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## THE SMOKE PROBLEM FROM AN ECONOMIC STANDPOINT.

By CHARLES W. FULTON (Paisley).

THE Textile Institute is fulfilling a long-felt want in affording opportunities of bringing together a large variety of interests leading to an exchange of ideas between different sections of the trade

Many important developments in the trade have lain dormant for years, due to no other cause than the lack of suitable opportunity for an interchange of ideas between the different sections, and, also possibly the belief in the necessity of secrecy. It seems apparent that the Textile Institute will be an important factor in breaking down these false barriers which are an obstruction to the general interests—what benefits one section will in nearly all cases be found to benefit the whole, because nowadays our trade has to be considered as a whole in competition with the trade of foreign countries as a whole, and therefore it behoves us to be more co-operative in our methods in order to retain our position as pioneers.

The Textile Institute is becoming the medium for bringing together the technical expert and the practical man, and offers an opportunity of hearing questions discussed from different viewpoints.

Now, in presenting to you the following remarks on the smoke problem, I want to make it clear that I come before you not as an expert on this subject, but only as one who has had to consider the smoke problem as a user and from a purely commercial standpoint, and with some reticence I decided to read this paper.

Many things can be done, but are not, simply because in practice it costs money to do them. All our rivers could be made perfectly pure, but, if the law were rigidly enforced in all cases, many concerns would have to close up. In short, if in practice it paid to consume smoke, none would be made.

Now, to arrive at a sound conclusion as to whether the installation of a smoke-consuming system will pay or not, it is necessary to take a more comprehensive view than that usually taken by those in control of a works, because in many establishments the steam-raising gradually settles down to a more or less fixed procedure, and, as a consequence, when a new system is placed before the manager with what often appears to be excellent guarantees of economy, the manager (a little apathetic as regards this department) forgets certain factors which must, of necessity, be taken into account before he can be assured that the installation will lead to a better balance sheet, which is the only vital question for him to consider.

It is simple enough to run an installation of boilers without smoke by supplying a sufficient excess of air to kill same, but this costs money.

The two important factors which must be considered are as follows:—

(1) *Coal Efficiency*, i.e., lbs. of water evaporated per lb. of coal burned.

(2) *Boiler Efficiency*, i.e., the total evaporation per boiler.

By putting down plenty of boilers and steaming them slowly, it is a comparatively easy matter to get no smoke and a high coal efficiency, but this does not pay, because of the increase of the following factors:—Capital, interest, upkeep, depreciation, and labour cost on boilers, housing, space, and attachments. Therefore it becomes apparent that a guarantee of reduction on the coal bill by itself is no assurance of a commercial advantage or a better dividend.

In individual concerns, these factors are not sufficiently realised, but in the case of the larger combines with central offices, where it becomes possible to compare one mill with another, and that from a dividend point of view, it is now recognised that, while the highest coal efficiency can be got at, say, round about 20 to 25 lbs. of coal burned per square foot of grate area, the most economical rate of burning from a profit point of view is much higher, say, about 30 to 40 lbs. per square foot, depending upon circumstances.

In looking at the question of the smoke problem, it naturally divides itself into two main headings:—

(1) How are presently-installed steam-raising installations to be made smokeless with an increase of profit?

(2) What is the best system of smokeless steam raising to adapt for new establishments?

The questions to consider under these two headings are quite different, because in the first case the capital is already sunk in plant, whereas in the second case the capital is there to be spent in whatever direction seems best from a commercial standpoint.

Referring to the first heading, there are several mechanical stokers on the market which can be made to work smokeless and give a good coal efficiency; the advantages and disadvantages of these are known, so that I need not here enter into a discussion of them. Speaking generally, however, the experience of these systems seems to be that they have the common commercial disadvantage of a too limited output of steam per boiler, or, in other words, they only give high coal economy and smokelessness within too limited a range of output, and, from a business point of view, a high boiler efficiency is as important as a high coal efficiency.

When fresh coal is thrown on to a fire it becomes an absorbent of heat, which goes to volatilise the bituminous portion of the coal; this is a cooling process which means that the carbonaceous part has to wait its turn to receive heat sufficient for its own combustion, therefore it is apparent that to have a smokeless chimney the pro-

ducts of distillation should be produced continuously, and these products be constantly consumed by bringing them into as high a temperature zone as possible, because when this is done intermittently it means a sudden cooling effect simultaneously with a large increase of volume, both factors leading to smoke.

As the smoke problem resolves itself into an economic problem, a study of the economic requirements becomes necessary. The main sources of loss in steam raising are:—

(a) The lost heat carried away in the gases passing up the chimney.

(b) The loss due to incomplete combustion of the carbon in the coal.

(c) Loss due to imperfect firing such as holes forming in the fire which allow a large excess of air to pass unutilised, and which amounts to cooling the fire with a stream of air which gets heated up only to carry the heat units away into the atmosphere.

(d) Loss due to open doors while cleaning the fires, allowing an excess of unutilised air to pass into the furnace.

These sources of loss, speaking generally, become greater as the duty of the boilers is forced up beyond, say, 20 to 25 lbs. of coal burned per hour per square foot of grate area, but the boiler efficiency (*i.e.*, output) must of necessity be considered along with the coal efficiency in the study of this problem from an economic standpoint.

*Referring to (a).*—One lb. of carbon contains, say, 14,500 B.T.U. (British Thermal Units) of heat. Suppose we burn completely one lb. of pure carbon in the theoretically correct quantity of air, and supposing the residual gases to be at a temperature of 300 deg. Fah. (above atmospheric temperature), we find that we have 920 B.T.U. of heat passing up the chimney. If we are using twice the theoretical quantity of air, we lose another 855 B.T.U., but in practice 600 deg. Fah. is not uncommon, in which case our losses would be doubled, and in practice it is common to find more than double the theoretical quantity of air being used. From this it will be seen that any excess of air above the theoretical quantity means more lost heat, and, further, as much heat as possible should be absorbed into the water in the boiler so as to reduce the temperature of the gases passing up the chimney, as the loss under this heating is affected by both volume and temperature.

Now we have seen that it is essential for commercial reasons to get a high boiler efficiency; to do this we must burn in ordinary practice about 30 to 40 lbs. of coal per square foot of grate area, which necessitates a large excess of air to get the rate of combustion high enough. This excess of air, as above stated, means a loss of efficiency not only because of the extra volume carried up the chimney, but due further to the fact that the larger the volume the faster it must travel, and so the less time is given to it in contact with the heating surface of the boiler, and so the exit temperature is higher, hence we have (1) higher temperature, and (2) greater volume.



The natural suggestion that arises therefore as a means of meeting item (a), is to increase the quantity of coal under combustion, thus reducing the rate of combustion, or, in other words, give each pound of coal longer to burn. To make this point quite

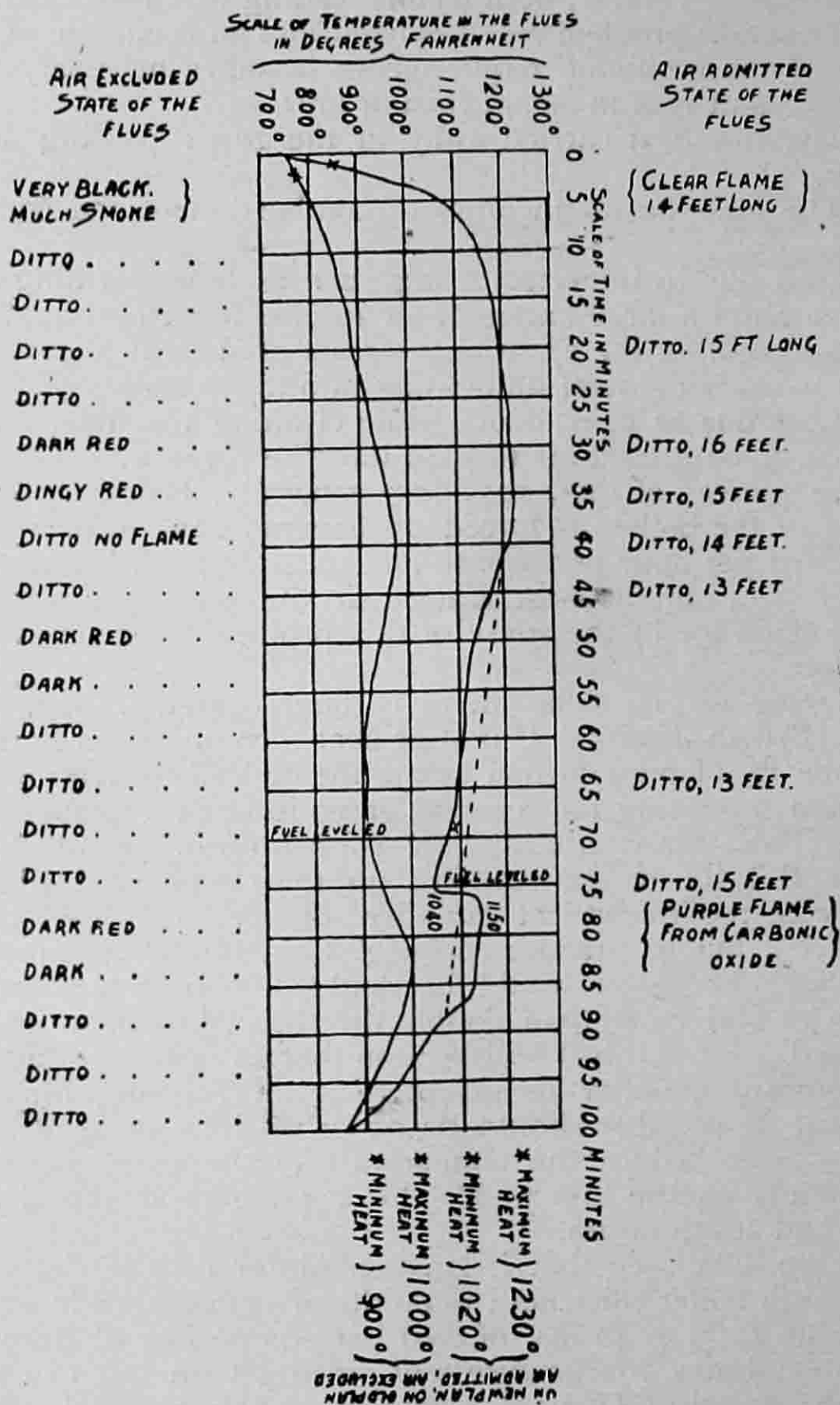


FIG. 1

clear, suppose we have two fires of the same grate area, one with twice the quantity of coal burning as compared with the other, then, in order to get the same quantity of coal burned per square foot of grate area in both, the time given to burn one pound of

coal in the one fire is twice the time given in the other; the rate of combustion being lower per pound, we can get the required quantity burned per square foot to give the necessary boiler efficiency with much less excess of air.

*Referring to (b) (i.e., loss due to incomplete combustion).—*If one lb. of carbon is burnt to CO, 4,450 B.T.U. are evolved, whereas when completely burnt to CO<sub>2</sub>, 14,540 B.T.U. are evolved. This shows the tremendous importance of getting complete combustion. A very high furnace temperature, and one that remains so uninterruptedly, will be the best conditions under this heating.

*Referring to (c) (i.e., loss due to holes forming in the fire).—*In practice, when steaming hard, it has been found almost impossible to prevent holes from forming in the fires unless by highly skilled hand firing, and even under these conditions, if the fireman covers a bare place when firing, this place when he next fires is liable to be the heaviest portion. To solve this problem satisfactorily it requires a condition such that, as soon as a hole tends to form through more rapid combustion at any place, more supply should automatically pass to that place.

Above I submit a copy of a diagram of an experiment made expressly for the British Association assembled at Manchester as long ago as 1842 by Mr. Houldsworth. A charge of 3 cwts. of coal was thrown on a furnace, and the temperature in the flue rose in 25 minutes from 750 deg. to 1,220 deg., when it began to fall to 1,040 deg., the fuel not having been disturbed during 75 minutes. Perceiving the temperature in the flue to have become so low, Mr. Houldsworth had the fire levelled (*i.e.*, the vacant spaces covered). Note the sudden rise in temperature from 1,040 deg. to 1,150 deg. This shows how long this subject of holes in the fire has been under consideration in Manchester.

*Referring to (d).—*To meet this source of loss, all intermittent cleaning should, if possible, be eliminated, therefore removing the necessity for opening doors during the operation.

I shall here describe a somewhat novel system which seems to me to be a move in the right direction. Figs. 2 and 3 represent a longitudinal and transverse cross-section of the flue of a Lancashire boiler, showing the formation of the coal.

In ordinary practice the firebars of a Lancashire or Cornish boiler are fitted across the diameter of the circle of the flue dividing it into two halves, the bottom half of which is unutilised. In this new system the bottom half of the flue is utilised by adopting a V-shaped formation of grate, as shown, the bars ending in an open-topped channel into which is fitted an ash-extracting screw shown at A, which is so designed that it takes the ash uniformly throughout the length of the furnace and delivers it at the front of the boiler, as shown in Fig. 2 at B. This screw has also got clinker breakers attached to it, shown at C, which effectively break any clinker that may be formed, enabling it to be discharged by the carrying portions of the screw, which are built in sections on to a hexagonal central shaft, thus making this system very

suitable for clinkering coal, due to the hottest zone always being in the centre of the furnace above the clinker breaker, and keeping the clinker from covering the bars and so choking the supply of

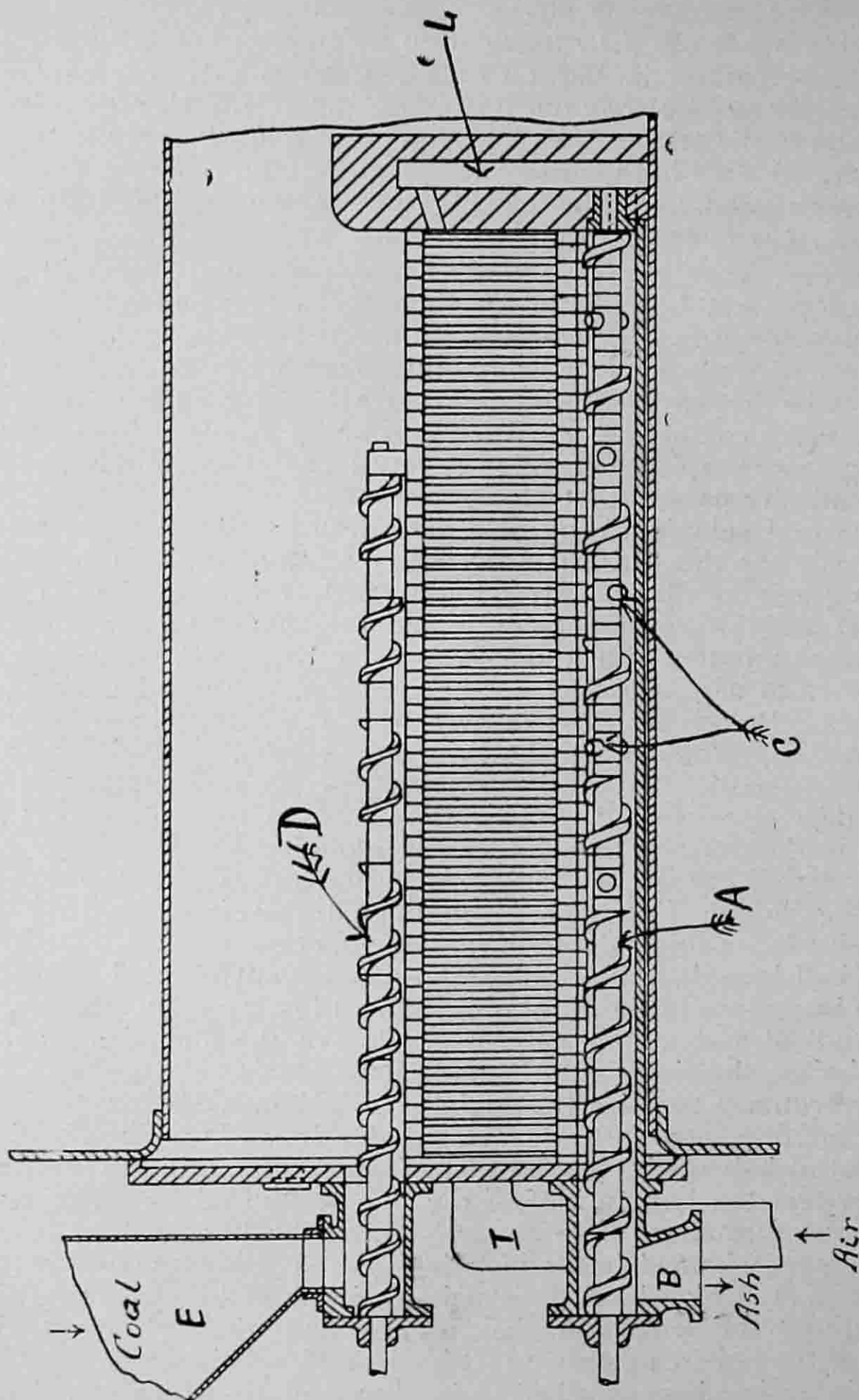


FIG. 2.

air to the furnace. The nature of the fire in this system is more akin to a gas producer inside the flue with a deep, highly-incandescent mass of fuel giving the air a long time in contact with the

fuel instead of a low temperature with a short time as in an ordinary fire. The coal is fed into the furnace by two interrupted screws, shown at D, Figs. 2 and 3, from the hopper E, which screws are completely protected from overheating, due to the fact that they are always surrounded with black coal; these screws form an important feature of this system, because when the coal comes to an interruption in the thread, it naturally takes the easiest course of resistance, and so is squeezed towards the centre, and when the coal arrives at the point desired towards the centre of the furnace, the resistance becomes more, when that point is reached, than it takes to pass the coal along the interruption, when it is caught up by the next portion of the thread, and the same condi-

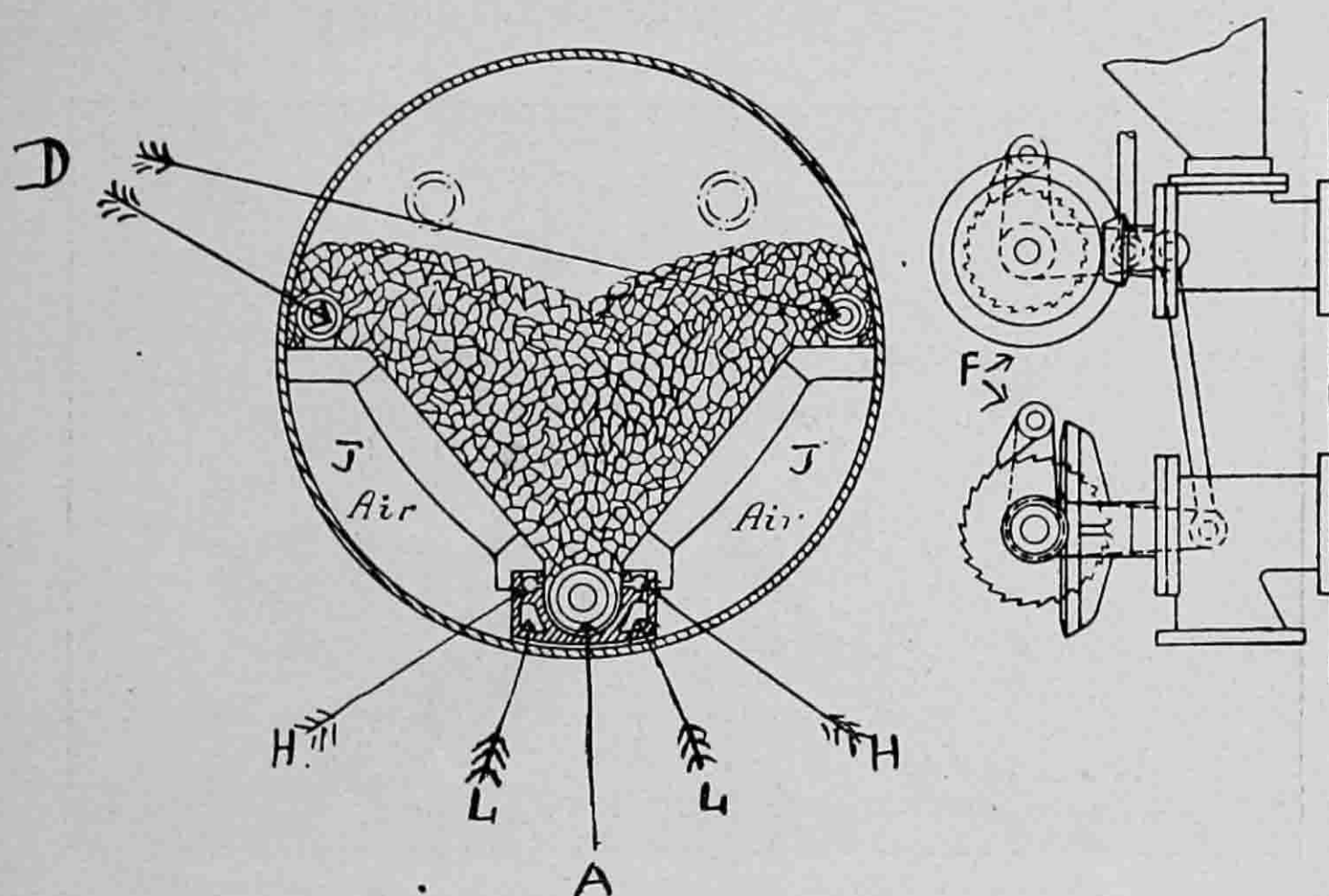


FIG. 3.

tions maintain at the next interruption, and so on. By this means an ideal system of feed is obtained, referred to under heading (c); that is to say, no holes can form in the fire, because so soon as a hole starts to form, that automatically becomes the place where the most coal will be delivered. F on Fig. 3 represents the mechanism for driving the screws, which has a large variation of adjustment to suit different rates of steaming and different classes of coal.

The ash-extracting screw is kept cool through allowing a small supply of water to pass along to the back end of the trough at the position marked H, Fig. 3, so that the ash is delivered in a damp condition at the front of the boiler. From a fan air is supplied through the ducts which passes in underneath the bars to the space



J, and this can be regulated according to requirements. Auxiliary air may be passed through L up through the back wall as shown. Fig. 4 shows the grates of two Babcock boilers viewed from the back; the ash-extracting screws are seen clearly here, and two of the feeding-in screws in the troughs in the walls can also be seen, the other two being hidden in the centre wall.

The results obtained from this system, so far, are very encouraging, because a high coal efficiency, along with a high boiler efficiency, is obtained with complete smokelessness.

Referring to sources of loss under heading (a), (b), (c), and (d):—

(a) (*i.e.*, lost heat carried away in the gases passing up the chimney). This loss is reduced, because of the large amount of

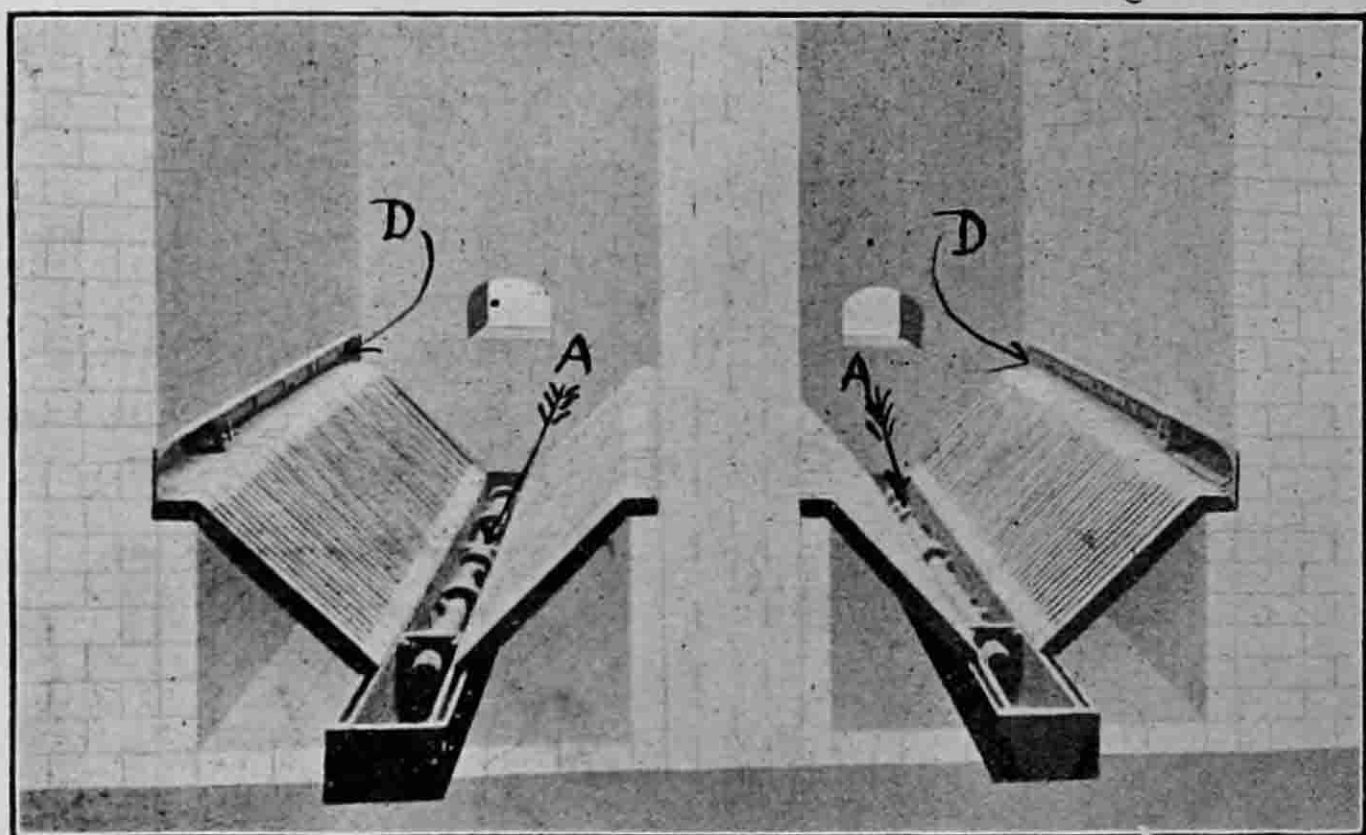


FIG. 4.

coal under combustion leading to much more heat obtained through radiation, resulting in the possibility of getting the boiler efficiency high, through burning a sufficient quantity of coal per square foot of grate area at a slow rate of burning per lb. of coal without so much excess air to get this quantity burned per square foot, the reduction in the volume giving more time in contact with the heating surface.

(b) (*i.e.*, the loss due to incomplete combustion of the carbon in the fuel). Due to the centre of the furnace being always at a very high temperature and due to the air having to pass through a deep body of incandescent fuel, the temperatures are continuously much higher than in an ordinary fire, which gives a much better chance of complete combustion, and as the coal distills from the

sides of the furnace around and above the feeding-in screws D continuously, this distillation or smoke is continually overcome by the high temperature flame bed, up the centre, hence this system is smokeless.

(c) The loss due to holes in the fire is eliminated as explained.

(d) The loss due to open doors, while cleaning, is also eliminated because there is no cleaning.

A further advantage of some importance is that, in a large range of boilers, it would be the natural thing to have an automatic coal-feeding and ash-removing system attached, in which case there would be only a supervisor for a range of boilers to look to adjustments.

Many textile mills have economisers installed; where this is so, there is a higher economy than in installations which have no economisers, but, of course, if a better system of burning the coal could be obtained, so that more of the heat was got into the boiler, economisers would be unnecessary, and the maintenance and capital expenditure on them eliminated; this is certainly the right direction in which to work, because economisers at their best are only there as a result of inefficient furnace systems.

Below I give the compartive tests carried out recently on two Babcock boilers in a large works near Glasgow:—

	Hand Fired.	New System.	Hand Fired.	New System.
Date .....	15/1/13	24/3/13	28/1/13	4/4/13
Heating surface of boiler in square feet .....	1,260	1,260	1,260	1,260
Grate area in square feet .....	28·9	28·9	28·9	28·9
Gross weight of fuel used, in lbs.....	6,363	4,514	8,848	6,988
" " " per hour	795·37	564	1,106	873·5
Gross weight per square foot grate area .....	27·5	19·65	38·23	30·2
Total water used, in lbs. ....	25,800	28,780	39,495	41,131
" " " per hour .	3,225	3597·5	4936·91	5141·3
Total water used per square foot heating surface .....	2·56	2·85	3·91	4·08
Water to coal apparent .....	4·06	6·375	4·46	5·88
Water to coal (ash and moisture deducted) .....	5·44	8·07	5·98	7·17
Evaporation from and at 212 deg. (per lb. of combustible) .....	6·58	9·82	7·23	8·68
Factor of evaporation .....	1·216	1·217	1·216	1·214
Temperature of feed water .....	40 deg. F.	40 deg. F.	40 deg. F.	44 deg. F.
Waste gases leaving boiler, average temperature .....	..	464 deg. F	923 deg. F.	534 deg. F.
Average steam pressure, lbs. per square inch .....	91	93	92·6	99

Note.—Fuel weighed and water measured from tank.  
Duration of test = 8 hours.  
Class of coal = Best washed singles.

In these works there are no economisers, and they require a high boiler efficiency, and you will see that the comparative results,

under their old conditions of hand firing against the new conditions, show an actual money saving of about 25 per cent. and this economy is established simultaneously with the elimination of smoke which, with hand firing, was very black.

There is another important commercial factor which I should like to call attention to, namely, the B.T.U. of heat in a cheap coal can be bought for much less money than in a dear coal. From recent figures quoted in Glasgow, I find that coal costing 4s. 3d. per ton contains 10,100 B.T.U., whereas coal costing 17s. per ton contains 14,830 B.T.U. Taking it roughly, and supposing these figures were 10,000 and 15,000 respectively, it works out, in this instance, that if we could utilise the heat units in the cheap fuel as efficiently as in the dear fuel, we should get per £1 with the cheap fuel what we would have to pay £2 13s. 4d. for with the dear fuel, but in many cases (due more to mechanical difficulties than any other reason) it is impossible to get the required amount of steam from the cheaper fuel, and it seems clear that a better system of burning the coal will have a bearing on this aspect, because where a cheap fuel is being used with a large per cent of ash, this means a continual loss in cleaning the fires, with a tendency to produce smoke when firing up after cleaning, which loss is eliminated with such a system as I have described, and, further, if a system be adopted which increases the amount of coal under combustion to, say, twice the amount with ordinary systems, there would be as much fuel under combustion, with a coal containing 50 per cent of ash, on this hypothesis, as there would be in the ordinary systems with an absolutely pure coal containing no ash, and hence it is clear that the output could be much more readily maintained with a system of this kind than with the orthodox system of fire. I was recently studying some figures of a large textile concern in Scotland, and in one case 54 per cent., while in the other 75 per cent., of efficiency was obtained, but when brought back to a money basis, the 54 per cent. was considerably more economical than the 75 per cent., due solely to the fact of the much lower cost per B.T.U. of heat in the low-grade fuel.

The foregoing seems to me to be the lines on which the presently-installed boiler systems may be made smokeless with a commercial gain.

Referring to the second heading, *i.e.*, the system of first producing gas from the coal, then firing the boilers with the gas, this method, which does away with the smoke nuisance, has advantages, but it would appear that, generally speaking, up until now the capital expenditure has been so high that this method does not come into the realm of practical politics for most commercial concerns. However, there are two new factors which will no doubt have an influence in bringing this system more prominently to the front for new concerns.

Firstly, important developments are taking place in connection with the distillation of coal, more particularly from the point of



view of the recently enhanced value of the by-products that can be obtained therefrom, namely, sulphate of ammonia and the lighter oils. It is rapidly becoming more generally recognised that coal contains extremely valuable by-products, and I think there is no doubt that there will be great advance made in methods of distillation increasing the per cent. of the more valuable by-products, such as benzol, for which there is a rapidly growing demand for internal-combustion engines, etc. The indications are that there is a big field for development in this direction which will have an influence on this method of first making gas and then firing the boilers with the gas.

Secondly, the new system of firing boilers with gas, recently discovered and known as the Bonecourt System, for producing radiant heat by means of flameless incandescent surface combustion. This recent discovery enables gas to be burnt with the highest possible economy, and further leads to a radical reduction in the size of steam boilers, housing, space, etc., with a consequent saving in capital expenditure.

The distinguishing and essential feature of this new process is that a homogeneous explosive mixture of gas and air, in the proper proportions for complete combustion (or with air in slight excess thereof) is caused to burn without flame in contact with a granular incandescent solid, whereby a far larger proportion of the potential energy of the gas is converted into radiant heat. The advantages claimed for this new system are (1) the combustion is greatly accelerated by the incandescent surface, and may be concentrated just where the heat is required; (2) the combustion is perfect with a minimum excess of air; (3) the attainment of very high temperatures is possible without the aid of elaborate "regenerative" devices, and (4) owing to the large amount of radiant energy developed, transmission of heat from the seat of combustion to the object to be heated is very rapid.

There are two principal forms of the surface combustion element, one known as the "Diaphragm," and the other as the "Cavity-Cobble" or "Granular Bed." The former shown on Fig. 5, consists of a slab of porous fire-clay of any required size and shape, mounted in a frame attached to a box or fuel chamber, from which the combustible or explosive mixture of gas and air under a suitable pressure percolates through the porous diaphragm till it reaches the outer face, where it can be ignited. If less air than is theoretically required be present in the mixture, flames will appear on the face of the diaphragm and it will become heated. On reducing the richness of the mixture, but still maintaining the pressure, these flames will disappear, and in a very short time the mixture will begin to burn inside the porous slab at about  $\frac{1}{8}$  of an inch from its surface, producing an incandescent or glowing surface devoid of flame and giving out great radiant heat. The temperature near the surface is about 1,500 deg. F.

The granular bed form of apparatus, however, presents a far wider field of application than the diaphragm which arises partly



from the fact that higher temperatures can be obtained (over 3,600 deg. F.), and that the arrangement permits of the application of the process to steam boilers and all shapes and sizes of furnaces. The principles involved are the same in both, but the physical arrangement of the active elements is substantially different. In this system the diaphragm is replaced by a bed of granular refractory material, on the surface of each granule of which flameless incandescent surface combustion occurs. These granules can be easily packed into tubes which can be bodily immersed in water for steam raising purposes.

Fig. 6 shows the Bonecourt system of steam raising. The fundamental principle adapted is the provision of a number of tubes (usually horizontal) of approximately 3 ft. in length and

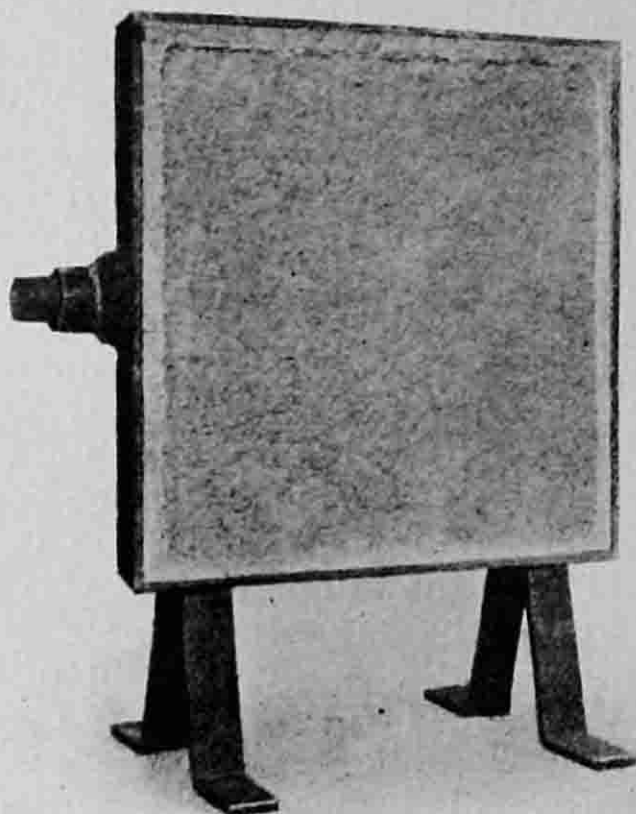


FIG. 5

3 ft. internal diameter. It is within these tubes that the combustion takes place, and from them that the heat is transferred direct to the surrounding water.

The tubes are packed with lumps of refractory material, shown at P, Fig. 6. At the entering end of the tubes a fire-clay nozzle is placed which serves the double purpose of preventing combustion of the gaseous mixture until it reaches the refractory lumps and also of keeping the active heat of combustion away from the metallic joints in the boiler. The gaseous mixture is forced with a pressure of about  $\frac{1}{2}$  lb. per square inch through the refractory lumps either by suction or pressure, according to the requirements of individual cases, and the combustion takes place on the surface of the refractory material at the entering end of the tubes. This

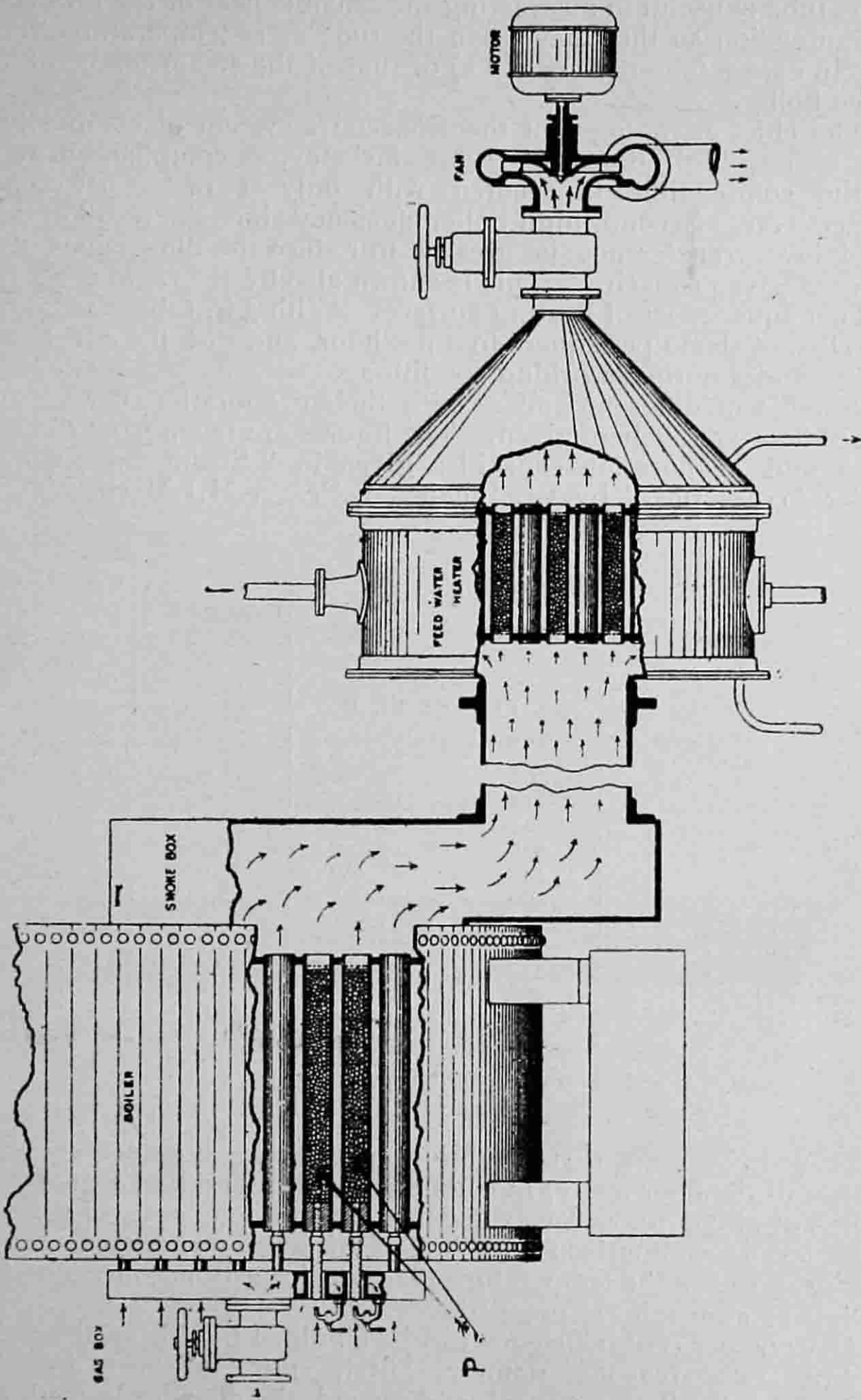


FIG. 6.

combustion is complete in about 6 in. of travel, and the remainder of the tube is useful in abstracting the sensible heat of the products of combustion so that they leave the tube at a temperature very little in excess (about 70 deg. C.) of that of the steam temperature of the boiler.

The chief advantages of the Bonecourt system of combustion are:—First, high burning or gas efficiency, as complete burning of the combustible is secured with only 1 or 2 per cent. of excess air. Second, high boiler efficiency since the result of this rapid heat transference is greatly to reduce the dimensions of a boiler of given capacity. This is shown also by the rapid evaporation per square foot of heating surface. With 3 ft. tubes the figure is 20 lbs. of steam per square foot per hour, and with the 4 ft. tubes 14 lbs. under normal working conditions.

A table of different boilers with their evaporation per square foot of floor area is here given. The figures are taken from dimensions and evaporation capacities given in "Steam Boilers and Boiler Accessories," by W. Inchley, B.Sc., A.M.I.Mech.E.

	Floor Area.	Head Room.	Evaporation.	Evaporation per sq. ft. of Floor Space.
	Sq. Ft.	Ft. In.	Lbs.	
Bonecourt.....	19'5	8 0	2,500	128
".....	40	12 0	5,500	137
".....	68	14 0	11,000	161
A.....	212	18 9	8,000	37'7
".....	292	18 2	12,000	41'2
".....	318	19 3	16,000	50'0
".....	440	23 10	30,000	68'2
B.....	209	18 0	8,130	39'0
".....	233	21 0	12,000	51'5
".....	323	21 0	19,200	59'5
".....	552	24 0	39,500	71'6
Lancashire.....	468	11 6	7,800	16'7
Cornish.....	298	9 6	2,600	8'7

Note.—A and B are standard types of water tube boiler.

It will be seen that the Bonecourt boiler occupies about a quarter of the floor space, in comparison with land type water tube boilers of about 10,000 or 12,000 lbs. evaporation, and, of course, much less in comparison with boilers of larger capacity.

Fig. 7 shows the temperature diagram for a Bonecourt tube for boiling at atmospheric pressure.

Over 90 per cent. efficiency can be obtained by this system.

For two reasons—namely, first, the advance in the methods of distillation of coal, and second, the advance in methods of burning gas—I think we may look forward to an increasing growth in the system of firing boilers with gas. With this method, of course, smoke is eliminated.

In concluding I should like to call attention to the question of oil as a substitute for coal. We have heard a great deal during the last year on this subject, and I think there is no doubt but that this system will become more prominent in the future, but the following particulars of the output of coal will make it clear that it will be a long time before oil will become in any sense a substitute for coal.

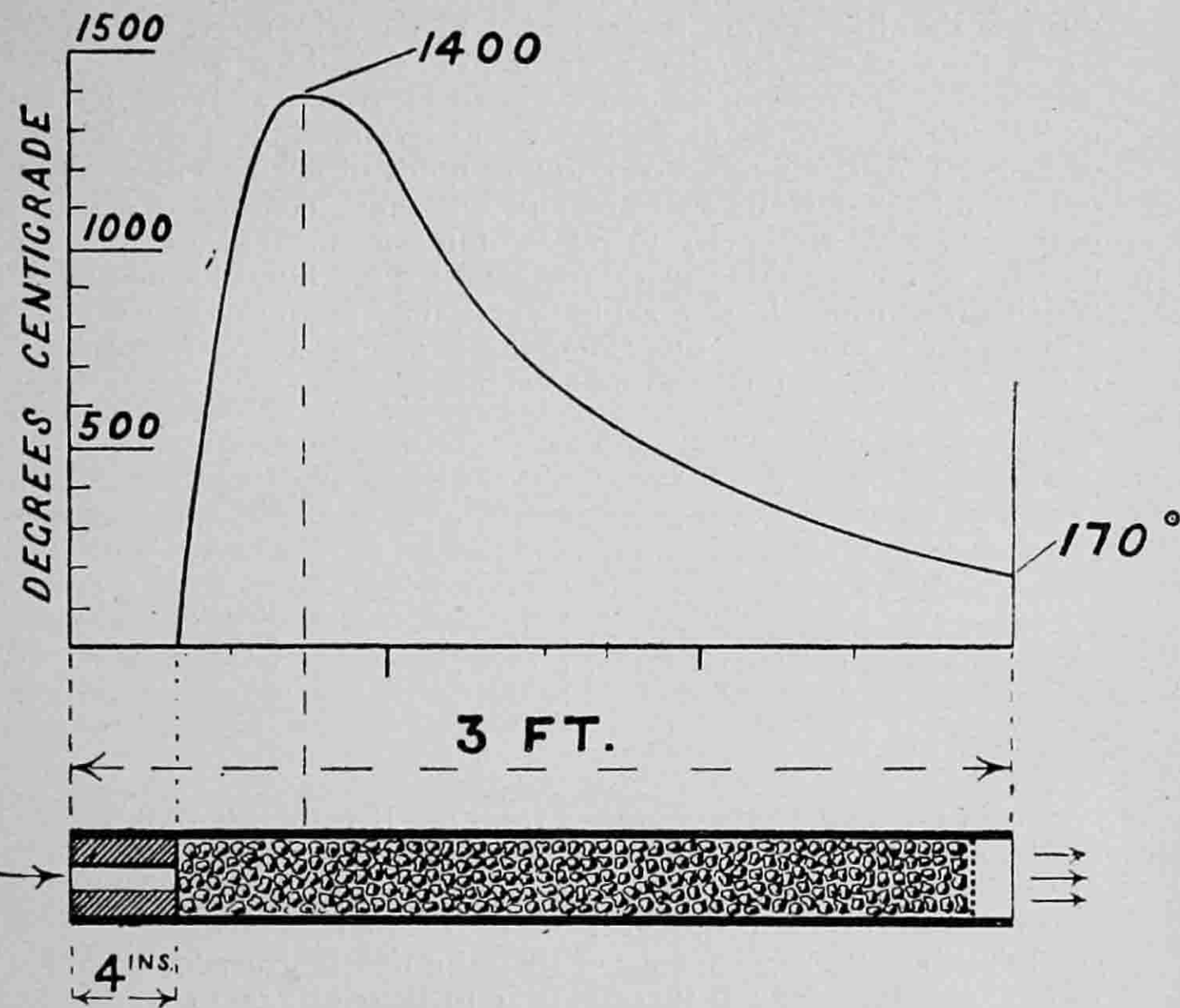


FIG. 7.

From the Indian Year Book I give the coal output per annum for 1910 in the following countries:—

U.S.A. ....	447 million tons.
Great Britain ....	262 " "
Germany.....	150 " "
France.....	32 " "
Belgium .....	23 " "
Russia .....	22 " "
Austria Hungary .....	15 " "
Japan .....	15 " "
Spain .....	4 " "



On the authority of F. E. Saward, the eminent New York expert, in his report for 1912, the world's coal output for that year was 1,278,577,812 tons. These figures are very significant, and whilst I am on this subject it might be interesting to add the following information:—

In U.S.A. in 1840 the output was 2 million tons in both bituminous and anthracite taken together, to-day it may be taken at about 500 million tons, and this growth in output has taken place during the life of an individual. The yearly increase in the world's output may be taken at from 40 to 50 million tons.

The Northern Appalachian coalfield in America, lying North and South, beginning at Alabama and terminating at the shores of Lake Erie, contains 58,000 square miles of coal. The Chesapeake and Ohio Railway Company will have completed shortly coal piers with a capacity to release into steamers 58,000 tons of coal in 10 hours; these piers are supplied by huge locomotives, which draw in one load 5,000 tons at a time in trucks which hold 50 tons each, moreover this Company is at present contemplating building trucks to hold 100 tons each.

Year.	Country.	Output per man.	Average Value.
			£ s. d.
1889	U.S.A. ....	421 tons.	0 5 3½
"	Great Britain .....	315 "	0 6 4½
"	Germany.....	276 "	0 5 8½
1910	U.S.A. ....	617 "	0 5 10¼
"	Great Britain .....	257 "	0 8 2½
"	Germany.....	240 "	0 10 0

From the above data compiled from the British Board of Trade Coal Tables, it is interesting to note that both in Great Britain and in Germany the output per man is going rapidly back, whereas in America the reverse is the case, and the future looks serious for this country when the significance of these figures is grasped, because in the United Kingdom there appear to be over 3,000 coal mines working under the Coal Mines Act, and about one million persons employed, 80 per cent below ground.

As a means of realising the cubic contents of the output in the United Kingdom in 1911, in the aggregate it would represent the cubic contents of a tunnel 5 ft. high by 5 ft. wide, equal in length to nearly four times the circumference of the earth at the equator, and this huge trade so vital to the interest of our country, would appear to be in jeopardy, because in the lifetime of an individual America's output has grown from almost nothing to nearly twice our own. But the matter does not end here, because Britain has built up her foreign-going and coastwise mercantile fleet in the development of coal transport which now has attained no less than about 86 million tons (64 foreign and 22 coastwise) annually, and embodies about 90 per cent of the total weight of all foreign con-

signments exported from Great Britain. To-day the difference in the overhead cost of extraction in Great Britain and U.S.A. is about 4s., and would more than counteract the geographical disability of the American Continent in entering neutral coal markets in the Mediterranean and elsewhere provided specially designed coal carrying steamers were requisitioned. Meantime the freight difference is 7s. to 8s. more than from Great Britain. To encourage such developments the announced U.S.A. tariff stipulates a 5 per cent rebate on dutiable goods entering the U.S.A. freighted by American owned and built steamers. Our insular conservative methods coupled with the belief in our superiority as a commercial nation must admit incontrovertible facts and waken up to a sense of the imminent danger we are unconsciously drifting into, as the cost of coal must permanently influence our cost of productions in all directions, and more particularly in our densely populated industrial centres, and while America's rapid advance is due largely to natural resources, America's methods of handling such large quantities is worthy of careful noting by those interested in our country's welfare.

In conclusion, what I have said may give the impression that I have dealt more with questions of economy than of smoke consumption, but it has long been recognised that the smoke problem really resolves itself into an economic problem, and I hope the above analysis of what seems to me to be the necessary conditions to be complied with will at least help to stimulate thought on this subject, for when it pays to raise steam without smoke, the smoke will gradually disappear, a consummation so vital to the health of the people.

#### DISCUSSION.

The CHAIRMAN asked whether the V-shaped flues were suitable for Lancashire boilers. He noticed that in the experiment quoted in the paper washed slack was used, and he would like to know whether ordinary coal was suitable.

Mr. R. A. FRANK (Manchester) said he could not see why the efficiency with a cheap coal was only 54 per cent, whilst with good coal it was 75 per cent. With regard to the various ways of making steam without smoke, no reference had been made to the method of coal-dust firing. That was one of the coming ways of producing steam without smoke of any kind. When they required steam they switched on the pulveriser and lighted up like an ordinary gas jet, and when they had finished with the steam they turned off the gas jet—if that term could be used. He had been very interested in the remarks regarding black smoke, because one would imagine that the ordinary Lancashire boiler could not work without producing black smoke. The British Cotton and Wool Dyers' Association, with which he was connected, had an annual coal bill of £60,000, and they did not allow black smoke at any one of their branches. They had 40 or 42 chimneys. Occasionally black

smoke might be emitted, but it was due to the absence of the fireman or to something unusual. The efficiency was certainly more in the region of 75 per cent than 54 per cent. They had chimneys in certain districts in Manchester where the inhabitants at times inquired if the works were stopped, because they could not see any smoke issuing from the chimneys. That did not occur for an hour or two only, but from January 1st to December 31st.

Mr. T. R. WOLLASTON (Manchester) said: Mr. Fulton uses the words "coal efficiency" and "boiler efficiency" at the beginning of his paper in a way which might well be dropped by general agreement. I think we members of the Textile Institute should agree at once to accept the terms coal efficiency or boiler efficiency as synonymous and as meaning the percentage of the B.T.U. in the coal obtainable in steam. Mr. Fulton might have said "boiler output" here. He uses the words "boiler efficiency" in the right way later in his paper, as applied to the Bonecourt boiler. I think it is accepted by all who have considered the subject scientifically that the ordinary boiler grate, flat, and with only six or eight inches of fuel on it, is a poor apparatus for securing perfect and consistent combustion. We know that the allowance of air accepted as suitable for the boiler furnace is double or more the amount theoretically required. Without labouring the subject, it is generally agreed that the gas producer, with its great depth of fuel bed, is the only apparatus soundly devised for proper coal combustion under scientific chemical conditions. It is interesting to note that the latest developments in automatic stokers point to the realisation of this fact. When Mr. Fulton showed me his design, as described in this paper, about twelve months ago, it appealed to me as the best I had seen applicable to the internal-flued boiler, because it most closely resembled the gas producer. My opinion is now that if, as Mr. Fulton implies, his mechanical feeding and ash extraction devices are satisfactory for a large range of poor fuels, he has the best automatic stoker for Lancashire boilers yet devised. Mr. Fulton has naturally not yet available many test records, but those he gives do not show anything remarkable. I have calculated the efficiencies from Mr. Fulton's figures, assuming coal of 11,000 B.T.U. value, and they appear to be:—First hand-firing test, 43 per cent; second hand-firing test, 48 per cent; first new system test, 68 per cent; second new system test, 63 per cent. One wonders how any firm who could afford two Babcock boilers could be satisfied to run them on an average 45 per cent efficiency until Mr. Fulton came along. If we refer to Messrs. Babcock and Willcox's catalogue, we find they claim as much as 82 per cent efficiency. Of course any maker of special appliances is lucky to come across such an example of wilful waste to practice upon. Mr. Fulton has given an admirable summary of the work so far done with the Bonecourt boiler. There is beyond doubt a great future for gas-fired boilers on this or similar systems. I have seen a test conducted



upon a small Bonecourt boiler which showed 93 per cent. efficiency on the gas heat value, and there is no doubt that, providing only that non-sedimentary water is available, this result can be consistently maintained. Now let us assume 75 per cent. efficiency for of 62 per cent., higher, perhaps, than the average boiler efficiency throughout the country. In addition, we can get sulphate of ammonia from the gas worth eleven shillings gross per ton of coal gasified, or, say, 5s. net after making all allowances for extra capital charges, labour and land. In other words, if one can get common slack for 5s. per ton, one can get steam for nothing. This implies, however, a fairly large installation, and, above all, a good load factor. It is the absolute solution of the smoke problem.

Mr. G. B. STORIE said he contended that no Lancashire boiler had yet given an efficiency of over 85 per cent., and even with an efficiency of 85 per cent. it would be economical to instal either water economiser or heaters. In the case of the tests quoted, he found that if economisers had been installed, the evaporation on March 24th would have been 10·8, on the 28th of January it would have been 9·3 instead of 7·23, and on April 4th the evaporation would have been 9·9 instead of 8·68. In the test made on January 28th, the figure of 923 deg. Fah. temperature of the flue gases entering the chimney was quoted. He contended that it was not engineering if the plant was wasting so much heat. Personally he had taken a great interest in the smoke problem. He held a position with one of the largest corporations in England as smoke expert, and his experiences in that capacity convinced him that anything a corporation might do to deal with the smoke question would not only benefit the community, but would put money into the pockets of steam users.

Mr. E. P. WARD (Huddersfield) said it was their aim to eliminate smoke as far as possible. He thought there was some confusion in one part of the paper in regard to temperature and the formation of CO. If Mr. Fulton intended to refer to the losses due to the formation of CO, he (Mr. Ward) did not quite see that high temperatures and thick fires—which was what it amounted to—were going to help, although they certainly would help in the direction of consuming what would otherwise be unconsumed carbon. Another point in the paper had reference to the excess of air increasing the volume of the gases. In regard to excess air, he would like to quote two cases—one in which there was 6 per cent. carbon dioxide in the flue gases, and another in which there was 12 per cent. Taking the 6 per cent., they could work it out that the nearest temperature would be about 1,330 deg. Fah., and in the second case, 12 per cent., 2,620 deg. In the case of 6 per cent. carbon dioxide, the volume of air taken into the furnace with the coal was practically doubled, yet the volume of gases leaving the bridge was only about 18 per cent.



increase in the case of the pure carbon dioxide. The reason for that small increase was simply that the gases containing only 6 per cent. of carbon dioxide were at a lower temperature, and consequently there was not so much expansion. When they got towards the end of the heating surface of their boilers—when the gases tended to come more to an equal temperature—then, of course, they would get a very much greater speed of gases in the case of the 6 per cent. carbon dioxide. That, however, did not signify anything, because when the gases were getting towards the end of the heating surface it did not matter at what temperature or volume they were; to all intents and purposes they had done their work. Varying views were held upon high speeds. Dr. Nicolson, for example, held that high speeds were essential for high efficiency and transference of heat. As to economisers, if they had a better system of burning their coal, economisers would be unnecessary. Referring to the very low evaporation of water in the hand-fired tests, Mr. Ward remarked that the boilers must have been very badly managed. It seemed to him that the whole matter resolved itself into the question of thickness of fires, and had thick fires been tried on hand-fired furnaces he thought better results might have been obtained. He would also like to point out that nothing had been said about the analysis of the flue gases. They could not properly deal with excess air in their furnaces unless they had some testing apparatus which would give them the percentage of carbon dioxide in flue gases.

Mr. FULTON, in replying to the discussion, said the V-shaped grate was quite applicable to the Lancashire boiler. As to the quality of coal, that system of furnace seemed to be much more useful for all qualities of coal than the ordinary system of fire. Mr. Frank had asked why 75 per cent. efficiency should not have been got from the low fuel as well as from the high. He could not answer that; all he could say was that 54 per cent. was being got from the low fuel, and he presumed it would be due to the larger percentage of ash contained in that low fuel. He was unable to say anything about the method of coal-dust firing. He was not an expert on this subject, but as one who had paid some attention to the subject, as a user, he thought his experience with the special furnace referred to might be interesting to the general body of members. In regard to getting smokeless results, that was, in his experience, a much easier problem in a Lancashire boiler than in a Babcock boiler, because there were many methods of introducing air in the back bridge, sometimes with an increase of economy. He quite agreed with Mr. Frank that there were many ways of working Lancashire boilers smokeless. His chief aim in reading the paper had been to indicate the directions in which this question of steam raising was going to evolve, particularly in relation to the commercial aspect—in connection with capital expenditure, or from a dividend point of view. In regard to the burning of the screws, if the boiler was damped down at night it was advisable to rake back

the coal from off the screws, or close it completely so that no air was allowed to pass in. In one case, of which he knew, the screws did burn, but it was due to the coal being left over the screws overnight and the air being allowed to go in at the front of the boiler. Mr. Wollaston had spoken of the use of the term "boiler efficiency." He (Mr. Fulton) intended to convey output per boiler. His purpose in introducing the tests on the Babcock boilers was to give an idea of the results so far obtained by the system, and to show that when it was applied to those two boilers, working under very adverse circumstances, it made the difference he had mentioned. Later on it would be possible to ascertain the actual benefits of the system to more efficient plant. Mr. Storie had alluded to economisers. There certainly were cases where economisers would be an advantage, and possibly with such a system as this. Dealing with Mr. Ward's point as to higher temperature in the furnace, Mr. Fulton said that what they wanted was a high temperature, which would consume the carbon. He agreed that the speed of gases might have a bearing on the better extraction of heat, but he thought that would not be sufficient to overcome the increased loss due to the shorter time in a boiler plant.

Mr. E. D. SIMON (Manchester) said he was exceedingly pleased the Textile Institute had taken up this subject. The movement for securing smoke abatement in Manchester was started about nine months ago, and the policy pursued had not been to persecute or bully manufacturers, but to draw the attention of mill managers to this growing evil of the smoke nuisance. He was glad to note the expressions that day to the effect that smokelessness paid. There was no doubt that it did. Unfortunately many managers did not realise that. What they had done in Manchester was to appoint a smoke inspector, who went round to all the worst districts, and when smoke was emitted from a chimney for more than the statutory limit, he drew the attention of the manager to the fact. The inspector had been well received almost everywhere, and his efforts had met with a good deal of success. They needed the help of the manufacturers in this matter. They were nearly all sympathetic, but did not do much active work in the campaign. What they would like would be to get some local manufacturers to start a kind of co-operative association, similar to the one at Hamburg. There a good many manufacturers had joined together and had engaged an expert engineer, who went round and reported on boiler plants as to efficiency and smokelessness. This was started some years ago, and had steadily grown. Now the association employed four or five engineers and several assistants, and the growth of the association was the best proof that it was paying. The results, as regards smokelessness, had been extremely good. They wanted a similar association in Manchester, and he did not think there was much doubt that it would pay; whilst it was certain to be of enormous benefit to Manchester.

Professor G. F. CHARNOCK (Bradford) said he would like to put in a plea for the better training of firemen. It seemed to him that it mattered very little what type of apparatus they employed. They would never get the results they were seeking to achieve unless they got firemen with more intelligence. The smokelessness in many cities abroad was largely due to the training of firemen. In many cities in Germany he knew that steam users had formed associations for the sole purpose of arranging for the proper instruction of firemen in well-equipped schools. If such a step could be taken in this country, the smoke trouble would soon be a vanishing quantity. One point had occurred to him whilst the paper was being read. When they had gone to the trouble of making gas, why not put it into a gas engine at once, instead of adopting the roundabout way of putting it through the steam engine?

Mr. F. T. HILTON (Manchester) said that all the attention of engineers and manufacturers had been devoted to the prime movers, and steam engines were now as efficient, possibly, as they could be expected to be. The boiler-house had been neglected. The greatest mistake which could be made was to regard any duffer as good enough for a fireman. What the engineer should do was to get the analysis of the flue gases and ascertain the percentage of  $\text{CO}_2$ . Apparatus could be obtained at a reasonable price for recording flue gases, and showed precisely what was being done. If the condition of affairs was shown to be unsatisfactory, he had to get to know the way to effect an improvement. He could do that by arranging the draught suitable for the particular coal that he was using. His own belief was in thin fires and frequent firing in preference to thick fires, both from an economical standpoint and from the standpoint of smokelessness. He was old-fashioned enough to believe, also, that if they had a good fireman, equally good results were obtained by hand firing as by the other method. Conditions could be materially improved, even with existing plant, if a better class of fireman was employed, and if better wages were paid; whilst if the manufacturer or the manager took more direct interest in the boiler-house an improvement would be effected all round.

Mr. HÜBNER (Manchester) said that when the Manchester Air Pollution Advisory Committee got to work they might hope to get most useful records and information. The question of smoke abatement was becoming more and more important, and, whilst the engineers would have to do the chief part of the work, he thought the chemists would also have to be called in to help by giving advice.

Mr. FULTON observed that he thought the more economical methods of the distillation of coal would lead to an extension in the producing of power outside of cities, where big central stations would be established, and the power transmitted electrically. Expert



supervision in the boiler-house was only too frequently-lacking, as Mr. Hilton had remarked. While he thought the training of firemen was most important, he thought that if a system could be secured which would obviate the necessity for the higher-grade intelligence which had been referred to, he believed it would be a step in advance. Very often it was more difficult and tedious to get men to do a certain thing than to evolve another method of doing it mechanically. He agreed with Mr. Hilton in regard to the advantage of thin fires.

Mr. HERBERT BRIGHT (Rochdale) complained that coal could not be purchased for works on analysis. The great difficulty they had was to get a coal supply regular in quality, and when they complained that the quality was not regular they found they had no legal remedy. If anything could be done to give manufacturers legal status regarding settled analysis of the coal it would be a good thing, because much of the nuisance arising from excessive smoke was due to coal being supplied which was inferior to that for which they had contracted.

The CHAIRMAN remarked that Mr. Bright's suggestion was a very practical one. He hoped the Council of the Institute would bear it in mind, along with the other points which had been raised.

Mr. BLEAKLEY moved a vote of thanks to Mr. Fulton, and expressed the hope that the Institute would move in the direction of securing the abatement of the smoke nuisance.

Mr. F. R. McCONNEL, who seconded the resolution, said that whilst the education of the fireman was necessary, the education of the fireman's master was equally necessary.

The resolution was heartily carried, and the conference terminated.

### DISCUSSION ON MILL DRIVING.

A further conference was held in the evening for the continuance of the discussion of textile mill driving.

Mr. F. R. McCONNEL, who presided, referred to the importance of looking ahead to the time when their present methods might be totally scrapped. They had already seen great changes in mill driving, and felt confident that there would be further advances.

Mr. G. B. STORIE, in a short paper on Steam Driving, said:—In presenting the paper on steam at the Hawick Conference, I deemed it advisable to set down definite opinions upon several questions open to considerable controversy, with the object of promoting discussion. Some of my remarks have been rather severely criticised, and it has been suggested that I have predilections for the turbo-alternator which led me to prejudicial expressions of opinion. I endeavoured, however, in the paper to state facts, based



on experience, in an impartial manner as far as possible, and my object in the first instance was to demonstrate the reliability and economy not only of steam turbines, but modern steam prime movers in general.

No doubt the greater portion of my remarks were confined to the turbine; the fact, however, should not be overlooked that, unlike the reciprocating engine, the turbine is a comparatively new machine, and its merits are less known to the majority of power users than those of its rival. Having had considerable experience in the working of these machines, I think you will agree that I was justified in presenting the paper in the form in which it appeared.

Owing to the limited time at my disposal in which to read the paper, I was prevented from referring to the boiler plant, and as the question of boiler efficiency was raised by one or two of the speakers at Hawick, I should like to refer briefly to the subject this evening. I think it was Mr. Wollaston who mentioned that steam plants rarely worked within 10 per cent. of their full efficiency, and he believed that the 10 per cent. went not in the engine, but in the boiler. Speaking generally, this is correct, and a careful examination of the various units comprising a steam plant indicate a much higher degree of efficiency on the engine side than is the case in the boiler-house, and for each 1 per cent. probable gain in the engine-room, some 3 to 4 per cent. might be obtainable in the boiler-house. The greatest room, therefore, for improvement in steam power plant is to be found in the boiler-house, and if improvement is to be effected, closer attention to the problems and economies connected with the generation of steam is necessary. Although boilers and other apparatus used in the generation of steam have been brought to a high state of perfection, it would be well not to overlook the fact that the efficiency is not to be measured by this alone. A plant may consist of all the latest appliances, yet its efficiency may be indifferent, if it is not operated with care. At the present time, the need is not so much for improved appliances as for the better use of those which are already available. Low boiler efficiencies are not due to the system as Mr. Wollaston would infer, but are the result of negligence on the part of the steam user. Generally speaking, it is a fact that spinners and manufacturers employ highly-skilled men to take charge of their engines, and leave the boiler-house, where three-fourths of the total cost of the power is expended, in the hands of unskilled firemen. The great increase in the price of coal calls for higher efficiency, and if the statement is correct that the average efficiency of the boilers working in this country is only about 60 per cent., then there is surely ample room for improvement. An increase of 10 to 15 per cent. would represent a great overall gain, and I consider that if there was a better understanding on the part of the steam user regarding the scientific problems involved in the working of steam boilers, and improved supervision, there should be no difficulty in obtaining this.

I made no reference in the paper to turbines fitted with gears for reducing the speed of the main shaft, but in page 412 of the Journal, particulars will be found of a turbine of this type, suitable for driving a textile mill requiring 1,000 H.P. There is no reason why large turbines with reduction gear should not be employed in conjunction with rope transmission, for the driving of textile mills. They are now being used for marine work, and with the introduction of gearing there are possibilities of the turbine replacing the reciprocating engine for the propulsion of ships.

The result of trials carried out between two vessels, the "Cairnross" and "Cairngowan," the former fitted with geared turbines and the latter with triple-expansion engines, has recently been published. The two ships were almost identical, both as regards dimensions and tonnage, and the conditions of the trials were exactly the same, both boats sailing over the same course side by side. During the trial, the "Cairnross" used 22,000 lbs. of coal, and the "Cairngowan" 27,200. The result is extremely interesting, inasmuch as it shows that the turbine accomplished the work with 19 per cent less coal than the reciprocating engine. The average vacuum maintained in the turbine's condenser throughout the trial was  $28\frac{3}{4}$  in. I have already pointed out that a high vacuum is essential in the working of turbines, consequently an ample supply of condensing water is required. In the majority of textile mills the water supply is limited, but, as a rule, with the assistance of a water cooler, sufficient water can be obtained at a temperature low enough to maintain a high vacuum without recourse to a costly condensing plant. There are cases where the water supply would be insufficient for condensing purposes, even with the assistance of the cooler, and in such cases it would, of course, be unwise to instal a turbine.

There has been no reference made in the discussions that have already taken place to the back-pressure turbine, which I described and illustrated in the paper. I endeavoured to show the great advantages that would accrue if this type was worked against a back pressure, and the exhaust steam used for boiling and drying in dyeworks and other factories of a like nature. The reciprocating engine can be utilised for the same purpose, but as the exhaust steam must be free from oil, no internal lubrication is permissible. This, of course, is a disadvantage, as it prevents the use of superheated steam, and the engine in this respect is handicapped. Perhaps it would be of interest if I mentioned that a bleach works near Rochdale has been arranged on this system. High-speed engines have been installed to work against a back pressure, and the whole of the steam used for manufacturing purposes is obtained from the exhaust of the engines, which are direct coupled to electric generators. Previous to the new plant being installed, the steam for the works' use was taken from a battery of low-pressure boilers. These have been dispensed with entirely, and a saving of nearly 35 per cent. in the coal bill has been effected. Economies in such works are well worth the attention of those engaged in the trades.

The channels of loss are many, but these are capable of very considerable reduction without, as a rule, involving any great capital outlay.

With Mr. Crowley's permission, I propose referring to a subject to some extent outside the scope of my paper. Frictional and other losses in the transmission of power from the prime mover to the machine have not been referred to in any of the papers excepting the one on electrical driving, where the author mentions that the losses in electrical transmission are greater than in mechanical. This, I think, would not be disputed, and, with a view of creating discussion on this very important question, I give what I consider average figures of the losses from and including the prime mover to the machine. In the case of the mechanical drive, the power is transmitted through ropes and the electrical drive is arranged on the group system, with the motors coupled direct to the line shafts, the current being generated in the mill's own power-house.

#### MECHANICAL DRIVE.

Engine .....	10%
Ropes .....	3%
Shafting and belts .....	14%
	<hr/>
Total losses ...	27%
	<hr/>

#### ELECTRICAL DRIVE.

Engine .....	10%
Generator .....	7%
Cable .....	1%
Motors .....	10%
Shafting and belts .....	12%
	<hr/>
Total losses ...	40%
	<hr/>

In the case of a weaving shed or a spinning mill having one main shaft, by coupling the engine direct the loss due to the rope drive would be eliminated. There would also be a considerable reduction in the electrical drive losses if ring frames were driven with individual motors, which can now be obtained with efficiencies as high as 85 per cent. By dispensing with the shafting and belts in the ring-room, the saving in favour of the individual drive, compared with the group drive, would be 7 per cent. Perhaps I should add, that if the engine was replaced by a turbine in either case, there would be a reduction of about 3 per cent, due to the higher mechanical efficiency of the latter machine.

The question might be put thus: Will the increased production, due to installing the electrical drive, give a sufficient return on the additional capital outlay entailed, pay for the extra power required and show a substantial gain over the mechanical drive? I leave



the matter here, but I have little doubt as to what the result would be if the subject was carefully investigated.

Mr. T. R. WOLLASTON said he had had numerous inquiries recently from spinning and manufacturing concerns in regard to gas plants for gas power up to 1,000 H.P. with recovery. For every ton of coal put through the producers in a recovery gas plant, they could get something like 90 lbs. of sulphate of ammonia, which, roughly speaking, was worth 11s. With a thousand horse power, and working ten hours a day, it was possible to lay down a gas plant with recovery which would show some advantage, as he had shown in the Journal (Appendix 2).

Mr. CROWLEY, who dealt with electricity, said a number of claims were put forward by electrical engineers for electrical driving—amongst them being increased production and improvement in the quality of material. There seemed to exist a fallacy that these advantages could be obtained to the full by means of group electrical driving. A careful study of the matter would show that a number of the figures given for losses in transmission, and other points that might be argued against electrical driving, applied to group electrical driving on a large scale, but not to individual electric driving, where the machine itself was direct coupled, or by means of high-efficiency reduction gear, to the driving motor. Mr. Crowley proceeded to criticise the figures given by Mr. Storie as a comparison of losses by mechanical and electrical drive, and said that except in the case of individual driving of looms and ring-spinning frames, and machines for which high-class individual motors had been evolved, mechanical transmission probably won. It won by such a narrow margin that a very small improvement in drive wiped it out. From the point of view of propaganda, the electrical man laboured under one difficulty in that his losses were readily measured, whereas in mechanical drive, not only were the losses not readily measured, but he knew of no case in which they had been systematically investigated. He would like to see results on that, because he believed it would help electrical driving more than anything else. The two main points for electrical driving were (1) steadiness of drive, resulting in higher maintained speeds, increased production, and improved quality of material; (2) specific advantages on the adoption of the individual drive, resulting in still greater production and improvement in quality. The production was greater with the individual drive, because by that drive they eliminated still further the joining-up links between the source of power and the machine to be driven. There was a speed at which looms could be run on a perfectly steady drive, and beyond which they should not be run. Electrical engineers did not propose to exceed that speed, but they said that, with mechanical drive, looms were never run at the exact speed at which they could be run, for mechanical reasons or for textile reasons. He thought it must be admitted that they had made good their case,

because in every instance in which the individual electrical driving of looms had been installed, the speeds had been put up and kept up. As a result—partly of that increase in speed, partly of the quicker start which individual drive gave, and partly of the steady speed due to fewer breakages—the production had gone up even on plain looms 10 per cent. The same thing applied to the individual driving of ring frames. As to the individual driving of mules, it had not been carried to a serious extent, but the problem appealed to the electrical man because of the varying load during the mule cycle. As to the use of tachographs for purposes other than day-to-day observations, he had grave doubts as to whether any of the tachographs at present on the market gave anything like a true record of the speed variation.

The CHAIRMAN said he thought it would be well in dealing with these papers to keep in mind the distinction between prime movers and means of transmission, and to remember that the electrical drive was a means of conveying power to the different machines. He had to do with several mills, and held varying views. He could give strong arguments in favour of electric driving, and could point to its success in a portion of a mill which formerly took 50 H.P. to drive and now took only 30 H.P. with electrical drive. In another case, where ordinary steam driving was successful, he could say that he was an advocate of steam driving.

Professor CHARNOCK said the Institute could be congratulated upon the excellent series of papers which had been brought forward for discussion. The outstanding feature seemed to be the question of steady driving. He agreed with Mr. Storie when he said that the steadiness of the drive of a steam turbine was most remarkable. It was so great as to justify one in adopting the electric drive, since it was contended that that was the only means of taking full advantage of it. Mr. Crowley had stated his case for the individual electric drive very well indeed, bringing out the point that, by adopting the individual drive, they got increased production and improvement in quality. Mr. Crowley said that with individual drive a loom could be driven with a speed variation not exceeding 2 per cent. If that were so, then every loom in the country ought to be driven by the individual electric drive to-morrow. The question of speed variation had been in the hands of the engineers; now it was in the hands of textile manufacturers. The question was, did they get increased production, and did they get improved quality? It was only the textile expert who could decide that, and he thought the Institute ought to carry out tests to ascertain it. If they got an increase in production of 10 per cent, and improved quality to the extent of 5 per cent, it seemed to him that it did not matter whether the speed variation was 2 per cent or more.

Mr. E. P. WARD said it was an axiom of economics that man tended to satisfy his wants by the least possible exertion. In these

discussions they had to bear in mind that what they were after was to satisfy their wants in the best possible way. That being so, he thought it was bad policy for a large amount of time to be devoted to the perfecting of machines which were already verging on perfection, when other machines and apparatus were very badly in need of improvement. In steam production boilers were working at anything from 70 per cent. down to 50 per cent. efficiency, and most boilers were working at a very much lower rate of efficiency than they might do. He regarded the production of steam as a fine art, and where they had gone astray was in not having developed instruments that would tell them precisely what was occurring, chiefly in connection with the combustion of fuel. What they needed to do more and more was to investigate the possibilities of saving fuel in the furnaces. Nothing could be done in that direction unless they started from the standpoint of analysing the fuel gases, and analysing them continuously, say, by means of an apparatus such as a CO<sub>2</sub> recorder.

Mr. C. W. FULTON said that mechanical transmission under ordinary working conditions might become inefficient without it being noticed. That did not apply to electrical transmission.

Mr. INGHAM (Bolton) said the "mechanical man" had a means of settling whether his plant was efficient or not. If the efficiency was going down, the coal bill was going up, and he soon wanted to know the reason. He thought the most valuable piece of information that had come out in the discussion was that given on pages 413 and 414 of the Journal, where Mr. Storie had been able to produce an actual cost sheet for power at a certain mill. He would suggest that should be done for all the methods of driving advocated. If actual figures could be secured as to the working of similar-sized mills driven by various methods, it would be of immense advantage. He contended that the speed variations that were being obtained by mechanical engineers were quite as good as anything that could be got with electrical driving.

Mr. J. O. O'BRIEN (Manchester) said he had in mind the case of an Irish mill which had been driven for a number of years by a Hargreaves reciprocating engine and belt drive. Some years ago the firm determined to try individual drive for different spinning frames. These frames differed to a certain extent from the cotton frames, inasmuch as they were driven slower than the ring frames. They were known in the cotton trade some years ago as "throstle frames." The firm tried the individual drive for some years with results which were satisfactory, both as to increased production and to better material produced from the same mixings. They got a more even yarn with the electrical drive. A new mill had recently been put down, and instead of adopting an ordinary steam engine they had adopted a Curtis turbine for their prime mover. In addition to that, all their new spinning frames were driven individually from an electric installation driven by a turbine. As far as he could learn, they were highly satisfied.



Mr. OSCAR S. HALL said he knew of a little mill in Germany, the owners of which began making a speciality, which did not require many looms to be put down. From the figures which had been supplied to him as to the cost month by month of electric current, which was taken from a central station, there was left no doubt in his mind that for that particular firm the electric drive was far beyond anything which might be conceived, because the total bill was less than it would have cost for a man to look after the engine and boiler. Detailed figures should be placed at the disposal of the Institute, to be published in due course. From the commercial point of view, he agreed with the Chairman that it depended on circumstances in each particular case. He hoped to be able to get particulars of the results achieved at another German mill where the looms and motors had been built in such a manner that the loom motors were self-contained. The drive was by cut gears, which, in his experience, were better than any other gear for the conveyance of power.

Mr. HINDLE mentioned the case of a mill in Switzerland which was being driven by water motors, the motors being direct coupled. The mill had been run for five years, and the upkeep was practically nil. The best electrical driving he had seen was in a mill driven by a steam turbine and group driving. There was no doubt that card-room machinery was best driven by line shaft. To put a motor on any of the machines in a card-room would mean that twice the power must be exerted to start the machine that it took to run it, and that could not be economical.

Mr. W. BLEAKLEY said that in another association with which he was connected they had a controversy between representatives of gas power and steam power. Figures which he himself gave from a mill with which he was familiar were accepted conclusively by the representative of gas power as being unbeatable. Briefly they were as follows: That with about 400 H.P. the cost of the engine-house, steam engine, and every cost to be wiped out in 25 years, the cost of maintenance, fuel, wages, oil, cleaning, and everything, came to '25d. per horse power per hour. He wondered whether that could be beaten by electricity or oil.

Mr. STORIE said the figure of '25d. given by Mr. Bleakley showed what could be done if there was proper supervision both in the engine-house and in the boiler-house. It was evident that the plant was thoroughly looked after. He agreed with Mr. Ward as to the need of instruments and observations, although at the same time these were of very little use unless there was proper supervision and the instruments were properly checked and looked after day by day. Mr. Fulton had remarked upon the possibility of mechanical transmission becoming inefficient without being noticed. A manufacturer should go round his looms periodically—once a month or oftener—and check the speeds. Unless the belting was kept in

proper order, the variation in the speed of the looms would differ so much that he would not get two looms running alike.

Mr. WOLLASTON expressed himself in agreement with speakers who had said that every case must be taken on its own merits. The need for the consulting engineer and the specialist on mill driving was greater than it ever had been, and he thought it would become still greater. The steam engine, the turbine, and the gas engine had reached a high state of efficiency, and the Diesel engine had the highest efficiency, but the cost of fuel was great. In his opinion there were prime movers coming to the front which would beat them all. In regard to the case of '25d. mentioned by Mr. Bleakley, he might say that in the Appendices to his paper at Hawick he worked out a case of 250 normal brake horse power to '248d. per B.H.P. hour, and one 600 normal B.H.P. to '2d. More recently he had worked out a case for a flour mill to be electrically driven, to  $\frac{1}{8}$ d. per electrical unit. That was with ammonia recovery. He thought the enormous advantage to be gained through keeping a power-house log sheet to show how the cost of power was going should be impressed upon members of the Institute, and steam and power users generally. It was a very simple thing, and a lad of 15 years of age, giving ten minutes a day, could take all the records necessary.

Mr. CROWLEY said that in regard to the request for actual figures of results from individual electrical driving, he should point out that he could give exact cases, and he could take any person interested to factories where they could see the books showing an increase of over 10 per cent. in favour of individual drive over mechanical drive, for twelve months. Mr. Ingham had said that it was possible to tell the losses due to mechanical drive by the coal bill. He (Mr. Crowley) submitted that they might know by their coal bill that losses had increased, or that they were high, but the chief point was left—they had to locate the loss. That was what the individual drive allowed them to do. Mr. Hindle was labouring under a misapprehension when he said twice the power was required to start machines with the individual drive. What was required was twice normal running torque.

Mr. O'BRIEN moved a vote of thanks to Messrs. Storie, Wollaston, and Crowley, and Professor Charnock seconded the resolution. Both speakers expressed the hope that the Institute would proceed further with the inquiry into the subject of mill driving.

The resolution was carried unanimously, as was also a resolution of thanks to the Chairman.

The Conference then ended.