

and on scraping away the rust from the shell immediately over the arch of the flue and at the front of the boiler the chisel went through the plate, and on further examination at this point the plate proved to be as thick as tissue paper. This occurred at a lead mine in the North of England, and, being winter time, 40 men and boys were accustomed to take their lunch in this boiler shed. One can imagine the result had an explosion occurred. Such an instance as this could not occur in a water-tube boiler.

In a recently-published catalogue of a bent tube water-tube boiler, he had noticed illustrations showing a deposit of soot on the top of an horizontal tube which was very much exaggerated, and, even if it were correct, this coating of soot could easily be obviated by the use at regular intervals of the cleaning hose which was always supplied with their boilers. This was in reference to external cleaning, but he thought considerable difficulty would be experienced in cleaning a bent-tube internally.

The question of expansion had been raised, and there was no doubt that, when raising steam quickly in a Lancashire or Cornish boiler, strains were set up which were a menace to safety, and might cause explosions resulting in loss of life and certainly, injury to the boiler. In a water-tube boiler such strains would not be set up, for the weakest tube must give way under undue strain. In the Roots "K" boiler a special expansion joint was used, made of a soft metal, the exact composition of which was a secret. The object of this joint was to take up the expansion of the tube, and the instructions sent out for the erection of each of their boilers asked that these joints should not be screwed up too tight, and in fact it was preferable that a small "weep" should take place when the boiler is cold.

MR. ARNOT pointed out, in connection with Mr. Shirra's remarks, that his reference to the accidents with water-tube boilers referred to those in use in the Navy, and these accidents had principally occurred in boilers of the bent-tube pattern.

Within the last 20 years 20,000 boilers of the Babcock & Wilcox type had been made in the Scotch works of the company and put into use, and the few accidents that had taken place had, in every instance, been directly attributable to neglect or improper treatment in some form.

The circulation of the Babcock & Wilcox boiler was clearly demonstrated in the glass model exhibited, which showed that the circulation was well-defined and all in one direction, and it would be noticed by the thermometers that, as soon as the heat was applied to the tubes, the temperature of the water increased equally, and remained equal in both thermometers — another evidence of perfect circulation.

MR. JOHN TODER pointed out that during the Glasgow Exhibition of 1901, where Scotch Stirling water-tube boilers were at work, the Stirling Boiler Company closed one boiler down for one day in each week for the purpose of demonstrating how tubes could be cut out and how they could be replaced, any particular tube being selected, and this was at the option of the witness, and the average time was 40 minutes. He thought it was only fair to add that the operators were the company's own men and no doubt were skilled in the use of the tube expander.

MR. J. S. FITZMAURICE said that whatever might be their individual views on the subject matter of the author's paper, there could be but one opinion as to the importance of the question, "Water-tube *v.* shell-boilers," and the author was to be commended on his success in bringing together such a fine and representative gathering of engineers to discuss his paper. Messrs. Shirra, Fyvie and others had touched so fully on the matter that it was difficult for one to discuss the paper without traversing the same ground.

The principles on which the Babcock & Wilcox, Stirling and other water-tube boilers were constructed, were, he thought, fairly well known and understood by present-day engineers, and few would be bold enough to decry their respective merits.

In discussing a question of so much importance as the one under review, all party feeling should be subdued, and the matter dealt with on technical lines only.

The author stated that in well-constructed water-tube boilers the circulation was definite and continuous and the temperature throughout was equal ; therefore, no strains were caused through unequal expansion. He would ask the author if the Babcock & Wilcox boiler came under this category ?

It would be noticed that the heat direct from the furnace passed up and around the upper end of tubes, then down through the centre, and finally up past the lower ends of tubes to the smoke-stack.

The specific heat of steam was about one-half that of water, consequently the amount of heat absorbed was less where tubes were filled partly by steam and partly by water than in the case of tubes entirely filled with water ; therefore, the efficiency of heating surface was thereby reduced.

In the Babcock & Wilcox boiler the proportion of water to steam was greatest at the bottom or lower end of tubes and naturally lessened considerably as the point of discharge was reached ; therefore, the boiler tubes would be at a much higher temperature at the firebox end than at the opposite end ; moreover, as steam pockets would form on the upper side of the water-tubes, the top side of the tube would be at a higher temperature than the under side ; and it was on the top side that one might reasonably expect to find a rupture or defect in the tubes. With conditions such as these, could the author say that the temperature was equal, and that the expansion in tubes was not unequal in the boiler that he advocated ? In regard to incrustation : As far as he (the speaker) was able to judge, the Babcock & Wilcox and other water-tube boilers were, at least, just as liable to these troubles as shell boilers unless precautions, common to all boilers, were taken to prevent incrustation.

Some of the members would, no doubt, recollect a specimen of a water-tube exhibited at one of their meetings some time back by Mr. Norman Selfe. This tube was one of many taken out of the Newcastle City Electric Light Station boilers, and was coated with a deposit about $\frac{1}{8}$ in. in thickness.

The difficulty in detecting defects in the tubes, as referred to by Mr. Shirra, was no doubt common to all water-tube boilers. The question of "Straight *v.* bent tubes" was one that he trusted would be dealt with by their respective advocates.

In the matter of repairs, examination and cleaning, the straight tubes appeared to have a decided advantage over the bent. On the other hand, the bent tubes had an advantage over the straight tubes in so far that they allowed for the expansion of the tubes.

Regarding the circulation, it would be interesting to know what was the condition of the water under working condition in the steam drum of the Babcock & Wilcox boiler, especially at the furnace end. He noticed that the steam was taken from the steam drum at the back end of boiler; this was, presumably, to obtain comparatively dry steam.

In the model of the Stirling boiler, exhibited by Mr. Toder, it was noticed that the water in the left hand top drum was perfectly quiet; whereas, in the right hand drum it was in a condition of violent ebullition; and in the middle drum, from which the steam was taken, the water was comparatively quiet. From this practical test it was only natural to assume that the water in the front end of the steam drum of the Babcock & Wilcox boiler would also be in a state of ferment. Perhaps Mr. Arnot could say whether this was so or not.

Regarding heating surface, the author stated that its efficiency should be preferred to the quantity, and that one square foot of heating surface placed at right angles to the current of the heated gases, so as to receive the heat direct, was equal to four square feet when placed parallel to their flow.

Did the author apply this statement to multitubular horizontal boilers? If so, the efficiency of the Babcock & Wilcox compared very favourably with that of the colonial type of boiler.

The tests carried out by Mr. Fyvie, at Geelong, and published by the author, showed very disappointing results. The water evaporated per square foot of heating surface only amounted to 1.18 lbs. and the coal consumed per square foot of grate area 6.3 lbs., as against 4 to 5 lbs. and 20 lbs. respectively in everyday practice.

The author had overrated the trouble arising from the use of shell boilers, and if his statements were the result of his experience, then all he (the speaker) could say was that his experience had been a most unfortunate one. In a properly-designed multitubular or shell boiler the circulation was good, and there was no difficulty in cleaning it inside and out.

In practice, the feed-water should be heated as near boiling point as possible and filtered (hot) before being allowed to enter the boiler. If this were done, very few of the troubles referred to would be experienced.

The system of cleaning the Babcock & Wilcox boiler tubes was good and effective. The necessity of opening smoke-box doors to clean the tubes of a multitubular boiler was an objection, and no doubt caused loss in efficiency; but, after all, what did it amount to? About ten to twenty minutes per day for a boiler of, say, 60 or 70 tubes if a steam jet on the spiral projector type was used.

He had prepared a few figures of the working of a multitubular boiler used during the late Coronation illuminations, 1902. It was not by any means a test of what the plant could do under the most favourable conditions. On the contrary, so long as steam was maintained and there was no difficulty in doing so, no particular care was observed in the firing. The figures, therefore, might be accepted as the result of ordinary working conditions:—

BOILER DATA.

Colonial type, multitubular, underfired, side flues—

Diameter	...	...	...	6 ft. 6 in.
Length	...	...	...	14 ft.
Number of 4 in. tubes	...	...	...	64
Total heating surface	...	...	...	1055
Grate area 7 ft. x 4 ft.	...	...	...	28
Ratio of grate area to heating surface	...	...	1 to 27.7	nearly
Date of trial	...	...	July 11 and 12,	1902
Duration of trial 3+5 hours	...	...	...	8 hours
Coal consumed, 1521 lbs. + 3181 lbs.	...	...	...	4702 lbs.
Water evaporated, 14,619 lbs. + 25,190 lbs.	...	...	...	39,809 lbs.
Percentage of ash	...	...	...	15%
Kilowatt hours, 270 + 457	...	...	727	kilowatt hours
Water evaporated pro lbs. coal used 9.6 lbs. 7.9 lbs.	...	...	8.46	lbs. aver.
Water evaporated pro lbs. combustible coal	...	...	9.96	lbs.
The temperature of feed-water estimated at	...	...	150	
Steam pressure averaged	...	...	180	lbs.
Equivalent evaporation of coal consumed	...	...	9.4	lbs.
Equivalent evaporation of combustible coal	...	...	11.07	
Total coal pro grate area	...	...	20.98	lbs.
Water evaporated pro heating surface	...	...	4.7	lbs.

MR. J. MUIR said in past years in the interest of extensive use of steam, it was part of his duty to see the boiler under discussion at work, to consider and generally gauge its efficiency in all its details, which summarised the final factor, the economy of steam production, through the items, wages, coal, water and repairs. He had also endeavoured to gain a fair knowledge generally of the duty of the boiler under various conditions in this and other countries recently visited.

He would leave untouched a great deal of matter in evidence of the discussion, although, he admitted, all of much value and interest. Was not the crucial test of the boiler's qualities and capacity for work centered in its combustion with both hand firing and the chain grate stoker? We might agree to a certain

extent with those who hold that the boiler was a good and rapid evaporator; the disappointment to many was that it was not a much better evaporator, and at this defect many are puzzled. Thin heating surface in the form of tubes staggered over the fire to permit the heated gases of combustion to wend through the upward zig-zag spaces and encircle the tubes might have been sworn to in theory as the outline of an ideal steam generator. It did not, however, appear in theory that the wending and encircling of the heated gases amongst water-tubes would chill and check combustion in its initial stage, thereby reducing heat effect; but in practice this chilling effect was beyond dispute—therefore, defective combustion. Theory, of course, now said to herself when the scales had fallen from her eyes, "Certainly." If thin staggered tubes are effective for heating water rapidly, they are also effective for cooling gases quickly, the one condition is a corollary of the other.

In the boiler under discussion, the run of the heated gases from the fire through amongst the tubes to back flue could be conceived to be too short a run for any boiler, and although combustion was damped amongst the tubes as aforesaid the heat was very high, leaving the tubes, or in the back flue, perhaps, due to combustion making a second rally in this suitable space, with an improved admixture of the necessary air of combustion. The heat, underhand firing, was high enough to supply a second boiler, a condition that suggested alteration of design to more thoroughly exhaust utilization of this heat before reaching the main flue; and the future of tube boilers should evolve such a design. The vertical tube boiler seemed more adaptable in this direction of heat absorption, as the water-tubes did not smother the first efforts of the fire, and the combustion chamber was high, allowing combustion to be more advanced before striking amongst the tubes to cause chill. This boiler allowed of extension, so that the heated gases would have time to expend their heat, that on delivery into the back flue no further utilizing of the heat would be practicable and economisers unnecessary, boiler and

economiser in one. The feed-water in such an arranged boiler would enter at the coolest end, and reach its maximum of heat in the tubes next to the fire.

The author of the paper on the merits of the boiler under discussion emphasised the value of the heated gases striking direct at right angles up amongst the water-tubes. They characterised this as the boiler's supreme defect; if combustion had proceeded further before so striking, results would be better. The heated gases, no doubt, were carried right into the heart of the water to be evaporated, but they were there chilled before combustion was carried far enough, sending to the clouds underhand firing such an amount of unconsumed carbon that, in future, no municipal authority would tolerate; hence, the chain stoker, with its small coal fire and excess of air, was indispensable. The boiler under this dispensation made no smoke and kept very high pressure; steamed as steady as the town clock, but its average evaporation was not high. "Oh, but," say they, "that is only the average." Well, but in a factory the average evaporation is only looked at; spurts do not count except in the average.

He was associated with Mr. Fyvie in the making and experimenting with his chain grate stoker; they determined on smoke suppression, they suppressed smoke with the chain grate, at a cost of 15 per cent. of extra coal consumed on the average. Considering the works in whose interest the experiments were made ran into a coal consumption of a thousand tons per week, they were not yet advocating chain stokers. The speaker was of opinion Australia could not afford to throw away its heat units to suppress smoke; but smoke diminution should be every steam user's concern.

It was a *sine qua non* of a paper in praise of water-tube boilers that all the supposed defects of the shell boiler would be paraded.

In conclusion, he would refer to a paper read in May last, by Mr. C. E. Stromeyer, Chief Engineer to the Manchester Steam

Users' Association, on the work done by all classes of boilers, including tube-boilers. He would conclude by remarking that, as matters stand at present, Lancashire boilers with economisers are doubtless the most efficient as regards economy and up-keep.

MR. STROMEYER pointed out that Lancashire boilers work perfectly up to 200lbs. pressure—a pressure not often demanded, and that the so-called tank boiler met sudden calls for steam better than any water-tube boiler because of its resource in its large store of water.

MR. LEE, in reply, acknowledged with thanks the kindly way in which his paper had been received and discussed. He exhibited a tube in illustration of his remarks on the durability of the Babcock tubes, which members were invited to inspect, and said that he felt that those who had taken up the discussion had given much valuable information.
