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SOME NOTES ON WATER-TUBE BOILERS.

BY ALBERT E. LEA.

IN bringing this subject forward for the consideration of this Association, the author proposes to consider briefly, in the first place, the remarkable progress and development that has been made in water-tube boilers during the past thirty years.

During that period they have been tried for a variety of industrial purposes, and the demand for them is constantly increasing. Naturally, during that time there have been many types constructed, and many have disappeared because they did not contain the elements which are so essential to the satisfactory working of a perfect steam generator. Some types, however, have lived and prospered during that time, and have proved beyond doubt that they will class amongst the steam generators of the future.

Among the many subjects which now engage the attention of the engineering community, there are few of greater importance than those involved in the design, construction, and management of steam boilers. It must be admitted, however, that until recent years water-tube boilers have not occupied a prominent position in the estimation of manufacturers and users. The historic record of the steam boiler, if judged by its treatment, goes to show that it was very little in advance of an ordinary water tank, and even at the present day there are still in use in our midst some of the old leven. Our predecessors in the early part of last century confined their skill to improving the steam engine, and it was only when the necessity for higher pressure became apparent that they began to turn their attention to a better class of steam generator, which could sustain with safety a pressure of forty pounds per square inch, and over. It was proved that, by obtaining a higher pressure, in addition to a better efficiency of the engine, it was far more economical to the general working, and from that time onward a marked improvement in the constuction of steam boilers has been going on.

Since the introduction of steel as a boiler material, the construction of steam boilers has advanced to a very high degree of perfection ; and by the constant introduction of special machine tools, the manufacturer is enabled to eliminate from his work the many defects so common amongst the old hand-made boilers ; and in most establishments where only first-class work is done, many of the old-time tools, such as the set block, hand flanging tools and the deadly drift-pins, are conspicuous by their absence.

It is interesting, however, to note that, whilst material and workmanship have been perfected, the designs and types of prominent land boilers still remain very much what they were when Trevethick, in the middle of last century, introduced his cyclindrical and Cornish boilers.

Briefly speaking, there are two classes of water-tube boilers which demand special attention, viz., the bent tube and the straight tube boiler. Amongst the most notable of the bent tube type are the Stirling, Normand, and Thornycroft; and the most notable of the straight tube type are the Babcock and Wilcox, Belleville, and Yarrow.

In touching on the subject, the author would call your attention to the heating and circulating of water. We all know that water expands when heated above a temperature of 39 degrees Fahr. ; but possibly some of us have not realised that water is a very bad condutor of heat.

Water, when heated, cannot readily impart its heat to its neighbouring particles; each particle remains expanded, and rises, by means of its lightness, to the surface, the colder and heavier particles going down to be heated in turn, thus setting up currents. If we take an ordinary kettle over a fire, the water rises tumultuously around the edges of the vessel, and, going towards the centre, descends. This action takes place whilst the water is being gradually heated, but is not violent. But when heated to boiling point, each unit of heat converts a portion of water into steam, and increases its volume greatly, and the mingled steam and water rise, rapidly producing ebullition.

Now, if we place in the kettle a smaller vessel with a hole in the bottom, and supported at equal distances from the side, we separate the downward from the upward current, and we are able to force the fire without causing the water to boil over. This fact was observed by Perkins in 1831, and has formed the basis of many arrangements for producing free circulation. Having thus facilitated the circulation, we must provide for the most important objects in steam boiler design, viz., efficiency, durability, and safety.

When circulation is unassisted, the rising of the steam bubbles tends to cause priming; but when the currents are separated, this ceases, and a considerably larger supply of steam is driven off in a comparatively dry state. Thus, good circulation increases efficiency.

With regard to durability: how does circulation tend to make a boiler more durable? In this way:—If the water rapidly circulates, it causes the whole of the parts to be kept at a uniform temperature; and as the strength of a boiler is greatly influenced by unequal expansion and contraction, due to changes of temperature, good circulation is consequently beneficial. Take the ordinary Cornish boiler, for instance, filled to the proper water-level ready to raise steam. As soon as the fire is started, the top of the furnace tube becomes hot, causing expansion, whilst the bottom of the shell is perfectly cold. This tends to bulge the flat ends outward; hence the heavy gusset-stays used in shell boilers. Then, when all the water becomes heated, the whole of the structure elongates, and straining will occur unless proper provision has been made to counteract it.

There is no definite circulation in some shell boilers, the direction in which the water moves being irregular. This causes strains, as above explained.

We will now consider the circulation in well-constructed water-tube boilers, in which it is claimed to be definite and continuous, that the more the boiler is forced the better is the circulation, that the temperature throughout is equal; and, therefore, no strains are caused through unequal expansion. In consequence, no stays are required.

The author has repeatedly had steam raised in a water-tube boiler in half an hour without the slightest injury. The numerous boiler explosions that have occurred, causing loss of life and destruction to property, have resulted in the most searching inquiries as to the cause thereof, and in the framing of rules for the protection of the steam user and the public, and it is universally acknowledged that the claim of the advocates of the water-tube boiler, that the liability to explosions of that type is largely eliminated, is a just one. The author considers that water-tube boilers are economical in the use of fuel, and draws attention to the result of a test made at Geelong, particulars of which are appended. He also considers that, for power developed, they occupy less space than shell boilers; also that, although the first cost may be a little more than that of the shell boilers, the cost of maintenance is far less, and the life longer than that of the other forms. The author has not heard of loss of life or limb, nor injury to property, having resulted through the use of the type of water-tube boiler he has under his charge.

In the selection of a boiler, the amount and kind of heating surface should be considered, as the evaporation depends largely upon the construction of the boiler, together with the draught and combustion in the furnace. The efficiency of heating surface should be preferred to the quantity. When combustion has taken place in the furnace, and the heated gases have begun their flow to the chimney, the more they are turned from a straight course and made to impinge against the heat-absorbing surface of the boiler, the more water will be evaporated per square foot of heating surface and per pound of fuel used—hence one square foot of heating surface placed at right angles to the current of the heated gases, so as to receive the heat direct, is equal to four square feet when placed parallel to their flow. This shows the importance of placing the tubes in a staggered position, so as to get a direct impact with the heated gases against the entire surface of the tubes, as in the water-tube type of boiler.

In the ordinary multi-tubular boiler, the author considers that this breaking-up of the heated gases is entirely overlooked, and that the value of heating surface is overrated ; also that the internal area of combustion space in a four-inch tube per foot of its length is out of proportion and acts as part of a condenser, thus cooling the gases below the proper temperature for perfect combustion, and causing the tubes to become choked with soot and fine ashes; whereas with some water-tube boilers the flame and heated gases completely envelope the entire length of the tubes, and only a small quantity of soot accumulates on the top sides, the area of combustion space surrounding the tubes being regulated by the distance at which they may be placed apart. By comparing the difference between the same sized tubes when used as fire or water tubes, in his opinion a decision in favour of the water-tube type will easily be arrived at as being the most effective.

The facilities for cleaning and repairing some types of water-tube boilers is so well provided for that they can be examined from end to end, inside and outside, and always kept in the best condition for constant use. In these boilers, that portion of the heating surface in direct contact with the fire is not liable to be injured by excessive heat, to the same extent as in a shell boiler. Should a tube become burnt, it can easily be removed and replaced by a new one, when the boiler will be as good as before. On the other hand, the same action on a shell boiler would necessitate the cutting out of the defective part and placing a patch over the hole thus made, thereby deteriorating its strength, and this may mean reducing the original working pressure.

The author will now give a description of the model of the Babcock and Wilcox boiler that stands here for all present to judge for themselves as to its good qualities as a perfect steam generator; for, although it is well known to most engineers, there are many good points about its construction which may have been overlooked.

The boiler is composed of 4-in. tubes, placed in an inclined position, connected in vertical sections with a horizontal steam and water drum at each end, with a mud-drum at the back and lowest point of the boiler. The end connections or headers are in one piece, made of forged steel, for each vertical row of tubes, and in such a position that the tubes are staggered—that is, so that each row of tubes comes over the space of the lower row. The holes in these headers are accurately bored and faced, and the tubes fixed in by an expander. The sections being thus formed are connected to the horizontal steam and water drum and mud drum by short tubes. The short tubes are also expanded into bored holes having no bolts or studs, thus leaving a clear passage between the several parts. The openings for cleaning, opposite the end of each tube, are closed by hand-hole fittings, the joints of which are made in a thorough manner, so as to ensure a good metallic contact. These caps are held in position by wrought steel clamps and bolts. If attention is given to the design and construction of this boiler, it will be realised that it has the requirements of an ideal steam generator, and at the same time the advantage of a water-tube boiler will be recognised.

The steam and water drum is made of steel, the longitudinal seams are double riveted, all the fittings are extra heavy and of the most modern design, and the workmanship is of the highest grade. Without using abnormally thick plates, it permits free expansion, and has no joints exposed to the fire, with the exception of the circumferential seams in the steam and water drum, and this can be avoided by arching the brickwork under the drums, if desired; but, in the author's opinion, it is not sufficiently detrimental to require that expense and trouble. Riveted joints in shell boilers, with their necessarily double thickness of plates in parts exposed to the fire, give rise to serious difficulties. Being the weakest part of the structure, they concentrate upon themselves the strain of unequal expansion, giving rise to leaks and oft-times rupture. The joints between tubes and tube-plates also cause much trouble when exposed to the fire direct, more especially if the tube-plate can be acted upon by cold air; and many who have had experience with locomotive or other tubular boilers will readily realise the force of the remarks on this point. The thick plates used in the furnace of a shell boiler hinder the transmission of heat to the water, and at the same time allow the plates to be overheated, and even burning sometimes takes place on the side next to the fire, which results in a loss of strength, cracks, and a tendency to rupture, and, no doubt, has in some cases been the cause of explosion. On the other hand, water-tubes, being thin and of small diameter, give such a ready transmission of heat, that the fiercest fire cannot overheat or injure the surface, so long as it is covered with water on the other side.

Another very advantageous point of the water-tube boiler is the subdivision of the water space to ensure safety from explosion of a disastrous nature. How well this is done can easily be judged from the model.

Your attention is now drawn to the combustion chambers, and the direction of the gases relatively to the heating surface. The furnace is under the front or higher end of the tubes, and the products of combustion pass between the tubes until the heat is, as far as practicable, extracted. The draught area is the whole area in which the tubes are enclosed, and by the arrangement of flame bridge plates the gases have ample time to impart their heat to the tubes before entering the chimney; and through the tubes being practically at right angles to the course of the gases, the heat impinges thereon instead of passing along in parallel lines, as in the ordinary fire-tube boilers. The gases passing across and between the staggered tubes are brought into contact with the whole of the heating surface, rendering the boiler highly efficient.

Then, let us take the construction of the boiler as regards constant circulation of water, and the maintenance of the whole of the parts of the boiler at a uniform temperature. In this boiler the water, as it is heated in the tubes, rises to the upper end and is converted into steam. The mingled columns of steam and water are of less specific gravity than the solid water at the back of the boiler, and, therefore, naturally rise through the vertical headers into the drum where the steam separates from the water, which flows back again to the back headers, thus causing a constant circulation. As the passages are large and unimpeded, this circulation is very rapid, definite, and in one direction, the steam getting away as fast as it is produced, and, being replaced by a fresh supply of water, absorbs the heat of the fire to the best advantage, causing thorough commingling of the water all through the boiler, and consequently an even temperature. By this means incrustation is prevented to a great extent in the tubes, and any deposit likely to form will be deposited in the mud-drum, where it can easily be blown off.

One cannot have a better proof of the reputation of the water-tube boilers than the fact that the whole of the 30,000 horse-power of boilers at the World's Fair at Chicago, in 1893, was of the sectional water-tube type. This was the outcome of one of the conditions, viz., that of safety. This class of boiler was determined on as the only proper admissible one, as had been proved by years of practical demonstration.

The accessibility for cleaning is a most important point in the construction of any boiler, and with this type it is exceptionally good, because the parts are directly accessible both inside and outside for inspection and cleaning. By removing the caps at the end of the tubes, the interior of the tubes are absolutely accessible, and any scale or incrustation can be removed by a tube scraper. There is a man-hole in the steam and water drum which gives ready access to that part, and hand-holes are provided in the mud drum for readily cleaning it. The outside of the tubes are cleaned by means of a steam jet fixed on to a flexible steam hose, which is operated through small holes fitted with drop doors, the holes being only about 3 inches by 2 inches for each row of tubes, and the small door closing as soon as the steam jet is withdrawn from the tubes, thus preventing a large amount of cold air entering the combustion chambers. In the case of ordinary multi-tubular boilers the fire-tubes receive the dust from the flue and thus quickly become coated from one fourth to one half of their diameter, whereas the water-tubes can only retain a limited quantity on their upper side, and after that it becomes in a measure self-cleaning.

There is one point worthy of mention, and that is the ease of transportation. When boilers have to be sent long distances by road, as frequently occurs in these States, water-tube boilers have a special advantage, since all the parts are of comparatively light weight. The Babcock and Wilcox Company have a specially designed boiler for Colonial purposes, in which the steam and water-drum are placed transversely instead of longitudinally, and an extra steam drum is provided. In these boilers the heaviest part is not more than eight cwt.

The author, in concluding this paper, ventures to predict that, in the near future, high pressure water-tube boilers will so demonstrate their efficiency and their superiority that they will be universally adopted.

Extract from Paper read by Mr. William Fyvie before the Victorian Institute of Engineers :—

RESULTS OF TRIAL OF POWER PLANT AT MESSRS. COLLINS BROS.' WOOLLEN MILLS, GEELONG.

Engine.—Tandem Compound Condensing. Cylinders, 12in. and 22in. x 36in. stroke; air-pump driven through bell-cranks from tailrod of low pressure Cylinder.

Boiler—Babcock and Wilcox standard type for 160lbs. working pressure, 1265 sq. ft. heating surface, grate area 26½ sq. ft., fitted with super-heater having a heating surface of 170 sq. ft.

Date of Trial—(Duration of Trial 4 hours)	9/9/02
Class of Coal used, South Bulli. (See Analysis below) ...	Bulli
Total Coal consumed during the trial (in lbs.)	672
Coal consumed per sq. ft. of grate per hour...	6.3
Total Quantity of Water evaporated during the trial ...	5960
Water evaporated per lb. of Coal from 58 deg. F. to steam of 140lbs. and 456 deg. F....	8.87
Equivalent Evaporation per lb. Coal from and at 212 deg. F.	11.11
Mean Steam Pressure in lbs. per sq. in. above atmosphere during trial	140
Mean Vac. in Condenser by vac. gauge (in inches mercury)	27¾
Mean Temperature of injection water (injec. condenser) ...	58 deg. F.
Mean Temperature of stokehole	68 deg. F.
Mean Temperature of Steam at boiler stop-valve ...	456 deg. F.
Mean Temperature of engine room	73.6 deg. F.
Mean number of revolutions per min. during the trial ...	64
Indicated Horse-power	100.5
Net Water per I.H.P. per hour, including steam to jackets, re-heater, and boiler feed-pump (in lbs.)	14.82
Coal consumed per I.H.P. per hour, including steam to jackets, re-heater and boiler feed-pump (in lbs.) ...	1.67
Equivalent Coal per I.H.P. per hour, including steam to jackets, re-heater and boiler feed pump, provided the feed-water were taken from hot well at 156 deg. F., which is the usual working conditions (in lbs.) ...	1.534
Efficiency of the boiler and superheater combined ...	77.68 %
Efficiency of the boiler only, assuming it was all dry saturated steam that entered the superheater	74.87 %

PROXIMATE ANALYSIS OF COAL.

Water	.95
Volatile hydro-carbons	20.95
Fixed Carbon	68.40
Ash	9.70
	100.00

Efficiency of Coal by calorimeter tests, 13.810 B. T. U. per lb.