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DISCUSSION ON SOME NOTES ON WATER-TUBE BOILERS.

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MR. J. SHIRRA, in opening the discussion, said the subject was a wide one, and could not well be confined to the particular type of boiler with which the author seemed to have been fortunate in his association. An account of difficulties met and overcome would, however, be more interesting and useful than a record of monotonous success. He (the speaker) thought other people had found no lack of difficulties in their experience with water-tube boilers, and he hoped we should hear of how these had been overcome.

It had been remarked that water-tubes would be the boilers of the future. It would be as correct to say they are the boilers of the past, for ever since engineers appreciated the benefit of using high-pressure steam—that is, pressures above what the old waggon-boiler was good for—they had availed themselves of the enormous resistance to bursting and extended heating surface given by small water-tubes; and many ingenious, if crude attempts were made in the first half of the last century to produce practical tubulous boilers. It might be pointed out that considerable success in the running of steam motor-cars was attained even before the advent of the railway locomotive, and these cars had almost universally water-tube boilers. But long before that, this principle was utilised, and he had seen in the museum at Naples water-tube boilers, in bronze, nearly 2000 years old, which were in use in Pompeii. Perhaps it would be more correct to call these water-fire-bar boilers, for the tubes formed a grate on which charcoal was burnt in an internal combustion chamber to heat the water in the surrounding urn. Of course, these were not steam generators, but were water-heaters—chandiéres—a function for which the water-tube is admirably adapted, though there is room for doubt as to its merits as a steam producer.

But it was not until the latter half of the century that this type of boiler reached a practical stage. From 1860 to 1870 the economy of high-pressure steam was fully realised, but the crude methods of boilermaking then in use, and the failure of the iron-makers to supply reliable plates of large size, led to many boilers of this type being made, most of which are now forgotten. Of course, we had long had the Galloway tube applied to Cornish or Lancashire flues—and the haystack boiler, so long first favourite on the Clyde River steamers, had water-tubes—but those we now consider are the varieties in which an external shell under pressure is dispensed with, and the tubes form the primary feature of the whole arrangement.

Perkins' boiler was about the first practical one of this type, and was a pure water-tube boiler, with none of the steam or water drums which make many of our modern ones more or less of a mixed nature, combining the qualities, good or bad, of both the tube and the tank systems. The Perkins, father and son, were the pioneers and protagonists of modern high-pressure steam practice, and a study of their inventions might point the path to success in steam-raising and using. Perkins' boiler, about 1870, was a battery of horizontal tubes, 3 in. diameter and $\frac{3}{8}$ in. thick, with close-welded ends, connected in vertical rows by several short lengths of smaller tube screwed in. The feed pipe was branched with a connection to each element—there was no possibility of inspecting or cleaning the tubes internally, and it carried 200 to 300 lbs. pressure. Yet a boiler of this class had been at work for 13 years at Perkins' factory when partly cut open for inspection by the Admiralty Boiler Committee in 1874, and was found in good condition. The secret of its success was the feed water used—the engine had a surface condenser which worked under a plenum—that is, the steam was condensed under pressure at a high temperature, which, of course, involved a high back-pressure on the exhaust side of the piston, never less than that of the atmosphere, but this effectually precluded any leakage of air through the low-pressure glands or of circulating water into the feed—which are the agents of destructive corrosion in boilers usually. The sacrifice of a few pounds terminal pressure in an engine running with 300 lbs. initial was compensated to some extent by the absence of an air-pump and the non-necessity of a feed-heater. In the tug-boat "Filga," plying in salt water, the same desirable conditions were attained, and the boiler lasted for some years, while in the "Propontis," where another type of water-tube boiler was tried about the same time, though elaborate precautions were taken to secure pure feed water, rapid corrosion took place, leading to fatal accidents. This shows that success with these boilers may be due to causes beyond the vision of the ordinary hot-water engineer. But the system was too heroic for ordinary mortals, and has not found favour.

The Howard Safety Boiler had some vogue about this time. There were several varieties of the Howard boiler, some not unlike the Babcock & Wilcox, but with the headers built up of castiron boxes connected by a central-jointed bolt, or simply of a D-shaped vertical wrought-iron pipe, to which the horizontal tubes were connected by screwed nipples. The tubes had rings welded on the ends to reinforce them and take the thread, but faulty welds and broken tie-bolts led to fatal accidents, which belied the boiler's name.

The "Root" boiler was introduced about this time, and had some success, but the amount of castiron about its headers and the tortuous and constricted connections between the tubes have handicapped it in competition with better arrangements.

The Belleville boiler was extensively used in France for small powers before it "boomed" as a marine boiler, but never had much vogue as a land boiler elsewhere, while its day as a marine boiler seems to be past.

Then the Babcock & Wilcox boiler came to the front in the seventies, and as we know it to-day it is the outcome of years of practical experience and improvement by talented engineers. The castiron headers formerly used have been supplanted by forged steel ones, and the tubes, in the lower rows of the marine type at least, are of Mannersman steel, a brand which combines softness and ductility with strength and soundness. The headers are splendid products of engineering work, but obviously require special plant for their output and a centralisation of manufacture, which precludes the construction of boilers of this type ever becoming a widely-diffused industry. He thought no one would deny that the Babcock is the best of its particular type—that is, of water-tube boilers, with approximately horizontal tubes, and, when not hard driven and supplied with good feed water, it is as safe as any. The company has done great service to the engineering world, too, by issuing its books on "Steam," "Water-tube Marine Boilers," etc., which put before the working engineer the science of steam production, and of using salt or hard feed water, in a clear way. The works ordinarily available on these matters leave much to be desired—the usual "Handbooks for Marine Engineers," for instance, being deplorably deficient on these points.

But all this does not imply that theirs is the best boiler absolutely, or even the best water-tube boiler. The author claimed a perfect circulation of water for it, but it shares the defect of all water-tube boilers, that the circulation is uncertain and capricious, yet it is much more likely to be good in boilers with the tubes arranged more vertically. The economy as regards coal consumption is really as much a matter of fire-bars and furnaces as of whether the heat passes through the convex or concave side of the tube first. He thought that in the ordinary Babcock & Wilcox, designed originally probably for burning American anthracite, the fire-bars are too near the tubes, and the flame, with a coal fire, is cooled and extinguished before the combustion of the hydro-carbons is complete. With vertically-arranged tubes we can more easily secure a large combustion chamber and perfect consumption of the gases. He knew of a Babcock & Wilcox boiler that was, at starting, heavily filled with Newcastle coal; there was a great production of smoke and of soot on the tubes, so that the tubes next the fire were overworked and failed, and the headers were damaged in extracting them. On the other hand, he had been told that a similar boiler, elsewhere, worked easily with coke fuel, made no smoke and gave no trouble. With a suitable furnace the bitumous coal might have been equally successful. There is, however, a consideration we must not overlook—the proportion of actual heating surface to grate area. The nominal heating surface is the inside area of all the tubes, but the actual heating surface when at work is indefinitely less than this. In ordinary shell boilers we know that vertical heating surface is much inferior to horizontal, because the steam bubbles travel up the plate and keep the water from contact with it. So in a water-tube, the steam and water are compelled to move together, and the more steam we make the less heating surface is in contact with the water—thus, the efficiency may be said to vary inversely with the rate of combustion.

If, through any defect in the circulation, the steam displaces the water in any tube for a short time, the thin metal is much more likely to get red-hot than a thicker boiler-plate, and the evil effects of grease or scale are felt much sooner and more severely than in the "tank" variety.

That such accretions do occur in the tubes is a well-known fact, and he had no doubt that most of those present who were familiar with those boilers could adduce instances. He had no special information beyond what could be obtained from the engineering papers, but he might call attention to one or two cases from these.

In the Board of Trade report on the failure of a tube in a Babcock & Wilcox boiler in London, in November, 1900, the commissioners state: "The explosion was caused by a tube having become so weakened by overheating as to be unable to resist the steam pressure, and this overheating was caused by an accumulation of deposit in the tube, which prevented the proper circulation of the water through it. The commissioners have formed the opinion that this type of boiler cannot be safely used unless great care is taken that the water should be as free as possible from solid matter. They are of opinion that the New River Company's water is quite unfit to be used in its natural state."

If this boiler cannot be safely used with the water supplied for domestic use in the City of London, we can hardly accept the optimistic statement of the author. Of course, it is preferable with all boilers that the water should be softened or de-tartarised, as some call it, before being used, it is more rational to extract the calcareous matter before putting it in the boiler than from the boiler afterwards—but even when this is done there is danger.

In July, 1901, a tube burst in a Babcock & Wilcox boiler at Runicorn and severely scalded the fireman; it was not the first one that had gone in the boiler. This was fed with condensed water, carefully filtered through sawdust to eliminate any grease. Nevertheless, a slight trace of oily matter was present, which the representatives of the Babcock & Wilcox Company blamed for the accident. No definite verdict was given at the inquiry, but the Board of Trade surveyors and Mr. Stromeyer, chief engineer of the Manchester Steam Users' Association, were of opinion that the grease had little to do with it; but the boiler being heavily fired, steam pockets had been formed which prevented due circulation of the water, and led to the overheating. There was some correspondence in *Engineering* over the matter, and Mr. C. Brown, of the great Swiss firm of Brown & Boveri, wrote on this idea of capricious circulation that " M. Brull, a late president of the Sociéte des Ingenieurs Civils à Paris, impressed by the very indifferent results obtained in an installation of 5000 h.p. of boilers of the Babcock & Wilcox type, devised a very ingenious apparatus to determine the amount and direction of water circulation in the tubes of such boilers. The results of M. Brull's observations confirm 'Boilermaker's' speculations (referring to another correspondent), the flow from the back to the front, headers being confined exclusively to the very lowest rows of tubes—in all the other rows the flow is inverted, being from the front to the back headers. The duty required from the boilers was light, 2·3 lbs. to per square foot of heating surface."

Casualties of this nature are not, of course, confined to Babcock & Wilcox boilers. The immunity of the water-tube boiler generally from wide-spreading disaster is acknowledged; still, if the unstayed end of one of the large top drums was to give way, we would probably have as serious an effect as with the collapse of a Cornish or Lancashire flue.

A frequent failing of vertical tube boilers is the corrosion of the tube ends externally where expanded into the drums. He did not know if this defect had been observed in the Babcock & Wilcox type, but there is no way of detecting it until the tube leaks. There was a fatal explosion on the "Daring" just two years ago—the prototype of one of the Thorneycroft classes, which was due to the tubes giving away at the lower drum,—and in a small boiler of the Thorneycroft type he had occasion to report on the same defect was constantly recurring, fortunately without fatal effect, but with the frequent disablement of the launch in which it was fitted.

Casualties and danger to life are really much more frequent with the water-tube boiler than with the ordinary type. A return of such in the British Mercantile Marine, for the five years ending with 1901, was recently issued as a parliamentary paper. The number of casualties per 1000 boilers in use of the fire-tube type was 43·2; of modern water-tube boilers, 120·6; of persons killed, fire-tubes, 1·36 per 1000; water-tubes, 86·2; and persons injured, 1·5 and 103·4 respectively.

And this is not to be wondered at! Perhaps the majority of casualties with the ordinary marine boiler are due to defective sludge and man-hole doors. Now, these more or less horizontal water-tube boilers have a huge array of such doors, held each by a single bolt; there is always a temptation to tighten up this bolt when any leak shows, and thus to overstrain and break it. He had no doubt that the recent casualty in the Belleville boiler of the "Good Hope" was caused thus, and it might happen also with another type. We are told of the facility for inspection these doors give us—no doubt, we could see if the tube was obstructed by scale by removing them and looking through at a lamp at the far end, but could we detect a pit-hole at the middle of a tube's length? Not without some such apparatus as is used for examining the rifling of a 50 calibre gun, a mode of inspection which would paralyse the "practical man" we hear so much about.

He hoped to get some information as to how these boilers are surveyed, and their probable life. Do they run till the tubes give out, or can incipient failure be detected? How often are all the doors taken off, and does the average boiler owner calmly submit to the delay and expense of skilled labour needed to handle these all-important fittings? If so, a salutary change must have come over his nature with the adoption of the water-tube. He had read lately of a casualty with a Green's economiser, only a variety of water-tube boiler. It had been thoroughly inspected by the maker's surveyor a few months before, when under two per cent. of the caps or doors had been taken off the tubes for external examination, and, from this *ex pede Herculem* judgment, they had been pronounced all right. One of the caps began to leak, and two men went into the flue, with the usual long spanner and an iron pipe on it to tighten it up—broke the bolt, and were scalded to death before they could escape. The bolt had been so weakened by corrosion as to stretch and allow the cap to leak, and several more were found in a dangerous state on inspection. Of course, all the caps ought to have been taken off in the first survey—so with water-tube boilers, but the surveyor will need all his firmness who insists on this. The inspection must be a tedious and expensive job, and no satisfactory assurance of safety can be had even then.

The great merits of these boilers are the portability of their parts and the possibility of erecting them *in situ*; their comparative lightness allows them to be installed on an upper floor sometimes, or one tier above another, so economising ground space, and these properties are no doubt invaluable in some situations. But after erection, in use, they require very careful firing to get economical results; they need very pure feed-water, free from air, grease, lime or chlorides. If forced—and every boiler-owner wants to force his boiler sometimes, and some all the time—the excess of steam in the lower tubes leads to overheating and rupture, and the rapidity with which steam can be raised is a doubtful merit. Dr. A. C. Kirk told the Admiralty Boiler Committee, in 1874, that the reason some engineers take so long to raise steam was more on account of the cylinders than the boiler, and we have the cylinders to consider still, while with adequate circulating arrangements steam can be got as quickly in shell boilers as in tubulous ones, as the "Minerva"-"Hyacinth" trials have shown. The small amount of water in the purely water-tube boiler is a real danger, and the excess of it in the tank type is not altogether a fault, as it forms a valuable reservoir of power. When cleaning fires with the water-tube the steam is apt to fall very low, and running an engine off one must resemble running an hydraulic power plant off pumps without an accumulator.

If the Scotch or Lancashire boiler be as scientifically constructed under skilled engineering superintendence, as the best types of water-tube boilers are, and fired and fed as carefully as a well-conditioned water-tube one requires to be, we would have boilers that would give little trouble, and be more competent to cope with the exigencies of steam-users than the water-tube, even if the latter is wet-nursed on milk of lime, and laboratory analysis made of its water every watch, as seems to be needed at least with the marine boilers of the variety we are considering.

Mr. W. H. German said the subject of the paper was one capable of such endless discussion, and from so many points of view, that it would seem quite impracticable for any one speaker to offer opinions on the many aspects of the question. Instead of traversing the matter generally, it appeared to him desirable to confine his remarks to certain items only; at any rate, such was the conclusion he had arrived at after perusing the reports of the committee appointed by the House of Lords to consider the question of the type of boilers to be adopted for the English navy, and, as an instance of the complexity of the subject, it was, perhaps, appropriate to mention that the conclusions arrived at by that committee had not been unanimous.

The author made a strong point of the lesser liability to explosion of the water-tube boilers, and said that he had not heard of loss of life or limb, nor injury to property having resulted through the use of water-tube boilers of the type under his charge. That there was reason for this contention was beyond dispute, for the smaller diameter of parts admitted of increased pressure in direct ratio, but even in this sense there were qualifications, for the very smallness of parts involved multiplicity, and he had noticed, from Press reports, that only a few weeks since, at the works of Messrs. Bellis & Morcom, Ltd., Birmingham, a tube in a Babcock & Wilcox water-tube boiler exploded, causing the death of one man and serious injuries to four others from scalding. The boiler had been in use for seven years.

Now, in drawing attention to this unfortunate occurrence, he had not the least intention of disparaging the type of boiler referred to; but the following question was not unnatural—Was a boiler attendant safer in a stoke-hole with a Lancashire boiler than with a water-tube boiler, say, of this kind? If the stoke-hole be closed, he (the speaker) thought he was, for the risk was practically confined to the one shell, which (if made by a reputable firm in accordance with up-to-date practice) rendered its chance of failure exceedingly remote, as defects in material would be disclosed in the process of planing, drilling and rivetting, whereas with this type of water-tube boiler there was the multiplicity of doors to the tubes, and again the greater chance of defects in numerous tubes remaining concealed.

Another point he would lightly touch upon was the value of heating surface, in connection with which the author said that the quality of the heating surface should be preferred to quantity, and spoke of the rapid transmission of heat through water-tubes, also of the retarding of heat transmission by the thick furnace plates of a shell boiler, apparently inferring that the former type was the more efficient, whereas he thought it was generally conceded that for evaporation efficiency one square foot of heating surface in a Lancashire boiler was equal to two square feet in an ordinary water-tube boiler.

To his mind, the expression one sometimes heard that water-tube boilers were universally superior to the shell or fire type, or *vice versa*, could only be regarded as the voices of the partisans, for the choice of a steam generator should be governed by the conditions to be fulfilled, which might be instanced in the following extreme cases :—

1st.

High pressure necessary. Transit for large pieces expensive. Pure water. Floor space limited or of great value. Rapid steam raising required.	A good case for a water-tube boiler.

2nd.

Pressure, say, not to exceed 120lb. Transit cheap. Impure water. Ample ground area. Sudden demands for steam.	A good case for a shell or fire-tube boiler.

It was in cases where the issues were not clear cut, where the conditions were complex, and other considerations entered, that the problem of selecting the most suitable type became difficult, and if the discussion should enable any of us to better appreciate the relative merits and demerits of different kinds of boilers the paper would have amply served its purpose.