fairly high efficiency. There were one or two points in connection with the trials to which he should like to call attention, as they seemed to indicate that the conditions under which the test was made were, in some respects, unfavourable to economy. In the first place, it should be noted that the rate of evaporation has only 1·18 lbs. of water per square foot of heating surface at feed temperature, or equal to 1·42 lbs. per square foot at and from 212° Fah. At such a low rate there was risk of a low efficiency on account of the greater loss from radiation from the brickwork setting. The average of a great number of tests made with this type of boiler indicated that the best economic results were obtained with a rate of driving between 2·5 and 3 lbs. of water per square foot of heating surface. In the second place, the consumption of 6·3 lbs. of coal per square foot of firegrate was also very low, and, unless the coal was most carefully stoked, would tend to produce a rather low temperature in the furnace, which was not conducive to a high boiler efficiency. On a firegrate containing 26½ square feet area consuming fuel at the rate of 6·3 lbs. per square foot per hour, the temperature of the fire would probably not be higher than 1800° Fah. If 1800° be taken as the mean temperature, and assuming the waste gases to be 150° Fah. above the steam in the boiler, then the following figures indicated the maximum efficiency obtainable without making any allowance for loss by radiation or imperfect combustion :—

$$\frac{(1800° - 511°)}{1800} \times 100 = 71\ \%\ ° \text{ efficiency.}$$

In a recent paper, in the *Engineer*, on the efficiency of steam boilers, the writer pointed out that although many makers claimed for their boilers an efficiency of from 70 to 75 per cent., the average of the boilers in England would not be much higher than from 50 to 55 per cent., and said that 65 per cent. should be considered a satisfactory figure.

Mr. Norman Selfe said that, while the author of the paper did not profess to throw very much light on the subject dealt with, it had formed the groundwork for a wide discussion on one of the most important subjects which the engineer had to deal with. He seemed to be most favourably impressed with the one special type of water-tube boiler to which he devoted the most attention, but he did not attempt any exhaustive criticism of its comparative merits and demerits.

Fortunately for the value of the discussion, much valuable data had since been contributed by subsequent speakers, and the categorical enumeration of failures of inclined straight-tube boilers made by Mr. Shirra must convince the most profound admirers of the author's favoured boiler that it was yet a long way from being what an ideal boiler should be. So much information of the same kind had been contributed by other speakers, that his (the speaker's) remarks would take another direction. No exception would probably be taken to the statement that many of the author's observations were so true as to be axiomatic, and thus afforded no scope for discussion—such, for instance, as the importance of circulation in a boiler and the necessity for keeping the heating surfaces free from soot and fine ashes. When, however, they came to examine the arguments by which the author of the paper attempted to show the great superiority of water-tube boilers over their competitors, then it almost seemed that he was logically and scientifically weak.

To prevent any misunderstanding, he (the speaker) might as well say at once that he was a great believer in the water-tube boiler, and was certain it had come to stay, for many special reasons; but, if its superiority under all conditions was to be claimed, then they must have the results of a number of careful and impartial tests put before them, and not merely one-sided statements.

The first thing to note about water-tube boilers was that, as the great bulk of their surfaces was constructed of relatively thin

metal, a facile transmission of heat to the water was thereby provided, and, as metal was generally sold by the pound, such boilers ought to be very much cheaper for a given area of heating surface and evaporative power than the Cornish, Lancashire or even the underfired multitubular type. The author had not, however, shown that such was the case, and if it was not, why not? It was to be hoped he would do so in his reply. It was utterly absurd for anyone to compare the efficiency of a badly designed and badly set boiler of the "tank type" (as he was sorry to say they were now called by irreverent people) with a water-tube boiler fresh from the hands of clever experts, who were directly interested in proving it to be the more economical. Any test to be of value must be made under equal conditions and by purely disinterested experts. Within his personal experience a multitubular boiler was so badly set that while everything that should have been cool was nearly red hot, very little steam was made, and yet a very small alteration secured a grand efficiency in evaporative power.

When they came to the question of "safety" then it was even probable that a boiler, all in one piece, of which the strength was well understood, might by some people be preferred to another one that could be taken to pieces like a Chinese puzzle with hundreds of bolts, nuts and potlids.

As far as security from explosions went, it might safely be said that a properly-designed and cared for boiler of the old type never did explode whatever the class it might belong to, and that all accidents were due to causes that might have been avoided. The records furnished by some of the speakers who had preceded him seemed to show that an inclined tube boiler with one header for a great number of tubes offered special inducements for trouble to ensue with forced firing which was sometimes unavoidable where boilers were used. In its adaptability to excessive pressures from 160, say, to 250 lbs., the water-tube boiler presented specially favourable qualities; but

looking carefully at the engineering records as they individually appeared, there did not seem at present to be any grounds at all for the assumption that the average water-tube boiler was a better evaporative machine than its old-fashioned compeers. When they reflected on the great and daily changes to which they as mechanical engineers were becoming used, it was marvellous to see the invention of the great "Dick" Trevitheck (the man who really invented the most of the locomotive for which George Stephenson got the credit), that was the Cornish boiler, still holding its own after one hundred years of work and still being adapted for every successive rise of pressure up to 180 lbs. or more.

What the author said about there being no definite circulation in such a boiler could be cured by simply putting the flue or furnace on to one side of the centre line, so as to have an up-cast and down-cast side for the water flow. Mr. Kidd, who preceded him, had a great deal of experience with such Cornish boilers. If water has to be used which contained much mineral matter, then the tubes of a water-tube boiler line up with a casing or coating which might be hard as marble. In an inclined tube boiler which came within his own practice the coal bill was doubled from this cause, and when the tubes were cleaned it took two men twenty minutes to a tube, and he ascertained that the cost of keeping this boiler properly clean was equal to the cost of the boiler itself. So serious was this trouble in America that it had developed a special industry, and there were now contractors who undertake this cleaning. They brought along to your boiler house a small machine shop, engine and all, and rigged up a multiple boring machine in front of your boiler. In their pictorial advertisements these people showed with pride the enormous heaps of scale as compared with their rivals in the trade, which they had bored out by their apparatus from Messrs. So-and-So's boilers.

The mere contemplation of the fearful and wonderful-looking inventions which the American scientific journal advertised

for cleaning the water-tubes of boilers were enough to scare any cautious engineer from introducing them unless he had water of an unimpeachable character. They knew, of course, that in a multitubular boiler, hard scale fell comparatively easy off the outside of a tube—very different to the other case, which required a boring machine to get it removed from the inside where it was wedged in under a continuous arch. The remarks on page 45 of the author's paper, as to the deposition of dirt on the outside or inside of tubes, proved nothing, for, if the water-tube could be cleaned by a steam, jet then the same application could be made to the inside of a fire-tube.

The author concluded his very interesting paper by predicting that in the near future water-tube boilers would demonstrate their efficiency, but seeing that they had already had such very large opportunities, even in this backward country, did it not seem remarkable that they had not done so already, if their advantages were any more than nominal ?

In the Power House at Ultimo there were, he believed, both multitubular and water-tube boilers, and it would be most interesting (if it could be done under the authority of the Commissioners for Railways) to have comparative tests carried out between two of them, one of each type. Before such a trial the settings of both boilers would have to be approved by their respective partisans and then the same weight of coal being served out to each, the water evaporation should be carefully measured. In this, the partisans would have no part, as both boilers during the test should be in charge of persons absolutely uninterested. In such a way valuable information might be gained and much money saved to the State if the very best conditions applied in both cases.

At the present time there were reasons for believing that the multitubular boilers could be made to give much better results than have hitherto attended them. Such a test as he had indicated would have still more value if a third boiler of the vertical tubulous type were included in the experiment.

On page 38 the author of the paper stated these two leading classes of water-tube boilers, viz., those with vertical bent and those with horizontal straight tubes. As the advocates of the bent-tubed types seemed to make no more trouble of boring out the scale when their tubes became encrusted than the straight-tube people did (and there was obviously no more trouble when they looked at the tools used) it would be interesting if, in his reply, the author would give them some more information as to the relative evaporative powers and first cost of the two classes. Since the foregoing was written, the further information afforded by the discussion showed that the type of water-tube boilers with vertical, or nearly vertical, tubes had quite as good grounds for claims on the consideration of all impartial engineers who wished to save their employees' money as the much-vaunted horizontally-inclined type, with the many-bolted covers, had.

Unfortunately for the scientific aspect of engineering, the commercial element in connection with it was now so dominant that there was no necessity, it would appear, latterly for a man to spend a lifetime in the pursuit of his profession. If he wanted a boiler he had apparently only to send word to a few agents, and they would furnish him in an hour with more information than he could assimilate in a week, and it would only remain for him to give the order to the one who produced the prettiest-got-up book.

No doubt most valuable information was contained in some of these trade catalogues for an experienced reader; but they appeared to be as dangerous as dynamite to a layman. Of course, we were all aware of the saying, "No case, abuse the plaintiff," and often note that, when a man told you of his great honesty and what a rogue the other fellow was, the matter might be worth looking into. Well, in one of these valuable books on boilers he found an illustration and description of a rival design, and this was the disingenuous way in which it spoke of it. First, instead of speaking of it as having curbed tubes, it called it a crooked tube boiler, both a distinction and a difference to be

noted. Then it said something to the effect that it had no good points at all but every bad quality that could possibly adorn a boiler. Well, this so interested him that he made inquiries about this bad boiler, and he could now say safely, and that without any personal references, that the consideration he had so far given to these two boilers had shown him that this so-called crooked tube boiler (in reality all the tubes in it that had curved ends at all were bent to one uniform radius) was a far superior machine, both from the theoretical and practical standpoint, than the boiler advocated in the book which set out to abuse its rival so roughly.

He believed the average experienced engineer had a very open mind on this boiler question, and he supposed half-a-century of practical acquaintance with the subject gives him a claim to speak.

Vast sums were now expended in putting new machines before the public in trade books—some ingenuous and make you wise, others disingenuous and tell you lies—because it was contained in a beautifully-got-up and illustrated catalogue. They sometimes were asked to take as gospel statements that were really of no more value or true than a soap or pill advertisement. When they found a dozen different manufacturers all telling you that their machine was the best, whether it was an electric motor, steam wheelbarrow, or a sausage machine, and that their rivals produced only wasteful crudities or base imitations of their goods, then the cautious man must slow down and wait for proofs. He felt that information brought forward by the various speakers who had preceded him in this discussion had been of great service to him, and the result so far was certainly to confirm a faint impression only which he had before, that the vertical type of water-tube boilers, of which the Yarrow, Normand and Stirling were notable examples, were far before and would survive those of the Roots, Babcock and similar designs. Of course, like those around, he was still open to learn more on the general question. Leaving great things for small, he would like

to ask, Was not the normal position of the furnace door "closed?" and was not the normal position of the ash-pit doors when at work "open?" If such was the case, would the author tell them in his reply how it was that the Babcock boilers had ash-pit doors so arranged so as to project over the floor plates when the boiler was at work in the way of the firemen, instead of sliding, and thus keeping a clear floorplate?

MR. CLARKSON pointed out that the nearly horizontal tubes of the Babcock & Wilcox type of boilers gave trouble through overheating, due to defective circulation, and, while the more vertical tubes of the Stirling type was an improvement, he considered that the bending of the tubes was a drawback, and that he favoured the upright type of water-tube boilers in which all tubes were straight, such as the Hornsby type, and he submitted particulars of an evaporative test made by Professor Robinson with one of these boilers.

MR. O. W. BRAIN said on the occasion of his visit to the London Power Station, he was shown Babcock & Wilcox boilers working up to 700 horse-power, and was told that, even with forcing, there was no trouble at all with boilers of that type. He thought that the first installation was in Vienna, after the big fire in 1877. He might safely say that in Germany, Vienna, Hungary, Italy, France, and the United States the greatest number of the largest stations there were using the Babcock & Wilcox type of boiler. The same results were being obtained in the Ultimo Power House. Of course, that was only for one particular use; and he would not say, for one moment, speaking as an electrical man, that the Babcock & Wilcox boilers were suitable for all steam services, but there were very special reasons for using them in electrical power stations, more particularly where there was large power used. One of the main reasons of his advocacy of the Babcock & Wilcox boilers was that by forcing them you can meet all sudden, heavy requirements in traction stations. He was sure that he was safe

in saying that four-fifths of the large stations in the countries he had mentioned were using the Babcock & Wilcox type of boilers.

Mr. R. R. Ferrier said he had listened with great interest to the paper read, likewise to the many excellent contributions by various members in discussing the subject of the paper now before the Association.

In a community like this, which was not a manufacturing one from an engineering standpoint, they were indebted in a great measure to such papers and subsequent discussions, in educating them to better discriminate and to decide on the plant which was likely to be the best value for money spent, and to assist them in determining the plant best suited to particular circumstances. To decide the relative degree of efficiency of various types of boilers was no doubt a difficult problem to solve; there were so many points outside the boiler itself, which more or less affected the efficiency of a boiler installation. They had, therefore, to be very chary in accepting the maker's figures in this connection.

Workmanship.—This is one point on which makers of water-tube boilers are to be commended, the standard achieved being of an excellent character.

Safety of Boilers.—Owing to the large number of dismountable fittings which are a feature of water-tube boilers, coupled with the fact that the heating surfaces in many types cannot be sighted to the same degree as that of older types of boiler, the supervision is therefore of a more onerous character, and he was of the opinion that in many cases, especially when the feed-water is not good or specially distilled, the older types of boilers are to be preferred from a safety point of view.

Some of the chief points in favour of the water-tube boiler appear to be:—

(*a*) Large units attainable. This point is worthy of consideration for large boiler stations, also in cases when transport of other boilers would be difficult and costly.

(*b*) Economy of ground space for a given power, to be considered when ground is valuable and limited.

(*c*) A design of boiler suitable for the higher pressure now being generally adopted.

(*d*) Rapidity with which steam can be raised.

The water-tube boiler has evidently come to stay, but that it will entirely supersede the multitubular and shell types of boilers is very questionable. It is probably a parallel case to the two great problems which have been so much before the engineering world of late, viz., Electricity *versus* Gas and Electricity *versus* Hydraulic Power.

Each power has its own particular applications and uses, which will probably in time become more defined, and, speaking broadly, should not come into conflict.

In conclusion, he would venture to say that it is not so much in the type of boiler where economy might be looked for, but in the arrangement and careful supervision of the boiler station and the adoption of the various auxiliary plants, such as mechanical stokers, mechanical handling of the coal and ashes, steam super-heating and feed-heating by means of the waste gases, which are now becoming so widely used in large boiler installations.

Mr. J. B. Bawden said he had carefully read the paper on water-tube boilers, and quite agreed on many of the points raised, more especially with regard to the quick raising of steam as compared with an ordinary Lancashire or Cornish boiler.

It was an acknowledged fact that in a Lancashire boiler steam could not be raised quickly on account of the thick plates, whereas with any water-tube boiler steam could be raised in a very short time, and could be kept up easily, as had been demonstrated.

It had occurred to him that the author, in mentioning the types of water-tube boilers now in favour, had forgotten the "Roots" water-tube, one type which had been proved for years to be very good—in fact, his company, who were now manufacturers of the "K" water-tube boiler, one type of the "Roots," had just recently installed some of these at Amsterdam for the

Water Works Company there, and they had been tested in block by the Dutch boiler surveyor to his and the Amsterdam Water Works Company's satisfaction.

One great feature in water-tube boilers as against Lancashire or Cornish was the great increase in heating surface, and an even greater factor than this was the enormous lessening of risk from boiler explosions. Another important feature was that one was enabled to have a very large firebox, and could burn any sort of fuel, such as shavings, sawdust, &c., when necessary. For burning wood, this type of boiler was especially useful, and his company was now sending to West Africa water-tube boilers which had the firebars dropped about 7 inches below the dead-plate, the object of this being to ensure a thick coating of red hot ashes when re-firing. This was suggested by a consulting engineer for one of the West African mines.

He thought that most would agree that a horizontal tube as adopted in the Babcock and "Roots" water-tube boiler was preferable to what was known as the bent tube type. One reason, and he thought a good reason, was their accessibility for cleaning purposes and renewals, for in the horizontal type a tube could be replaced in under 60 minutes. In the bent tube type there must be considerable difficulty in cutting out a burst tube and in expanding the new one.

With reference to the steaming qualities of the two types, he should imagine that the horizontal type must be the better steam generator, as the gases from the fire on their way to the chimney must impinge directly on the tubes, whereas in the bent tube system there was a possibility of the gases merely circulating round the tube, and if this happened the tube would not so readily absorb the heat. This was mentioned in the author's paper, pages 40 and 41.

With reference to the danger from explosions, most water-tube boilers were set in iron or steel frames, and the tubes were not in any way touched by brickwork. It had been the speaker's experience to open up a Cornish boiler for examination,