAMPER GANGING IN THE G.M. DESTROYER

they do not contribute to the boiler's task of transferring heat from the fuel to the water or steam. Obviously the draught loss across the dampers in FIG. 4 (b) will be higher than in FIG. 4 (a) for the same gas mass flow. To keep the damper draught losses to a minimum, it is possible to gang the dampers together in such a way that the area available for flow is always as great as possible.

FIG. 5 shows the simple interlock which is used to obtain the minimum damper draught loss at all temperatures in the *Whitby* Class. It is similar to the interlock used in the past on boiler blow down cocks, and is intended to ensure that one damper is wide open at all times, with control being exercised on the other. This simple device has two disadvantages, however. The interlock is not perfect in operation, in that it is possible to move the cams into the positions shown in FIG. 6. and hence increase the draught loss unnecessarily. More serious, perhaps, is the fact that it presents the operator with two handwheels with which to control the steam temperature on one boiler, and any such unnecessary complication is undesirable. In this particular case, the result is that maintenance of a constant steam temperature is often too difficult for the operator when the boiler is anything but steadily steaming, and he tends to select a 'safe' position and leave the dampers alone, regardless of the steam temperature.

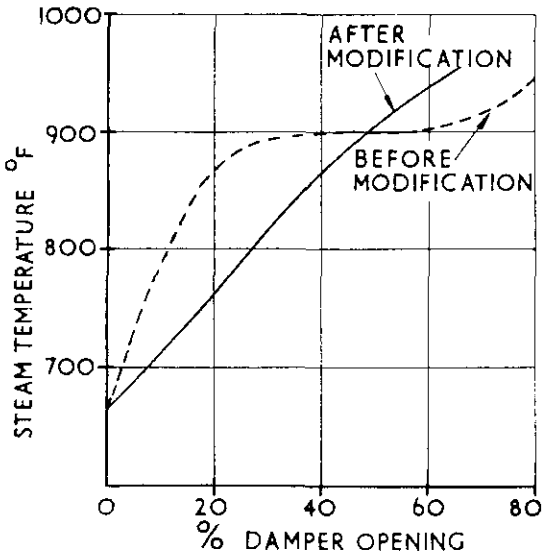

FIG. 8—G.M. DESTROYER DAMPER CHARACTERISTIC AFTER MOFIDICACATION

A different type of ganging was originally adopted in the G.M. destroyers. This is shown in FIG. 7, and is a lost motion device. Its result was identical to that of the *Whitby* design, in that one damper was wide at all times, and in the mid position both dampers were wide. It was, however, controllable by means of a single handwheel, and this made it not only simple for hand operation but also suitable for power operation by means of a single air driven motor.

Automatic Control of Superheat

If the response of a superheat control system is to be the same at all powers and temperatures, it is desirable that the variables shall

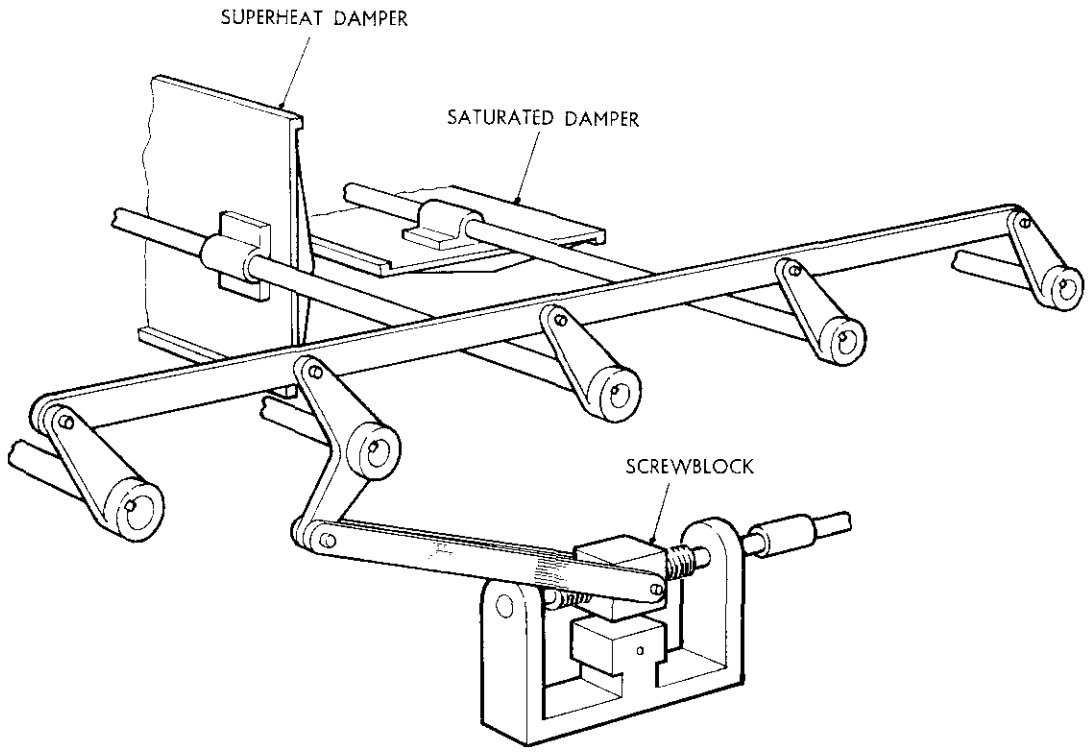

FIG. 9—MODIFIED DAMPER GANGING IN THE G.M. DESTROYER

bear linear relationships to each other. The dotted line in FIG. 8 shows the damper characteristics of the G.M. destroyer at 80 per cent power with dampers ganged as in FIG. 7 and it will be seen that the relationship between damper position and steam temperature is anything but linear. This is due to the damper characteristic causing the control to be ineffective for a considerable distance on either side of mid-position. It was found, as a result, that the response of the control system was very poor when manœuvring and instability of the control system ccurred if attempts were made to speed up the response. Furthermore, there was found to be excessive backlash present in this arrangement.

It was therefore reluctantly decided that although this particular method of damper ganging produced the lowest draught loss, it was unsuitable for use in conjunction with a control system and in any case contained too many sources of backlash. The damper operating gear was thus modified to that shown in FIG. 9, and it will be seen that the dampers are now never both wide open together; in fact, when either damper is wide the other is shut. Both dampers move in unison and the lost motion has been dispensed with. This produced the temperature/position characteristic shown in the full line in FIG. 8 and it can be seen that it is much more nearly linear than before modification. This is due to the fact that when one damper is in its least effective position, the other, on the contrary, is most effective. Thus the ineffective mid-range is largely cancelled out, and the result is that the controls now operate very satisfactorily, although the damper draught loss at any given temperature and power is slightly higher than before. It would have been possible to add flights to the damper blades to achieve a similar improvement in characteristic, but this would have been difficult in boilers already completed, and would not in any case have removed the backlash problem.

The investigation and development described was carried out on the prototype unit at the Admiralty Fuel Experimental Station, Haslar, where there is not only a G.M. destroyer boiler, but also one of each of the associated auxiliaries. It has thus been possible to investigate all aspects of any changes, for example, the effect upon the blower, and the modifications can therefore be used in the ships with confidence.

A Word of Warning

Although the selectable superheat boiler enables the turbines to be supplied with steam at any desired value within certain limits, there is unfortunately one danger present which cannot exist in a natural superheat characteristic boiler. If all gases are channelled through one pass and the fuel input is increased to its full power value, the situation is reached where the generator tubes in that pass are subjected to approximately double their normal heat loading, and, in some designs, the circulation in some of those tubes may break down. Thus we have the unfortunate situation that if a watchkeeper, worried by too high a steam temperature, closed the superheat pass damper to reduce the temperature, he might burn out some of the most highly loaded generator tubes in the saturated pass. It is important, therefore, that the handbook for any selectable superheat boiler should be consulted to determine whether any limitations are imposed on the damper positions at high powers.

This is an unpleasant example of that engineering half-truth which states that whenever a difficulty is removed from a system, a compensating difficulty is introduced somewhere else in that system. It is also confirmation of the fact that modern highly rated boilers are more complex than the familiar Admiralty three drum and that their correct operation is worthy of just as much care as is normally lavished on the turbines.