ERRATA.

Page 52,	line 8.—	for “= 13”	read	=·13
,, 56,	,, 24	,, “made in”	read	“made to”
,, 56,	,, 26	,, “per in.”	read	“per sq. ft.”
,, 65,	,, 7	,, “$\frac{0 \times}{2}$”	,,	“$\frac{0 + 12}{2}$”
,, 66,	,, 7	,, “$\frac{380 + 380}{2}$”	read	“$380 + \frac{380}{2}$”
,, 66,	,, 19	,, “sq. order”	read	“sq. inches”
,, 66,	,, 19	,, “= 2·35 sq.”	read	“= 2·35 per sq. ft. [fire grate surface.”
,, 68,	,, 21	,, “$\frac{62{\cdot}21+1}{12+0072}$”	read	“$\frac{62{\cdot}21 \times 1}{12+0072}$”
,, 68,	,, 23	,, “$\sqrt{64{\cdot}32+72{\cdot}744}$”	“	$\sqrt{64{\cdot}32 \times 72{\cdot}744}$”
,, 68,	,, 25	,, “68·2+20”	read	“=68·2×20”
,, 69,	,, 17	,, “$=1{\cdot}38 r^3 \times N$”	read	“$=1{\cdot}38\, D^3 \times N$”
,, 70,	,, 17	,, “$\sqrt{500+461+i}$”	read	“$\sqrt{500+461 \times i}$

DISCUSSION.

Mr. W. Sinclair said the application of forced draught to marine boilers has not altogether made matters easier for the men who have to run them, nor does it cure all the defects in natural draught claimed for it. From some years' experience spent with Howden's forced draught in various steamers, he had made the following notes:—With the ordinary style of stoking $\frac{7}{8}$in. of water pressure in ashpits should be the maximum, and when fires are clean $\frac{3}{4}$in. The continued use of even so small an advance in pressure as 1in. and $1\frac{1}{8}$in. results in troubles sooner or later. These troubles are well known to most engineers—buckled smoke-box doors, burnt-out check and baffle plates, and leaky tubes and seams. In connection with these, firstly, buckled smoke-box doors, the ordinary smoke-box door has usually, after a year or two's working, to be taken off and re-rolled, or else plastered with fireclay round the edges. This latter makes a wonderful difference in steaming. He had seen one steamer under steam having one boiler out of six fitted, as an experiment, with Silley's patent door, which is extensively advertised in engineering magazines. This had only been fitted a few months, and he personally could not form an idea as to the utility, though it seemed a strongly-made affair. It was designed to resist this buckling. Since then he had seen a Silley's door on the new A.U.S.N. Wyreema, which had been dull red hot and it showed no sign of buckling. The amount of cast iron used up in some vessels' furnaces in the shape of check and baffle plates is sometimes considerable. A vessel having twelve fires would average about three-quarters to a ton per annum in constant running.

Atmospheric conditions affect forced draught as well as natural draught, and no amount of increased air pressure in the ashpits seems to make up for bad combustion with a following wind; and, moreover, the increase of pressure seems to localise the heat in the furnace and combustion chambers, and makes the engineers in charge think about the boiler densities and furnace scale.

Sometimes during heavy weather, when a vessel is slowed down, attempts have been made to run forced draught vessels by natural draught. This generally results in leaky tubes and seams; the boilers get "tuned up," as it were, to the high furnace temperature, and any diminution of these clearly will cause trouble on account of the cold air impinging on surfaces expanded and set to high temperatures.

But with the advent of mechanical draught the old natural draught style of stoking passes. Heavy fires having a large body of heat and able to burn for about 15 minutes under the strong draught, or the light sprinkling of a few shovels of fuel every few minutes (as is the order in the navy), are the two styles in vogue. He said fifteen minutes, and he had frequently counted fifty to fifty-five shovelfuls of good Newcastle coal put on in this interval in a centre furnace. Of course, centre fires in three furnace boilers burn about 25 per cent. more coal than wing fires, because the fires are easier worked. In this connection he should think that boilers having large flat grates (such as obtain in water-tube and under-fired boilers) would lend themselves more naturally to accelerated draught. In a furnace tube where the air pressure enters from the ashpit in the usual fashion, the curved sides seem to guide the air more into the furnace wings than the centre, and these places are hardest to keep covered with coal. Most new marine installations have space between the corrugated wing bars and the furnace filled with fireclay, but this becomes neglected as time goes on and is a source of loss, permitting the air to enter the furnace in excess of what is required.

He believed in accelerated draught, but it offers great temptations to be overdone in the matter of cutting down grate area to the smallest possible quantity, and in the vessels he had noticed its working, he would repeat that sufficient grate area to allow of the maximum power being obtained with ¾in. water pressure will give excellent and economical results, but to go beyond that courts trouble.

Most of the data we have of high rates of combustion per square foot are obtained from warships, and these vessels are notoriously prone to boiler troubles.

Mr. F. E. Stowe said in introducing the subject of mechanical or accelerated draught the author has given the Association a clear, elaborate, and convincing series of statements and records thereon, and the wonder is that with this knowledge available so little has been done, other than in marine engineering, in the adoption of this adjunct to economical power reduction.

Coal is a fuel consisting largely of carbon, and with this carbon, as with all matter, the ultimate state under the application of sufficient temperature is a gas, but the varying degrees of temperature under which the constituents of the coal are volatilized will always determine whether combustion (more or less perfect) will be the result of admixture and volatilization, for it is possible to volatilize light carbon, cool it off, mix it with the correct proportion of oxygen, and (because of insufficiency of temperature) without combustion resulting. In the records of an experiment with wood for the purpose of deciding the best way of obtaining charcoal it was observed that as heat was applied with increasing intensity of temperature the first bodies to pass off were water and carbonic oxide. These were succeeded by a highly carbonaceous oil, and lastly by carburetted hydrogen.

If coal be heated in a boiler furnace, it is evident that with a varying temperature in and about the fuel the less volatile elements will be evolved only at the higher temperatures, but will, at the same time, also require less oxygen for perfect combustion. But air entering a boiler furnace in greater quantity than is required by the volatilized carbon must inevitably produce a reduction of temperature, since this air has a comparatively low temperature; but the less volatile compounds, being evolved from the incandescent coal, enter into combination with air of too low a temperature and in too great a quantity for perfect combustion. This action can be illustrated in the blowing out of a match, and if the action be noted it will be seen that the excess of air blown on to the match produces smoke even before the flame is quenched, since the temperature at the point of combustion is sufficiently reduced to cause combustion to be less and less perfect, and smoke is evolved until the process of cooling ultimately causes the cessation of combustion—or, to use a common idiom, the match goes out—from which it may be implied that the sure remedy for black smoke is high furnace temperature obtained by the thickening of the fire and the correct application of the requisite quantity of air—but never in excess.

The diagram (Plate XI.) shows the theory of combustion as carried out in a boiler furnace, and for convenience this is divided into three stages. As is shown, the lower or primary stage is the maintenance of a high temperature in an incandescent mass of fuel, the incoming air through the firegrate supplying the oxygen, which, mixing with the carbon of the coal, as soon as evolved, causes a rapid and intense combustion, resulting in the product carbon dioxide, or one part of carbon to two parts of oxygen. Now, in the secondary stage this intensely hot carbon dioxide passes through a mass of coal, heating it and taking therefrom another part of carbon, the resulting mixture being the gas known as carbon monoxide, or two parts of carbon to two of oxygen, but still of a sufficiently high temperature to cause the perfect admixture of assimilation of another part or quantity of oxygen, if such be supplied. If this other part of oxygen be supplied, we have then the final or third stage, wherein is the production of intense heat and the evolution of carbon dioxide, a boiler effluent, forming part of the so-called funnel gas. Of course, in all this the nitrogen forming seventy-seven hundredths of the atmosphere has been practically useless and, moreover, takes away quite a quantity of heat, as it leaves the funnel as part of the funnel gas.

In Fig. 2, Plate XI., the first two stages are combined in one by carrying a thick fire, the lower part of the fuel supplying the first stage and the upper part the second stage, while in marine boilers the third stage is completed in the so-called combustion chamber, the oxygen being supplied through the furnace door, over the top of the fire or through a hole under the bridge. In all this it is evident that an apparently impossible adjustment of the air is necessary in furnaces for even a slight perfection of combustion, and it would so become were it not that a sufficiently high temperature is usually maintained to allow of the assimilation of only as much oxygen as is required, in spite of the supply of the latter being in excess.

Accelerated draught, because it mechanically increases the liberation of carbon and supplies the additional oxygen (though not in excess) and a more rapid combustion is maintained, must of necessity produce a higher furnace temperature; but even then the possible efficiency is not so evident, unless it is remembered that the passage of heat through the boiler plates is proportional to the differences of temperature maintained on the respective sides of the plate. It would not avail much that 30lb. of coal was burned per square foot of firegrate with accelerated draught as against 15 without, or that twice the number of thermal units of heat were evolved were it not that the furnace temperature, being increased, ensures the passage of a greater number of thermal units. Again, the non-conducting carbonaceous oil, that is such a desirable thing in the domestic flue, is the cause of the greatest loss of conductivity in the boiler, where it adheres to the tubes, etc.; but since accelerated draught, with its higher furnace temperature, volatilizes all this, there must therefore result a very substantial gain in efficiency. There are alternative methods by which combustion may be improved, such as the supply of oxygen alone (provided this can be chemically obtained), the use of oil fuel in combination with coal; but even without these it must be evident that the chimney is doomed and that the far more easily controlled and efficient method of accelerating combustion mechanically will become universal.

Mr. O. W. Brain (visitor) said he was much interested in the "Temperley" steam extractor tubes, and had inquiries made in England, with the result that in one large electric light station where forced draught was used the results were said to be very satisfactory.

Mr. Forbes Mackay (visitor) explained some of the difficulties he had had to contend with in power stations, which had been overcome by introduction of induced draught, but he preferred natural draught.

Mr. W. H. Harricks said he must confess to a regret that the author's paper on a subject of such general interest has not elicited such a full discussion as he was sure he, as much as many others, must have wished for. Probably the majority of the members are so fully in accord with the author's views on the subject that they naturally, under such circumstances, have not entered into the discussion. There surely must be, however, a number who, like Mr. Mackay, would prefer, under ordinary conditions, to rely on natural draught, as also must there be others who believe in some other of the eight means of accelerating draught enumerated by the author in the beginning of his paper. It would have been interesting to have heard from them. Almost the whole of his experience had been with the form of mechanical draught specially advocated—viz., induced—and, although he could not refer to any comprehensive tests to substantiate the belief, the simple tests and other very apparent advantages that have followed as the result of every installation led him (the speaker) to support the author's contention that there are but few existing boiler plants that could not be greatly increased—certainly in capacity, and almost certainly in efficiency—by the use of mechanical draught. Its installation certainly involves some little attention from the engineer; but weigh the absolute control that he has, by its help, possessed of against his impotency when dependent on climatic influences.

There are one or two little things—not with regard to the main subject, but in reference to the details of fans—that he would like to hear something further about from the author. He makes use of a formula of the capacity of forced or induced draught fans which. he thought, requires some qualification. It certainly agrees pretty closely with that given by J. H. Kinealy for forced draught fans. It is—

$$A = 650 \times D^2 + \sqrt{i}$$

Where A=Capacity in cub. ft. per min.
D=Diam. of fan impeller in ft.
i=Water gauge in inches