BATTLE OF THE BOILERS

BY

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THE BATTLE

In the last years of the nineteenth and the early years of the twentieth century —1894 to 1903—the so-called Battle of the Boilers raged with varying intensity in marine engineering circles, in technical papers, and, owing to the vigour of some of the protagonists—notably William Allan, M.P. for Gateshead—in the daily press.

Towards the end of that century it had become increasingly evident that, if warships were to carry more and heavier armour and armament, the most obvious action would be to reduce the great weight of water carried in the cylindrical boilers, with other reductions in the weight and space taken up by the propelling machinery. Inventors of the maritime nations were advocating a complete departure from the old and tried ' Scotch ' boiler and offering steam producers wherein the water was carried in tubes heated externally by the furnace and capable of standing higher pressures.

The Admiralty studied the problem and the candidates considered for adoption included the Belleville—a large tube boiler—the Yarrow, Thornycroft, Normand, Reed and other small tube boilers, and the Niclausse—which had large tubes with internal small tubes. The Belleville appealed particularly on account of its apparent sturdiness and because it was already in successful use in the Messageries Maritimes. In addition, it required no access space at sides or back beyond that taken up by casings, mud drums and firing space. More room was thus available for fire grate area than any other boiler then known could provide, while the elements of which it was mainly composed could be removed through ordinary hatches, making the large openings, then usual in the armour deck, unnecessary. These advantages naturally appealed to the Director of Naval Construction.

An engineer officer—Edouard Gaudin—a native of Jersey, and easily mistaken for a Frenchman, was sent on a voyage of investigation in one of the Messageries Maritimes ships. His report, coupled with the fact that S.S. *Laos* of that line, had given three years' continuous service without important overhaul, determined the Admiralty—Sir John Durston was then the Engineer-in-Chief—to decide on this boiler for all the capital ships then about to be built.

Accordingly, the gunboat *Sharpshooter* had her existing boilers replaced by Belleville boilers and encouraging trials were carried out. Her new fuel consumption was found to be 1·8 lb per indicated horsepower, then quite a good figure. The large cruisers *Powerful* and *Terrible*, each with forty-eight Belleville boilers, were next put in hand, and during the following years several classes of battleships and cruisers were laid down.

During the same period, steam pressures were raised to 350 lb in some ships and to 300 lb in others. Piston speeds were also increased. These changes introduced new difficulties with steam joints and new problems with the white metal bearings. Other changes were also made and, unfortunately, as a direct consequence, too much space was surrendered in certain ships, so that access to the auxiliary machinery was cramped, making repair and attention difficult. Engine-room temperatures became very trying to watchkeepers and, all-in-all, some of these ships became decidedly unpopular with engine-room hands. The larger cruisers were all ' four-funnel ' ships. This feature carried much prestige. In China especially, a ' four-piecey funnel ' ship was looked on with great respect. Nor was the four-funnelled ship without its prestige value on the high seas generally.

This very extensive, not to say overwhelming, order for new ships and, particularly, novel boilers, during the late 'nineties' distributed in a comparatively short time amongst dockyards and contractors led inevitably to a variety of troubles. It soon became evident that there had been insufficient ' briefing ' either of the builders, the engineer overseers, or of the men who were to take charge of the ships in service. Small differences crept in, or were permitted, and unfortunate departures from experienced French practice were made. To-day so important a development would undoubtedly be accompanied by a ' Belleville Handbook ' and instructional courses would be arranged for officers and men. Had this been done the subsequent story might have been very different. But it was not, even though the possibility of trouble was foreseen. *Brassey*, of 1896, for example, while commending the Admiralty for its courage in going ahead and not waiting for the Merchant Navy to try out water-tube boilers first, at the same time foresaw considerable teething troubles and expressed doubt as to whether Belleville boilers could be forced.

Apart from the boilers, the turbine was coming to the fore in 1898, and there were rumours of liquid fuel. Russia was already trying it out in the Belleville-boilered ship *Russia*. So the Admiralty had plenty of calls on its attention.

As the new ships with water-tube boilers came into service, several experienced something a good deal worse than mere teething troubles. There were really serious breakdowns. These breakdowns were by no means always due to the boilers. But a good deal of mud stuck to the latter. Conspicuous amongst the failures was the breakdown of *Hermes*, involving her return home after only a year in commission ; and there was also the extravagant fuel consumption of *Europa* on passage from Portsmouth to Sydney. It took eighty-eight days, of which fifty-eight were under steam and the remainder coaling ; and consumption worked out at 5 lb per indicated horsepower ! That high rate of consumption was, in fact, largely a consequence of leaky condensers, leaky joints and a consequent high fuel expenditure in distilling. But it was the reputation of the boilers that chiefly and unjustly suffered.

In 1896 *Powerful* ran successful trials and her sister *Terrible* did well in the Boer War. But both ships experienced troubles due to cramped machinery space and excessive engine-room temperatures. *Powerful* continued in sea-going service until 1912. *Terrible*, having made one trip to China at 11·8 knots in 1902, burning 200 tons of coal a day, made another in 1904 at 12·6 knots, burning only 100 tons a day, indicating more competent handling and understanding, and disproving the idea, then current, of rapid deterioration of the boilers.

By 1900 there were already a million indicated horsepower of naval machinery dependent on Belleville boilers. But the Admiralty was by then being heavily criticized for its policy. *The Engineer*, for example, gave a great deal of space to the question, and was highly critical of the departure in boiler practice. In July, 1900, it did not hesitate to write of ' the failure of a great experiment,' and it joined in the appeal for a Committee of Enquiry. Comment elsewhere, after a paper had been read by Sir John Durston before the Institution of Civil Engineers was, ' that he had driven the last nail in the coffin of the Belleville boiler.' Another engineer said that the Belleville was probably the worst boiler in existence ! The boilers of *Powerful* and *Terrible* were retubed at about this time with solid-drawn tubes—a first fitting in later ships. There was an immediate renewed outcry, as these tubes had to be obtained from Sweden. British makers could not produce the right steel. Simultaneously attention was called to the fact that Russia, Holland, Portugal, and Elswick were trying the Yarrow boiler, and U.S.A.—very tentatively—the Babcock.

Sir Wm. Allan, M.P., was conspicuous in his attacks in the House and elsewhere. In September, 1900, the Admiralty yielded to the clamour and appointed a committee under the chairmanship of Admiral Sir Compton Domville to inquire into the question of water-tube boilers for H.M. ships. All the members of the committee were connected with the Merchant Navy or Lloyds, except Chief Inspector of Machinery J. A. Smith. Interim reports appeared in 1901 and 1902, and a final one in 1904. The very first report recommended the abandonment of the Belleville boiler except in ships already too far committed, and the fitting of Yarrow or Babcock boilers in future capital ships. The report was unanimous, except for some soft-pedalling by J. A. Smith. It is of interest to note that the committee also recommended the fitting of a mixture of cylindrical and water-tube boilers. This recommendation was adopted to some extent, but was recognised later to be a great mistake.

Despite the recommendations of the first report, Sir Wm. Allan kept up his attacks. So convinced was he of the demerits of Belleville boilers that in 1903, on hearing of proposed trial runs of *Spartiate* and *Europa* to Hong Kong and back he offered 2 to 1 against the former and 10 to 1 against the latter completing the trials—a bet he would have lost. The final report of the committee, dated June 12th, 1904, was sent to Admiral Domville for signature. By then the ' battle ' was dying down. He was flying his flag in the Belleville-boilered battleship *Bulwark*. In his covering letter he wrote :—

' My experience with the Belleville boilers on the Mediterranean station has been very favourable to them as steam generators, and it is clear to me that the earlier boilers of this description were badly made and badly used. We have had no serious boiler defect in any of the ships out here, and the fact that two ships are about to be recommissioned with only the ordinary repairs undertaken shows that their life is not so short as I originally supposed. However, the second commission of these ships will be a very good test of the staying power of their boilers.'

But breakdowns and delays had made, by that time, too strong a case against the boilers, even though many of the troubles experienced had nothing to do with them. For example, *Hermes* had to come home after one year in commission on the North American station ; *Spartiate* broke down badly on her first effort at acceptance trials—entirely due to condenser leakage and bearing troubles—and *Good Hope* never ran for any length of time at her higher revolutions until all her main bearings had been remetalled by Portsmouth Dockyard. The fact was that the ships then building embodied many new departures and advances. But the dog that got the bad name was the Belleville boiler.

Guerilla warfare and sniping against the Belleville boiler continued for many years, but the ' battle ', in fact, ended soon after the issue of the committee's first report in 1901. The word ' Belleville ' does not occur in the index to the second volume of *The Engineer* for 1902, nor does *Brassey's Annual* of 1903 make any comments. There remained the Belleville-boilered ships. Due to their earlier treatment, or to congenital defects, there were a few Belleville ships which remained ' lame ducks ' at the opening of the first world war, notably *Canopus*, upon which, for a time after the lost battle of Coronel, the defence of

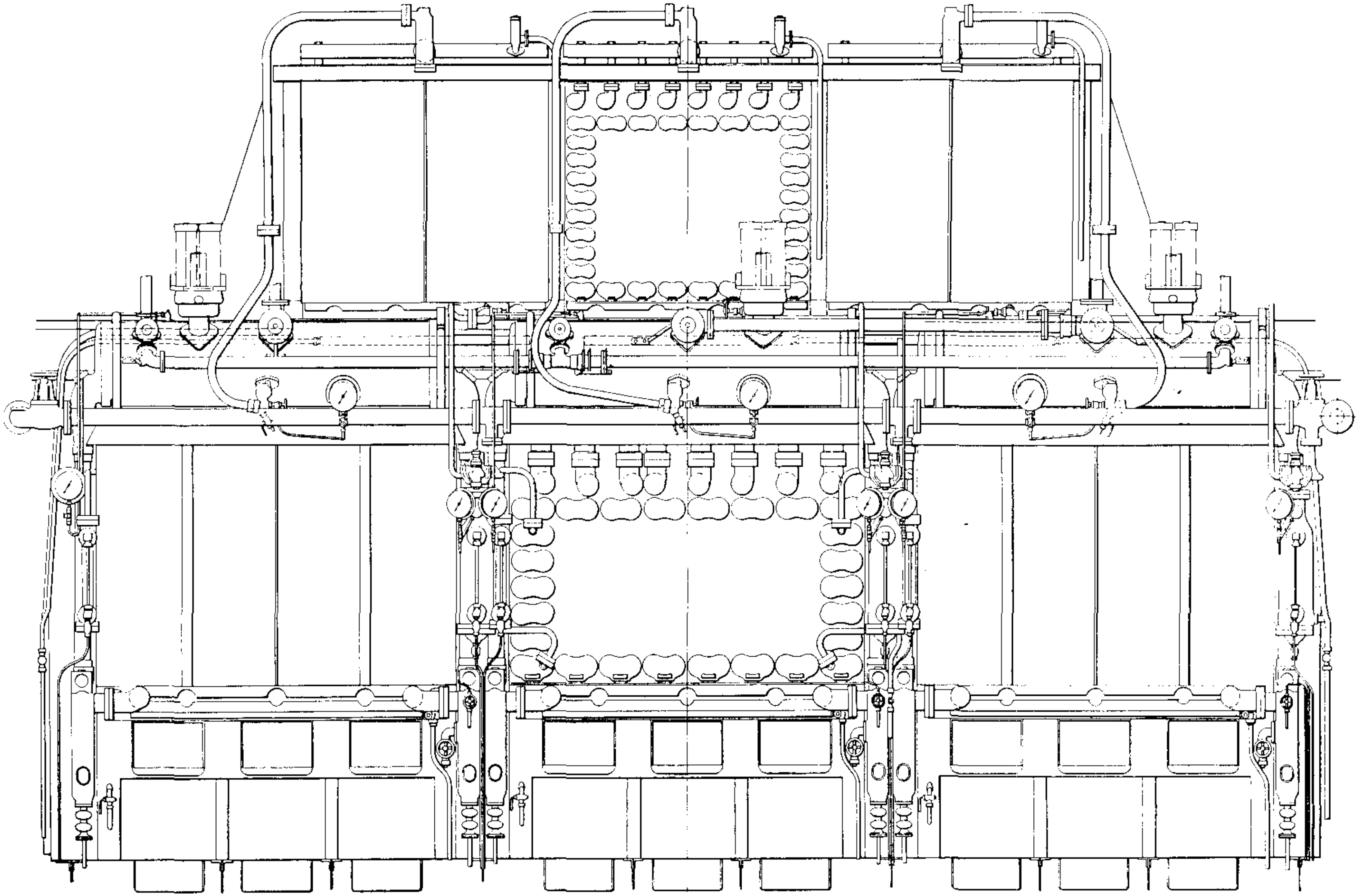

FIG. 1—BELLEVILLE BOILERS OF H.M.S. 'SPARTIATE'—FORWARD GROUP

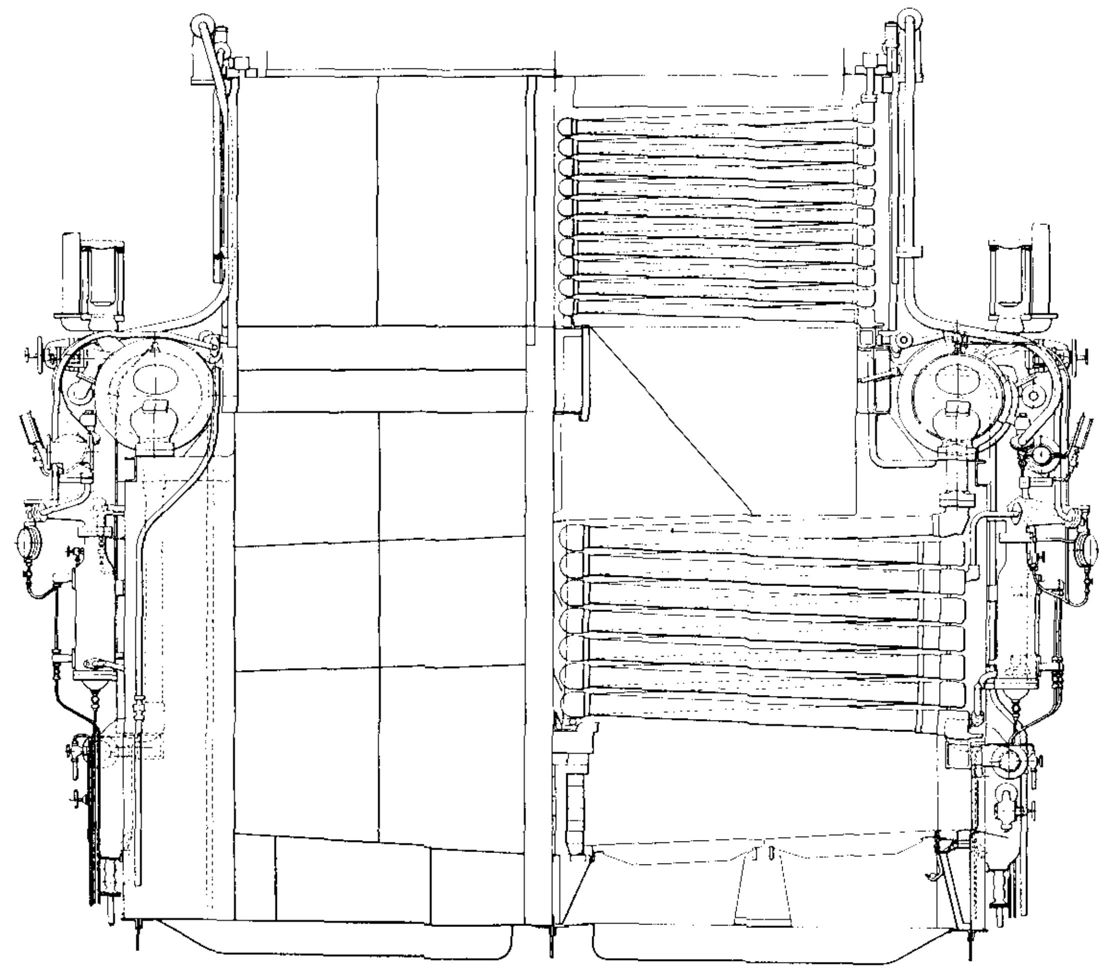

FIG. 2—BELLEVILLE BOILERS OF H.M.S. ' SPARTIATE '—FORWARD GROUP, END VIEW

the Falkland Isles solely depended. They had the reputation of driving their engineer officers to breakdown, or even insanity.

Unquestionably the Belleville boiler acquired a bad name far less through its own defects than through its association with defective machinery. Nor should the effect of the mistaken loyalty of many naval engineers to the Scotch boiler be overlooked. That loyalty was exemplified up to a few years ago, by an elderly retired marine engineer—a regular attendant at the meetings of the Institute of Marine Engineers—who would generally find the opportunity, no matter how apparently irrelevant to the paper under discussion—to get up and say, ' There is naething like the Scots boiler ! '

THE BELLEVILLE BOILER

So much for the ' battle ', now for some detail of the boilers. What was the design of this boiler that became the subject of a ' battle ' ?

The drawings, FIGS. 1 and 2, are redrawn from the issue of *The Engineer* for April 7, 1899, and show the boilers of H.M.S. *Spartiate*, a later *Diadem* class cruiser laid down in 1897. A Belleville boiler was built up of a number of flattened spirals or elements, each composed of straight tubes of large diameter —4½ in—screwed into malleable cast iron junction boxes at either end, those in front having hand hole doors. These elements rose from a common feed box in front of the boiler, and delivered into a cylindrical steam drum at the top, which was fitted with a system of baffles to prevent priming. Water level was about four rows from the top. Under steam, feed entered the steam drum, descended to the feed box by downcomer pipes—one at either end—through mud drums, which slowed down the flow, and captured any sediment, which could be blown down as needed.

The automatic feed control consisted of a chamber with float, whose movement varied with the water level, and depended for its efficient working on the almost frictionless movement of a spindle in a gland packed with ' Belleville ' packing—a metallic mixture, then a patent. A rod was attached to a lever from this spindle, and one could tell if water was passing by feeling it, while if pulled down it admitted extra water. Later automatics have improved on the Belleville and need less care and attention. In ships in which the writer served, the care of these automatics—forty-three in *Good Hope*—was the special duty of one mechanic. They were found to be completely satisfactory and reliable. But unfortunately, the Admiralty—probably from some economic motive—issued a packing to its own specification, which led to much trouble. Chief Engineer Gaudin, upon whose report it will be remembered the Admiralty adopted the boiler, refused to use this substitute, and eventually the Admiralty produced either the real thing, or a true equivalent.

The importance of automatic feeding, now realized as essential where the relation between water content and steam production is small, was impressed on the writer by Gaudin when first reporting to him on joining the *Spartiate*. Having replied in the negative to Gaudin's question, ' Do you know anything about Belleville boilers ? ' the writer was directed, ' Go along and pack an automatic gland, then you will known all about Belleville boilers ! '

Economizers were fitted, except in the earliest ships, built up of similar, but smaller, elements to those of the main boilers—see Fig. 2. They preheated the feed, and were invaluable in Fleet work for controlling the output of steam on sudden stoppages or alterations in speed. By flinging open their doors, draught could be checked, and the discharge of clouds of smoke—so important in coal-burning days—prevented.

A unique device was the junction of the bottom of the element to the feed-box by means of a single ' anchor ' bolt, with a coned nickel sleeve as the jointing material. This, the most delicate part of the boiler, unfortunately, needed more gentle handling and treatment than was reasonably to be expected from men only accustomed to cylindrical boilers, and the traditional use of a good deal of brute force in their maintenance. Freedom of expansion of the back junction was thus provided for, but it was important that this back box did not get fixed by the accumulation of soot. The disastrous and fatal explosion in *Good Hope* at Gibraltar, soon after her return from the much publicized trip to the Cape of Joseph Chamberlain in 1904, occurred when the anchor bolts were being tightened under steam. This accident, of course, revived all the old distrust of the Belleville and, in fact, of all water-tube boilers, and probably further delayed their introduction into the Merchant Navy.

A troublesome fitting, later discarded as unnecessary, and almost an inventor's fad, was the provision of fusible plugs in two of the front junction boxes of each element. They were intended to blow if water level reached danger point. But they frequently blew without real cause. In theory they could then be replaced by means of a ' pistol '. But few became expert in the use of this device and the majority never succeeded in mastering it. Such replacements under steam were seldom reliable. So the plugs were usually riveted over inside when the boiler was cold, or, contrary to regulation, replaced by steel plugs, leaving the care of the water level to the automatics and watchkeepers. After all, one or more jets of steam at 350 lb pressure, though only through a $\frac{3}{16}$ orifice, were found very disconcerting to efficient firing, during the time when someone on the floor plate struggled to stop them with a pistol !

Blowing engines were a part of the outfit, to supply air above the coal surface, but with good stoking their use was often discarded, though they were useful for tube sweeping in harbour.

Feed pumps were of Belleville design, up to and including the *Spartiate* class, but were superseded by Weir's in *Good Hope* class and later ships. Though no doubt satisfactory for the steady steaming of merchant ships, under service conditions they would suddenly and unaccountably stop. It was necessary to keep a heavy copper hammer hanging by each pump, from which a blow on the valve arm would usually restore them to duty ! Weir pumps were a very great improvement, though the larger sizes resented having to deal with the light work of harbour steaming, and would not have responded to a copper hammer ! They were kept in good behaviour by close and frequent attention to the fit of the shuttle, and like the automatics received the constant attention of one mechanic.

The boiler working pressure of 350 lb or 300 lb was reduced to 250 lb by a large valve in the engine-room, which also acted as a separator in case of priming. Another fitting, abandoned almost from the first, was a non-return valve in the downcomer, but the positive circulation later found to be assured proved it unnecessary and, in fact, with sudden changes of steam output, it probably had an effect quite opposed to its intention.

The Committee of Inquiry listed four primary defects in the Belleville boiler :—

(*a*) Defective circulation.
(*b*) Necessity of an automatic feed.
(*c*) Feed pressure greater than steam pressure.
(*d*) False reading of gauge glasses.

Chief Inspector of Machinery J. A. Smith did not agree, but the prestige of the rest of the committee smothered his objections. In the light of modern experience and practice these objections seem quaint, especially (*b*) and (*c*), which are now common practice. That the circulation was defective was not true. There is no boiler to this day where the circulation is more direct and positive, and in many modern boilers the travel of the steam, or steam and water mixture, is far longer than the 50 ft that so startled the committee. The last objection sprang from inherited distrust of anything but hand control, and memory of disasters that had occurred in cylindrical boilers from water shortage.

The committee also commented on the insufficient preliminary instruction given to those in charge. It may, indeed, be taken as a compliment to the engineering branch of the Navy, that it was capable of taking on such a novelty, without special courses or books of instructions and without much more trouble than actually occurred.

SERVICE EXPERIENCE

At first it was not understood how greatly the efficiency of water-tube boilers depends on their being worked at a high proportion of their designed output, though service conditions frequently involve the connection of more boilers than are actually required for economic steaming. During the acceptance trials of *Spartiate* in 1903, the advantage of maximum output per boiler was demonstrated. Somewhere to the west of Land's End, extreme condenser troubles developed, the density at the condensers almost defying the Service hydrometer. The contractors, Messrs. Maudslay, were then in liquidation, and

Gaudin had been appointed to act for the receivers, and so was endowed with unusual authority in relation to the dockyard officers. In this emergency they would have jogged home with all boilers connected and in use, and therefore circulation at a minimum or near standstill. He insisted, however, on reducing the number in use to the least required, if forced, for a reasonable speed, with the result that, owing to the rapid circulation, salt was deposited to a depth of nearly an inch on nearly all the tubes, and not only at water gauge level, as would have been the case if steaming easily. What is more, no tubes or joints gave out, and all were repairable, though many were badly bent.

Repairs having been completed and final trials carried out satisfactorily, *Spartiate* commissioned for a ' trooping ' trip to Hong Kong with relief crews for ships on the China station, in company with the *Europa* similarly engaged. On the return voyage both ships were to carry out a series of trials. The crews embarked were new to the boilers, and at least half the stokers were newly entered ' second-class ' and wholly inexperienced. But as the crew for the homeward journey would be mainly seasoned men from the Belleville boilered battleship *Ocean* the trials could be looked forward to with some confidence.

After a fortnight in Hong Kong making good large main steam pipe joints—a frequent trouble in those early days of higher steam pressures—the relieved crews embarked, and the two ships sailed for home, having the run to Singapore at economic speed to shake down.

The trials carried out were :—

Three runs of eight hours each at full speed ; fifty-four hours at three-fifths power ; thirty-two hours at three-fifths power ; four-fifths power on the last lap—Gibraltar to Devonport.

The new crew proved at first a great disappointment, as they had been brought up to put no trust in their automatics, but to treat their boilers as if they were cylindrical, and only to be forced at the quarterly trials. However, by the time Singapore was reached, they had been bullied into leaving the automatics alone, and into firing and cleaning the furnaces in the way already proved successful in *Spartiate*. At full power *Spartiate* developed 18,000 i.h.p. and made 20·75 knots, the *Europa* less, but still a creditable speed allowing for the boilers of earlier design, and troubles other than those due to her boilers. All *Spartiate*'s trials were completely successful. On the outward trip she had burnt 2,600 tons of coal for 13 knots, the *Europa* 3,600 for 10·75. On the return 10,000 miles *Spartiate's* figure was 4,500 and *Europa's* 5,600. Up to that date the nearest comparable figure was 4,000 tons by the *Blenheim* for the outward run.

The appalling fuel consumption of some of the earlier water-tube boilers was largely due to covering insufficiently the wide furnaces and to neglect of thorough cleaning at the sides—thus reducing the effective grate area. In addition, the prevalence of leaky joints and condensers involved extra distilling. Smokebox doors, too, were often too light and did not close properly, while distrust of the automatics led to priming. Incidentally, it was one of Gaudin's maxims that the proper place of the engineer officer of the watch was far more in the boiler-room than the engine-room, where the E.R.A.s could be quite well left to look after the engines, except on entering or leaving harbour, or at action stations.

The good fuel results of these trials, and *Spartiate*'s successful trials generally, were regarded with doubt and even suspicion in some quarters. But, as evidence of the genuineness of her coal economy (which would be appreciated by engineers and others of the coal-burning era) there can be quoted the fact that, arriving at Gibraltar and coaling before her record run home, she coaled at a rate that entitled her name to be placed on the board then kept at the end of the Mole, as having beaten all the regularly commissioned ships of the Mediterrean

Fleet up to that date—proof that she had not acquired any ' plush ' or excess coal. Fortunate in her chief engineer, she was also fortunate in her commander, the enthusiastic and original Guy Gaunt, and by the time she reached home the morale and esprit of the ship were of an order only achieved as a rule halfway through a commission.

Her small staff of permanently appointed officers and men again became the nucleus of a new complement of second-class stokers and inexperienced ratings to prepare for the annual manœuvres, joining up with the regularly commissioned ships of the Channel Fleet. Not only did *Spartiate* give satisfaction, but, on a run to the Canaries, when the order came to proceed independently at full speed, she showed her heels to the more recently built flagship—*Bacchante*—and was promptly detached on an independent mission.

A major defect of all cruisers of that period was the distribution of their coal into a large number of awkward placed, small and remote bunkers. In consequence, on any prolonged passage at half speed or over, an increasing number of hands had to be borrowed from the upper deck to trim coal—this, in spite of the large engine-room complements—600-odd in *Good Hope*. During this run to the Canaries, when ' Action ' was sounded, and all engine-room hands went below, the seamen emerged from the bunkers to their guns, looking like coal miners, many physically weary from hard work in the bunkers. Manœuvres over and the ship paid off, Chief Engineer Gaudin and the writer were transferred to *Good Hope*, a ship which with most other Belleville ships, lived out their useful lives, no longer the target of controversy. *Good Hope* was in continuous service until sunk at Coronel.

Subsequent to the commissioning of the *Spartiate* the writer was in charge of stoker firing parties lent to contractors for the acceptance trials of, among others, *Cressy*, *Hogue* and *King Alfred*, all Belleville ships, and all later credits and assets to the Royal Navy. One could not but observe, however, that while one went through her trials without a hitch, others by equally reputable firms took at least twice the time. The difference in each case was due to defective organization, inexperience or even obstinacy.

CONCLUSION

The Belleville boiler having been banished by the committee, it is to the credit of the Admiralty that it remained determined upon water-tube boilers and carried on with experiments with various types. It adopted the Babcock boiler generally for capital ships and Yarrow or other small-tube boilers for smaller vessels. The Babcock, though heavier and occupying more space than the Belleville, gave good and reliable service through the first world war, but the small-tube boilers gave a good deal of anxiety, mainly as a result of one of the less well considered recommendations of the Committee of Enquiry. It was that all tubes must be straight. This insistence on straight tubes led to the two lower drums being ' D ' shaped, and not cylindrical, from which arose the alarming and not always easily detected complaint known as ' wrapperitis ', which, together with leaky condensers, was a constant worry to Admiral Jellicoe in the Grand Fleet between 1914 and 1918.

Gaudin's direct appreciation of essentials, and clear statement of his opinions, regardless of the rank and importance of his hearers, is illustrated by the following story. Detailed to explain to the First Lord—A. J. Balfour—the nature of this trouble, he was asked, ' Who is responsible for this widespread defect ? ' and replied at once, ' You, sir.' Balfour, unruffled as ever, remarked that that was very interesting, but how did it come about ? ' When you were Prime Minister, sir, you appointed a committee of people, who knew nothing of naval boilers, to investigate. Amongst their recommendations they said " all boiler tubes must be straight." Hence the " D "-shaped drums and cracks at the junction of the tube plate and wrapper.'

During the ' Battle of the Boilers ', it must be noted that the Admiralty was faced with the consideration of other engineering problems. The steam turbine was developing, and there were problems connected with the efficient burning and possible adoption of oil fuel. In both these matters it took a courageous and ultimately justified lead. Was it not equally courageous in adopting the Belleville boiler? Was that boiler really as defective as it was made out to be ?

The writer does not think it was. He wonders, indeed, whether, had some other design been the first to be adopted, it, too, and equally, would have had to carry the odium of much prejudiced comment and the misfortune of much uninformed and unintelligent usage.