

greater degree if the tubes were small. With regard to heat transmission, and assuming this might vary from 1 to 5—that was to say, it might be five times greater if the water was flowing rapidly than if stationary, then the vaporization would be increased, also the durability of the tubes, and the effects of expansion and contraction would become more controllable in a well-designed water-tube boiler than in some types of shell boilers.

The question, however, of replacing the water evaporated by feed supply, was of more importance in the water-tube type than in the shell type, the margin of safety being less, due to the small weight of water stored in the generator, hence the necessity for maintaining a steady feed to correspond with the amount of water evaporated, and that no doubt was well recognized by most makers. It might be said that the horizontal tubular boiler was one of the cheapest types to construct for a given output of power, but he thought that the item of first cost was not one of great importance in all cases; the question of economy in running and the economical generation of steam was certainly of the highest importance, since the coal bills could not be paid once and for all like the first cost of a boiler.

The proper management of a water-tube boiler might call for somewhat more intelligence in supervision than an ordinary shell or horizontal tubular type, but this did not form an argument against its use.

One of the most important elements to be considered was the kind of feed water to be used, and where this could be obtained fairly free from solid matter almost any well-designed type of boiler would prove efficient; but if the water contained impurities, the shell type would prove more advantageous.

A question that was sometimes urged in favour of water-tube boiler was that they were free from liability to disastrous explosions, and there might be good reasons for such. In looking up reports on the working of the "Boiler Explosion Acts" in Great Britain, he found that during the past seven years the

water-tube boilers showed a most favourable comparison in that respect, and that the list of explosions where it had been found necessary to hold special enquiry proved beyond doubt that they possessed a greater degree of safety than any other type.

A feature of water-tube boilers which was especially valuable was the rapidity with which they could be fired up, and which, in times of emergency, was of great importance in large installations, say, those generating power for electric tramways, where the loads may fluctuate and vary considerably during certain periods of the day.

The facility with which they could be conveyed to places difficult of access was also in their favour, and another feature, which was often of very great importance in cities where land was valuable, was that they could be conveniently arranged in tiers, one above the other, as their light weight per horse power of output permitted of this being easily accomplished, with practically very little additional strength in the structural arrangements of the building. In that respect they certainly possessed decided advantages over the shell of cylindrical type.

The effect of corrosion in reducing the durability of shell boilers was well known, the origin being traced in some instances to the inclusion of air and the effect of moisture, the combined effects of which were greater in proportion to the weight of carbon dioxide existing in the air. The exclusion of air would, therefore, remove two of the active agents which produce corrosion, and as the proportion of air that could be enclosed in a water-tube boiler was less than in a shell type, the advantage in that respect was in favour of the water-tube type.

The health conditions of the work require some consideration, especially in the tropical climates, and in this respect the best type of water-tube boilers offer facilities for more open and better arrangements in the stoke-hole and ash tunnels than it is possible to get by any other class.

It was generally admitted that water-tube boilers contained more heating surface, per unit of output, than any ordinary shell or locomotive boiler, but he might mention that quite recently some experiments were made, by the introduction of water tubes in a locomotive boiler, on the London and South-western Railway, England, in which the order of things appeared somewhat reversed. In that case a boiler having a grate area of 20·3 square feet, with a heating surface of 796 square feet, was tested on a locomotive under similar conditions against a boiler containing 1291·6 square feet of heating surface and the same grate area, and proved its evaporative efficiency to be fully equal, with a considerable saving of fuel.

The water-tube type of boiler might be said to possess the following advantages over the cylindrical or shell type:—

Steam could be raised far more quickly.

Far greater power output in proportion to weight.

Easily transportable,

No special lifting appliances required for repairs and renewals.

Easily constructed.

Less cubic space per rated horse power for some types.

Could be readily inspected and cleaned.

Circulation in some types more or less definite, and improved with rate of combustion.

Provision for effects of expansion and contraction, good.

Fairly accessible for repairs.

No difficulty in maintaining steam pressure.

On the other hand, they presented a difficulty in ascertaining the condition of tubes during working operations; while damage to a single tube involved drawing the fire; greater attention was required, and there were more parts.

In most cases the parts were made small compared with the shell or fire-tube boiler, so that it was mechanically possible to build such boilers to meet the tendency to higher pressures without making the parts so thick as to offer serious obstruction to the transmission of heat.

Mr. HECTOR KIDD said the paper was more of a descriptive than technical character, and did not therefore permit of being discussed from what might be termed a data, or boiler test point of view, as no figures were given by the author to enable a comparison to be made between the the merits of the various types of water-tube boiler and other standard types of boilers. The paper had, however, the excellent merit of opening up the way for a full discussion of the relative merits of water-tube and other types of boilers, and he personally thanked the author for his paper, for there was little doubt that the discussion on it would throw considerable light on the important question of the relative merits and efficiencies of the various classes of boilers now in general use for supplying steam to manufactories and other purposes.

The author referred to six types of boilers, as representing the principal features in the design and construction of the modern water-tube boiler, and made special mention of the Babcock & Wilcox boiler as a type which afforded good facilities for examination, cleaning, and transportation. These were doubtless good features in any boiler, and it would, he thought, be conceded by engineers that the claims are well founded. It seemed to him, however, that similiar claims, equally well founded, could be made for many other types of water-tube boilers beside those mentioned; this point would doubtless be referred to by those interested in other designs.

The author's forecast, that the water-tube type of boiler was likely to be universally adopted, was not supported by any recent experience in the use of water-tube boilers on board ship.

For marine work, the Scotch boiler more than holds its own in the Mercantile Marine. In the Navy, not only did it hold its own, but it was rapidly regaining the reputation which it was thought by many to have lost by the advent of the water-tube boiler. Engineers who had not given much attention to the history of water-tube boilers might think that they were fairly modern inventions. If, however, they would examine the Patents

Office records, it would be found that they are as old as any of the standard types of boilers. There were about 150 types of water-tube boilers for which patents had been taken out, and for which special claims were made for efficiency, safety, etc.; the first patent, he believed, dated as far back as 1774. There was no gainsaying the fact that the water-tube type of boiler was being extensively adopted by concerns which used the largest amount of steam—such as electric light power stations, cable roads, large sugar refineries, iron and steel works, and others. This being so, it seemed to him that engineers, who were responsible for the design and equipment of steam boiler plants, should look carefully into the question of their merits with a view to determining what were the special features and working conditions which had led to their being so largely adopted. He hoped the discussion would bring out clearly the special merits which had brought the water-tube boiler into so much favour with engineers in all parts of the world.

The chief obstacle to the formation of correct opinion on the merits of the different types of boilers lay in the difficulty in obtaining accurate and reliable figures giving the results of evaporative tests, and tests made in the regular routine of everyday working. In many cases the figures were incomplete, and the tests wanting in some important detail required to complete the heat balance, and, consequently, were of little or no value. There were, however, a large number of reliable boiler tests on record, and it was to these that we had to refer for guidance in the selection of a boiler and in estimating their merits. The author said—"That, in selecting a boiler, the amount and kind of heating surface should be considered, and also that efficiency should be preferred to quantity;" and further on stated that "1 square foot of heating surface at right angles to the current of heated gases was equal to $1\frac{1}{2}$ square feet of heating surface placed parallel to their flow." He should like to ask the author, in his reply, to give some data bearing on these points.

As throwing some light on this question, the following extract from a paper by H. M. Rounthwaite on modern marine boilers would indicate the result of the experience of some of the leading engineers and boilermakers :—

“It has been found that 100 square feet of heating surface in a water-tube boiler is only the equivalent of about 66 square feet of heating surface in a cylindrical one, when the tubes are arranged zig-zag in the one, and no retarders are used in the other”—that was to say, the efficiency of the water-tube boiler surface was only two-thirds of that of the smoke-tubes of a cylindrical boiler. The most probable reason given for the difference in the efficiency of the two kinds of heating surface was that the direction of the gases between the tubes of a water-tube boiler were less easily controlled; whereas, the gases passing through the ordinary smoke-tube at a high velocity were continually being retarded by friction and became so thoroughly mixed that, practically, every particle of the gases was brought in contact with the heating surface, with the result that there was an efficient transference of heat. If retarders were used in the ordinary smoke-tube, the efficiency would be increased from 8 to 12 per cent., depending on the temperature of the waste gases passing to the chimney. Some trials made in America by J. W. Whitham gave an increase efficiency of 18 per cent. when the boiler was hard-pressed. The direction of the current of hot gases being nearly at right angles to the tubes of a water-tube boiler should make the heating surface highly efficient, but there was the difficulty of directing the flow of the gases equally among the tubes. There was also another reason for the heating surface of water-tube boilers not being so efficient as the surfaces of the smoke-tubes of ordinary boilers—they were generally grouped in nests; the front row receiving the first contact of the gases should be highly efficient, but, on the other hand, they partly screened the tubes in the back row. The percentage of the total evaporation for which each tube in the nest was answerable had been determined

by test, and showed that the front row did about 23 per cent. and the back row about 3.78 per cent. when there are 12 rows in the nest. An important factor in the efficient working of any kind of boiler was to keep the heating surfaces clean. As regarded the facilities for cleaning the tubes in water-tube boilers claimed by the author, it seemed to him a much easier method to sweep the deposit out of an ordinary smoke-tube than to clean the deposit off the tubes of a water tube boiler. This, of course, did not apply to boilers in which the tubes were nearly vertical. However, in comparing the efficiencies of the water-tube boiler and cylindrical boiler, the results obtained in general service must be taken, and not the figures from special evaporative tests, when all the conditions were favourable for high efficiency. As bearing on this point, the Report of the Admiralty Committee dated 28th May, 1903, might be quoted. They say: "From the evidence before the Committee, it appears that no type of water-tube boiler at present in use is, on service, as economical as the cylindrical boiler;" and Lord Selbourne stated that a similar conclusion had been arrived at by the owners of several merchant steamers now running in the Atlantic trade which were fitted with water-tube boilers. The experience gained in the Mercantile Marine and in the Navy with water-tube boilers seemed to indicate that, for economy, durability and reliability, the Scotch cylindrical boiler had, at the present date, some points in its favour. If we examined the tabulated results of trials with steam boilers on land, we do not find that the data therein contained supports the view that the water-tube type of boiler was more economical in fuel than were the standard types of boiler when worked under similar conditions.

In Donkin's treatise, "Heat Efficiency of Steam Boilers," there were 50 tables containing the results of 425 experiments made with many different varieties of boilers, and about the only conclusion that could be reasonably drawn from the results given in the tables was that all types of boilers, if worked under reasonable and similar conditions, would give about the same results in economy of fuel.

The makers of many types of water-tube boilers contended that, on account of the more active circulation of water in their boilers, the transmission of heat, and, therefore, the efficiency of the heating surface, was greater. There was no doubt whatever about the value of good circulation, as it tended to keep all parts of the boiler at a uniform temperature, and prevented the adhesion of steam bubbles to the surface of the plates—thereby reducing the risk of overheating.

The author claimed that the active circulation in the Babcock & Wilcox boiler would prevent the formation of scale in the tubes. This contention was not supported by the experience gained in the working of these boilers. We had only to glance at the advertisement sheets of many of the technical journals to see the number of patent devices which were in use for removing the scale from the inside of the tubes to see that they required scaling. The fact was, if there was scale-forming material in the water, it would be deposited when the water was evaporated, and the circulation, however active, would not keep it from accumulating on every part of the boiler and in every kind of tube—vertical, horizontal, or inclined. He had found that in the vertical tubes of an evaporating apparatus, where the circulation was extremely active, the scale was found to deposit rapidly in the tubes, and, if not frequently removed, it would soon block the tubes up solid.

With regard to the influence on the efficiency of the heating surface of a boiler with active circulation—such as that in a water-tube boiler, and what might be called natural circulation, such as occurred in an ordinary multitubular or locomotive boiler—he would like to draw attention to the very high rate of evaporation which resulted in the fire-box of a locomotive boiler—amounting, in some instances, to 35 lbs. of water per square foot of heating surface, and the circulation seemed to be sufficiently active to prevent any undue heating of the plates, although the shape of the fire-box was not favourable to good circulation.

Personal experience in the working and testing of steam boilers, and a fair acquaintance with literature on the subject, had led him to the conclusion that there was no best boiler so far as economy of fuel was concerned ; for the efficiency of a boiler did not depend on the type or on the particular way the water was circulated, but upon the simple principle that when there was a proper circulation of both water and the products of combustion, and—assuming the fuel to be efficiently burned—the economy would be a function of the average quantity of combustible matter consumed per square foot of heating surface ; or, which was the same thing, the pounds of water evaporated per square foot of water-covered heating surface.

In this connection, there seemed to him to have been sufficient practical experience gained to support the statement that no particular type of boiler was intrinsically better than all other types ; each type possessed advantages and disadvantages—the relative importance of which depended on the conditions under which the boiler had to work. The possible economy that might be obtained from all types of boiler used being equal, the standard type or types would be selected for other reasons than economy of fuel. Amongst the reasons that would guide engineers in the selection would be :

- (1) First cost.
- (2) Durability.
- (3) Facility for cleaning.
- (4) Cost of repairs and facility for making them.
- (5) Space occupied for a given capacity.
- (6) Possibilities of driving at both high and low rates of evaporation without a great loss of fuel economy.

With reference to the durability of the various types of water-tube boilers, it would add much to the value of the paper if the author could give some figures indicating the probable average life of water-tube boilers. The experience gained so far in marine practice indicated that the cylindrical or Scotch type of boiler had rather more than twice the life of the water-tube type ; the life

of an ordinary Lancashire, multitubular, or locomotive boiler of large size on land, if supplied with fairly good feed-water, should be from twenty to thirty years. The Colonial Sugar Refining Company, Limited, had boilers of the locomotive type at work in Fiji for the past twenty-one years, working day and night for about six months in the year. These boilers had cost very little for repairs; they were now in very good order, and were likely to have a life of another ten to fifteen years. These boilers were supplied with good water, and special care is taken to keep the water in the boilers free from the slightest trace of acidity—in fact, they prefer to keep it slightly alkaline by the use of caustic soda or lime. It might interest the members to know that these boilers were fitted with removable tubes, which were taken out once in every three or four years, so that they, together with the fireboxes and shells, could be thoroughly cleaned and inspected. The boilers had 2452 square feet of heating surface each, or a total of 29,424 square feet; the steaming capacity of the boilers was based on 2.5 lbs. of water per square foot of heating surface, but the chimney capacity was ample to permit of the boilers being driven up to a rate of 3.5 lbs. of water per square foot of heating surface. The tubes were 18 feet long by $3\frac{1}{2}$ inches in diameter; and the weight of the boilers complete, without water, was 30 tons.

In the various sugar factories of the Colonial Sugar Refining Company, Limited, there were a number of different types of boilers, all giving about the same economical results when worked under similar conditions. In one of the factories the boiler supplied by the makers were of the loco. Cornish type—that is to say, they each had a locomotive firebox and a Cornish barrel, the grate surface being 20 square feet and the heating surface 350 square feet. These boilers gave a very low efficiency, as the temperature of the waste gases going to the chimney was about 950° Fah.; but when they were converted into compound boilers, by placing multitubular boilers behind them containing 700 square feet of heating surface, the temperature of the waste gases was

reduced to about 500° Fah., and the efficiency of the boilers was raised in the ratio of 55 per cent. to 75 per cent.—or about 20 per cent.

With reference to the remark of Mr. Fyvie that the Babcock & Wilcox boiler was the "champion" smoke producer, experience seemed to indicate very clearly that the arrangement of the furnace, combustion chamber, class of fuel used, the skill of the firemen, and the rate at which the boiler was being driven were much more important factors in the prevention of smoke than any special features in the design of any boiler. It should not be overlooked that in most types of boilers the time allowed for complete combustion in the furnace and for the gases to pass through the flues or tubes to the smoke-box was seldom more than one second. In practically less than half-a-second all the chemical actions of the mixture of the furnace gases with the air had to take place in the boiler, and unless the furnace arrangements facilitated the rapid and thorough mixture of the gases, the result would be incomplete combustion and an abundance of black smoke.

Mr. Milson, in a recent paper on water-tube boilers, gave the time for any particle of gas to remain in an ordinary Scotch marine boiler as something less than one second, and for a Belleville boiler three-quarters of a second. In the large locomotive boilers referred to the time was less than a second.

He understood Mr. Fyvie in his remarks to say that the Babcock & Wilcox boiler gave considerable trouble through defective water circulation when working at high steam pressures. He hoped the author in his reply would give some data on this point. It would add to the value of the paper if the author could supply any figures to show what the rate of water circulation was in the various tubes, and also the figures of any test made to determine the highest safe rate of driving the Babcock & Wilcox and other types of water-tube boilers.

The figures in the extract from Mr. Fyvie's paper—giving the results of a test made with a Babcock & Wilcox boiler at Messrs. Collins Brothers' Woollen Mills, Geelong, indicated a