THE
INSTITUTION OF LOCOMOTIVE
ENGINEERS, LONDON.

Coal as a Factor in Locomotive
Practice.

BY
J. PELHAM MAITLAND,

Associate Member, Brighton.

With an abstract of the discussion upon the Paper.

THIRTEENTH PAPER
(OF TRANSACTIONS).

SESSION 1912.

*Read on Saturday, 21st December, 1912,
at St. Bride Institute, London,*

*Presided over by Mr. Charles A. Suffield, Chairman
of Council.*

LONDON :
Published by the Institution
1913.

Price One Shilling net.

The Institution of Locomotive Engineers.

PAPER No. 13.

Coal as a Factor in Locomotive Practice.

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J. PELHAM MAITLAND, Associate Member, Brighton.

The importance of coal as a factor in locomotive practice was vividly brought before the public—technical or otherwise—during the great strike early in the present year, although for many years the question of coal consumption has occupied a most prominent position in the consideration of the locomotive engineer, it being almost entirely used to provide the required heat for the generation of steam for the propulsion of the locomotives of this country.

Eminent geologists differ much in their theories as to the method of formation of coal. Of these, it is only proposed to deal here with two, viz.: the “in situ” and the “drift” methods. There is every proof that thousands of years ago the surface of the globe was principally covered by dense forests. It was during this period that occurred the violent volcanic and seismological disturbances, which are admitted by every scientist, and the traditions of which exist in the legends and mythologies of both hemispheres. These caused many a vast tract of forest land to be submerged by the displacement of the surface of the earth, and covered by strata of sand, mud and decayed vegetable matter, which process, in many cases, became, in the course of time, repeated, so that we find several coal seams one above the other. This is called the “in situ” method, but the “drift” method is a far more gradual development. Forests had become, in the course of time, marshy swamps, and, after another long period, the decaying wood has detached itself and been carried away to a lake, where, after further decay, it has sunk and been covered by sand and mud, this process also being repeated indefinitely.

We will now pass on to a consideration of the different kinds of coal used on British locomotives. For locomotive work a semi-bituminous coal should give better results than

any other. The table will demonstrate comparatively the values of the principal kinds of fuel—Welsh coal, if obtainable, is pre-eminently the best for locomotive work, and although making more clinker than some others, yet its property of being almost smokeless renders it most desirable in these days of zealous County Council Inspectors. The Yorkshire variety comes second on the list as desirable fuel for locomotives, as it is able to stand a heavy blast, although making much more smoke than Welsh if not adeptly handled.

Modern economic conditions demand, however, that many classes inferior to the above should be brought into use in locomotive practice. These will require skilful manipulation on the part of the fireman and judgment on the part of the driver, if scheduled time is to be adhered to. During the coal strike, briquettes and small dust were in use on many railways, and, in numerous cases, the engines were unable to maintain themselves in steam, despite the fact that the majority of the express trains were cancelled. Towards the close of this period somewhat better results were obtained with these, due to a great extent to the men becoming familiarised with this form of fuel, which shows that the narrow fireboxes usual on English engines are suitable therefor; but it cannot be denied that with the Wootton type of firebox very satisfactory results indeed were obtained. It may here be mentioned that this class of fuel—briquettes and dust—is almost entirely employed upon the railways of France and Belgium. It has been ascertained that, in the comparison of several different specimens of coal, many of the coals of lower calorific value produce steam much more freely and, consequently, are more satisfactory and economical than those of higher values. Of the many reasons put forward, the principal one is doubtless that many a good class of coal gives up its heat slowly, and, owing to the heavy blast, passes out of the chimney in a more or less solid condition before having given up a large quantity of its heat, whereas another coal is quickly disintegrated and gives up the heating gases freely. It has been found by experiment that the average heat value of one pound of locomotive coal is 14,500 B.T.U., and a fair specimen would give, upon analysis, 80 per cent. carbon, 5 per cent. moisture and about 15 per cent. ash, which latter would go to form clinker on the bars, which is a very important item for the consideration of the locomotive engineer. This necessitates a good class of coal being used for long-distance runs, and a powerful blast is desirable to wrench the clinker from off the bars. This latter substance adheres to

the firebars and will, in the course of a long journey, prevent an adequate supply of air from passing through it, and many of the rich gases will pass away unconsumed (due to lack of oxygen), with the result that the steam pressure will drop back. One pound of average coal in use upon British locomotives will require the oxygen contained in 20 lbs. of air for complete combustion, and will evaporate .144 cubic feet of water. The growth of dead weight and accelerated speed of trains which have obtained in recent years on British railways have necessitated more powerful locomotives, which, in their turn, require more dexterous manipulation if good results are to be obtained. It is, however, quite impossible to lay down any general law as to how a locomotive should be driven and fired, as experience shows that each engine has its individual peculiarities. Amongst these peculiarities, one of the most prominent is how and where the engine requires fuel. Of two engines of which the writer has had experience—of identical type, dimensions and order—the one required about 95 per cent. of the fuel in the back corners of the firebox and under the mouthpiece, and an occasional sprinkle under the tubeplate, whilst the other—especially, strange to say, with a heavy load—required about 90 per cent. under the tubeplate and 10 per cent. down the sides and in the back corners. In firing a locomotive, the proper method is to keep a bright fire, which can only be done by firing in small but frequent quantities, in those places where the engine requires it, and which can only be ascertained by personal experience with each individual engine. A much thicker fire should be maintained under the mouthpiece of the firebox than under the tubeplate, in order that air may be able to pass through the glowing coal in the front part of the firebox over the bank of fire and over the brick arch through the tubes. The quantity of air required is regulated by the dampers, usually fitted to each end of the ashpan, but in many cases only one is employed. Experience only will dictate the position of the damper. In this connection, it will be well to draw attention to the fact that whereas coal ignites at 800 deg. F., carbonic acid gas is not given off until about 2700 deg. F. At the ignition point of coal, smoke is given off in large quantities, which is in reality particles of carbon, which, although combustible, have not been able to obtain sufficient oxygen—through an insufficient supply of air—to give off the heat they contain, thereby passing out of the chimney in a thick cloud unconsumed, and therefore wasted. These particles of carbon are frequently accompanied by carbonic

oxide, which is given off at about 1200 deg. F., and, being without odour or colour, passes away unnoticed and gives out no heat whatsoever. On British locomotives it is the custom to admit air as required through the mouthpiece as well as through the dampers, even when firing is not in progress, but should too much air be admitted in this manner, the steam pressure will drop and, very probably, the tubes will commence to leak, due to the cold air attacking them. Too much air, however, is often admitted through the dampers, causing a shower of sparks, which not only represents waste of fuel due to imperfect combustion, but also is a great source of danger to passengers and those in the vicinity of the railway. On many foreign railways, when fuel inferior to British is used, it is necessary to admit as much air as possible, a spark arrester being placed within the chimney to obviate, or, at least, minimise trouble from sparks.

It is the usual practice, when an engine is not producing steam in sufficient quantity for its work, for the fireman to stir the fire at frequent intervals with a long fire iron, the action of which causes the coal to atomise more rapidly and therefore to give up its heat more quickly. This process also serves to fill up the "holes" in the fire, which are caused by the action of the heavy blast upon the fire, but should it be unskillfully done, great waste of fuel will result. When briquettes are in use, however, such a process is almost invariably necessary. The question of briquettes brings us to the consideration of the part played by coal in influencing locomotive design.

It is the aim of every locomotive engineer to produce as efficient a machine as possible, and no question demands greater consideration than that of fuel. Owing to the high price of liquid fuels in this country—due in a great measure to the distance from which supplies must be obtained, and in a certain degree to trusts—coal is, one might say, the universal heat producer employed upon British locomotives. As the price of this article is gradually on the increase, the question of coal consumption becomes more prominent daily. An increase in consumption of only one pound per mile for an engine performing 1,500 miles per week, means an increase of no less than 38.4 tons per year for one engine only. One will, therefore, not be surprised that the modern locomotive is fitted with many devices with a view to fuel economy, and at the same time obtaining, if possible, a greater degree of power.

The ordinary type of firebox between the frames is

more common here than on the Continent and in America, due to the restrictions imposed upon British designers by the loading gauge. The Belpaire form is of late finding more favour in this country, although to a certain extent it impedes the look-out of the enginemén. The tendency of the blast in these boxes is to tear the fire from under the tubeplate, causing air to pass through in too great a bulk—unless the fire be skilfully manipulated—causing a certain amount of wastage of fuel. In the Wootton, as also in the Flamme type of box, which extends over the framing, the same action takes place, but the banks of fire at the sides provide an incandescent—and not a “green” substance wherewith to fill the spaces through which the air would pass in too great a quantity. By skilfully keeping the four corners and the sides of the firebox well banked up, it is necessary only to fire the other parts of the box at very occasional intervals—if at all. The benefit of this extra side space is very marked, especially when the engine is exerting itself to the utmost, as the coal becomes much more completely atomised before passing out of the chimney, thereby reducing danger from sparks. In a test lasting over some months, under identical conditions and similar loads, conducted by a British railway some time ago, the engine with the Wootton firebox—an “Atlantic”—consumed on the average 39.5 lbs. of fuel per mile, whereas a 4-4-0 consumed 44.1 lbs. per mile. Both engines were non-superheaters, had 19in. cylinders, the “Atlantic” having 6ft. 7½in. driving wheels and the 4-4-0 6ft. 9in. The disadvantage, however, as far as England is concerned, of the Wootton firebox is that it can only be employed on engines designed with a trailing carrying axle, and, therefore, especially on roads where gradients are steep, requiring the utilisation of all available adhesive weight, other means of coal saving have to be employed. Of these devices the superheater, which has become such a prominent feature of modern locomotive design all over the world, will first be dealt with. Although somewhat costly to equip and maintain, there is not a doubt that great economies of fuel result from its employment, not only as regards the amount of coal consumed, but also bearing in mind the additional extra tractive power that the engine can exert by the use of superheated steam. Of two engines—identical except that the one—superheated—had 21in. × 26in. cylinders at 160 lbs. working pressure, and the other—non-superheated—had 19in. × 26in. cylinders at 175 lbs. working pressure—engaged upon similar work and loads for several months,

the former averaged 26.8 lbs. per mile, while the latter consumed 44 lbs. per mile. Best Welsh coal was employed during this period, and in this connection it is contended that Yorkshire coal does not produce so favourable a comparison, due to the smoke which the latter emits clogging the superheater tubes. The latter reason demonstrates the importance of keeping the fire bright and not too thick, as the blast on a superheater engine is naturally much less intense than on an ordinary firebox, due to the obstruction caused by the small tubes. The extensive scale upon which superheaters are fitted to modern locomotives on foreign railways speaks highly for their efficiency.

Another device for saving coal which is more economical to instal is the Galloway-Hill furnace, the principle of which is to admit steam to the fire instead of air. This method prevents the formation of a thick layer of clinker on the bars, thereby ensuring a more perfect degree of combustion. The writer has noted, in this connection, the performance of a 4-4-0 engine, which, with an average load of 12 bogie coaches, performed its day's work of 275 miles without the necessity of cleaning the fire, which, with an ordinary grate, would have been performed twice. The amount of clinker on the bars was not more than $1\frac{1}{2}$ in. thick. This shows that it is now possible with heavy loads to dispense with the extravagance of a dirty fire—another cause of waste of fuel.

A further cause of waste of fuel may be found to be due to insufficient attention given by the driver to the lubrication of the cylinders and valves. A little oil "saved" in lubricating the front end of an engine very often means pounds of coal increase in the coal consumption, for, before the engine can commence to tackle its train, it has first to overcome its own frictional resistances. Consequently, the greater the speed, the greater will be the total resistance to be overcome, apart from any such considerations as wind, gradients, etc.

A blast pipe which has become "made up" with oil, grease and similar substances, also causes additional fuel consumption, consequent upon the increase of back pressure in the cylinders. The question of blast pipes, however, is still the cause of much controversy. The formula laid down by the engine builders of 60 years ago, viz. : that the blast pipe should be one quarter the diameter of the cylinders, still has many adherents. From the author's experience, however, it would seem that it is impossible to lay down any definite law on the subject, even for one single

class of engine. Of two engines, otherwise identical, one is fitted with a $4\frac{1}{2}$ in. diameter blast pipe, and another with one of $4\frac{1}{4}$ in. diameter. Both are excellent "steamers" and perform exactly the same work; yet upon the latter being fitted temporarily with a $4\frac{3}{8}$ in. diameter pipe, the engine refused to maintain itself in steam. Many instances of this could be brought forward, and this peculiarity is principally the reason for the many devices adopted by enginemmen in order to improve the steaming qualities of their engines. These latter practices, which are strongly deprecated by British engineers on account of their alleged tendency to increase the fuel consumption of the engines and to increase back pressure, have the most divergent results. In many cases a bad steaming engine is converted into an excellent one with—strange to relate—economy of fuel, although similar attempts to improve an engine of the same type and dimensions have been quite futile; in fact, have made matters worse. In this connection, it ought to be mentioned that devices for cutting the exhaust in the blast pipe have been fitted to many modern engines on the Continent. On one of the new four-cylinder 4-6-0 type on the French State Railways, of which the writer has had experience, a cone is fixed in the blast pipe at the orifice. Should a more intense blast be required, the driver, by turning a wheel in the cab, lowers this cone down into the pipe. The effect of this procedure in improving the steaming qualities of the engine was most marked, especially on the level. The comparative inferiority of the coal used on French locomotives to that employed in England must be remembered, and it is doubtless this that makes such devices necessary. It is an old adage that "An engine which will not steam is an extravagant one," and it also is the cause of much worry and annoyance, for, should it be compelled to stand even for a few minutes, it will commence to blow off, and thereby probably cause complaint.

Besides the blast pipe, there are many other factors which contribute to the economical consumption of fuel. In this connection the brick arch should receive special attention, as it is obvious that a better degree of combustion will take place if this part of the firebox is kept at the maximum heat possible. A badly designed or badly placed brick arch has been the real cause of the high coal consumption or inferior steaming qualities of many engines. In order to facilitate the production of steam, a practice is finding favour on the Continent to cut away portions of the brick arch near to the tubeplate in semi-circular sections.

Experience shows, however, that the effect on the tubeplate is often most deleterious when this is done.

A smokebox which draws air is another cause of heavy coal consumption, as the partial vacuum which is caused by the blast and which draws the heat through the tubes, is minimised or destroyed. The heat of the ashes seizes upon oxygen in the air, combustion taking place at both ends of the barrel. A chimney liner, or chimney, out of truth with the blast pipe is another cause of bad steaming, and, therefore, of waste of fuel, and the greatest care should be exercised in seeing that chimney, liner and blast pipe are all absolutely true to plumb.

In the author's opinion, in dealing with heavy coal consumption, sufficient attention is not given to a very important side of the question, viz. : to the men in charge of the engine. Great care should be exercised in placing the most experienced on the heaviest work, but it is known that in many cases a man of less experience, but of more knack, will considerably reduce the coal bill of a locomotive. An instance may be mentioned of an engine which regularly burnt all its tender contained, even if a moderately heavy load was encountered. This, for a few nights, was given, on the same turn, to a "spare" driver, who, with an average load of 51 up and 47 down, performed the journey with 10 cwt. less, and, after a few nights, returned with 15 cwt. in hand, the weather conditions being identical; and many other instances can be adduced of similar performances, but the above will serve to demonstrate, by means of a concrete example from everyday running, that heavy coal consumption is not—*ipso facto*—the result of the design or erection of the locomotive.

The excuse of "bad coal" having become rather frequently used by enginemen who have been called upon to account for time lost on journeys, most chief locomotive engineers find it most important to have a chemical department attached to their head depot, where the heat values of the samples of coal may be ascertained. This is done by consuming a portion of the sample in a calorimeter, of which many forms are at present in use. By the use of this apparatus and of very sensitive thermometers, accurate values of the samples can be obtained. One must, however, be careful, when utilising the values obtained, to take into account the weather conditions, design of engine, weight of train, etc.; otherwise, should too much reliance be placed on the theoretical result, grave mistakes will inevitably ensue. Such a process is, however, of great value in ascertaining

the quality of the fuel received from the colliery as regards the price paid therefor. Even here, however, a slight error may assert itself, for it must be remembered that, after the coal leaves the pit-mouth, it suffers depreciation through exposure to the rain during transit, and, in some cases, through having lain for a considerable time upon a stack. The necessity of a good stack of coal at every locomotive depot is an obvious fact, but it is well to have it used up and renewed every two or three years.

In conclusion, it is scarcely necessary to add that, in considering the relation of coal to locomotive practice, and the issues it involves, one is confronted with a divergence—we will not say discord—of theory and practice. The mechanical efficiency of a steam locomotive, under good working conditions, is but from 60 to 70 per cent., and yet it remains the principal mechanical agent for haulage upon the land surface of the globe. This, and many of the facts stated above, only serve to confuse us in our attempts to unravel the mysteries of the modern locomotive, and, with every respect to the theoretical expert, it is only by personal acquaintance and practical experience that one can hope to acquire a satisfactory and comprehensive grasp of the principles of modern locomotive practice.

BRITISH COALS.

Locality.	No. of Samples.	Moisture %	Ash %	Calorific value in B.T.U.
Derby and Notts	16	—	—	13674
Shirebrook	4	5.37	10.59	12555
Yorkshire	19	—	—	14357.9
S. Kirkby	1	—	—	14547
Hickleton	1	—	—	14310
Shipley	2	7.5	5.6	13400
Brodsworth	3	5.15	4.87	13672
Staffordshire	12	10.01	4.95	12013
Durham	12	1.136	3.94	13802
Welsh (good)	12	.82	3.98	14825
do. Dowlais	3	2.56	2.38	15227
Fifeshire	8	9.84	6.19	12407* 13761†
Stirlingshire	1	6.18	5.30	13471*
Monkland Standard	—	3.39	6.90	13505* 13982†

BRIQUETTES.

"Graigola"	—	1.56	8.9	13730
"Star"	—	1.28	5.19	14486

* Wet Coal.

† Dry Coal.

DISCUSSION.

The Chairman (**Mr. Suffield**): Gentlemen, having heard Mr. Maitland's paper, it is now open for discussion, and I have pleasure in calling upon Mr. Bennett to open the discussion this evening.

Mr. Bennett: I have listened with great pleasure to Mr. Maitland's paper on "Coal as a Factor in Locomotive Practice," but am somewhat disappointed at his not dealing more fully with the physiographical outlook on coal, which would no doubt have been of much interest to most of us here to-night. He might, for instance, have told us that coal occurs in beds or seams from an inch or less to as much as 30 feet in thickness, associated with shales, sandstones and other sedimentary strata, and that there are usually numerous separate seams one above the other, the floor on which a seam rests being always a bed of shale or clay called the "underclay," which is believed to have been the soil in which the coal plants grew; and also that it yet contains many roots of those plants fossilised, and that some theories as to how the coal beds were formed are as follows: That the rank and luxurious vegetation which prevailed during the carboniferous age grew and decayed upon land but slightly raised above the sea, and that by slow subsidence this thick layer of vegetable matter sunk below the water and became gradually covered with sand, mud and other mineral sediment; also that then, by some slight upheaval of the sea bottom or other process, a land surface was once more formed and covered with a dense mass of plants, which, in course of time, decayed, sank and became overlaid with silt and sand as before, and, at length, thick masses of stratified matter would accumulate, producing great pressure, and this, acting along with chemical changes, would gradually mineralise the vegetable layers into coal. Also that it has been proved that the bituminous matter of coal is almost wholly composed of the spore cases and spores of plants, allied to our club mosses and ferns, and that peat is also a superficial and comparatively recent formation of the same nature as coal and covers large tracts in Ireland under the name of "bogs," and in England and Scotland under the name of "mosses"; and this may be seen growing, and the rate of its increase is oftentimes considerable. It also consists

mainly of the remains of the bog moss, the lower parts of bog moss dying and decaying, whilst the upper parts continue to flourish; and the decayed parts consolidate in time into a soft solid, in which the fibrous structure disappears, and this, in chemical composition, is substantially the same as coal. And that submerged forests afford striking proof of subsidences and, in the south of Devonshire, so we are informed, remains of a submerged forest are visible under five fathoms of water; and, on the coast near Lincoln, low water exposes stumps of trees protruding through a deposit of peat. From these and from other facts, it is believed that the British Islands and the western part of Europe generally must have subsided at least seventy feet since these trees were alive; but nowhere are there marks of such excessive subsidence as in the southern oceans, where many coral reefs and islands speak of the submergence of the foundations on which they were built. The sedimentary strata of the earth's crust everywhere bears evidence that these sinkings and risings have been going on since the beginning of geological time. Nor has the movement always been in the same direction, the same portions having been repeatedly submerged, and also as often upheaved. This also is most strikingly seen in the "coal measures" as they are called; in the same coal field or pit, there are often to be found several seams of coal one above the other, with sedimentary strata showing quite plainly between them; therefore from what can be said of coal, it is clear that each seam bespeaks an oscillation of the level, a submergence and an upheaval.

Coal consists mainly of carbon and compounds of carbon with hydrogen, and, when coal is heated, these compounds are driven off as coal gas and what remains is mostly carbon in the form of coke.

Anthracite is coal from which the volatile parts have been driven off by the internal heat of the earth.

Of coal, there are several different kinds and many more qualities, but there are five distinct varieties:

Anthracite consists almost entirely of free carbon, generally jet black in appearance, but sometimes greyish like blacklead; it has a specific gravity generally of about 1.5, but this is sometimes as high as 1.9; it burns without emitting flame or smoke, and requires a strong draught to burn at all; it is capable of evaporating (theoretically) nearly 16 times its weight of water; but to obtain good results from it, careful stoking is necessary, as, when suddenly exposed

to heat, it is very friable, breaks up into small pieces, and falls through the bar spaces if disturbed much, as it does not coke.

Dry Bituminous Coal contains from 70 to 80 per cent. of carbon and about 15 per cent. of volatilisable matter; its specific gravity is from 1.3 to 1.45; it burns easily and swells considerably while being converted into coke; the harder kinds do not burn so readily, nor do the pieces stick together so easily.

Bituminous Coking Coal contains from 50 to 60 per cent. of carbon, and is generally of about the same specific gravity as the Dry Bituminous; it contains, however, as much as 30 per cent. of volatilisable matter, and, consequently, develops hydro-carbon gases; it burns with a long flame and sticks together in coking so as to lose all trace of the original form of the pieces; it, however, requires special means to prevent smoke.

Cannel (or long-flaming) Coal is seldom used for steam purposes, as it gives off large quantities of smoke and is very scarce; it is, however, the best coal for the manufacture of gas.

Lignite or Brown Coal, which is of later formation than the other coals, in some instances approaches to a peaty nature; it contains, however, when good, from 56 to 76 per cent. of carbon and has a specific gravity of from 1.20 to 1.35; it also contains large quantities of oxygen and a small quantity of hydrogen; the commoner kinds of Lignite are poor and contain as little as 27 per cent. of carbon and therefore are not suitable for steaming purposes.

Again, I do not agree with Mr. Maitland as regards the firing of a locomotive boiler. I fail to see why there should be such a drastic change made in the firing of one boiler as against another, especially as he mentions that, where this difference in firing has been required to make the boiler steam, the boilers have been exactly of the same design. Is it not possible that Mr. Maitland may have absorbed some peculiar ideas from the different drivers and firemen with whom he may have done service at different times? But, at the same time, I quite agree with him that the secret of first-rate firing is to fire frequently a little at a time; it requires perseverance, but it is the only way to accomplish hard running for an extended period with anything like success. Each round of firing should consist of about six shovelful of coal, one for each of the four corners of the firebox, one close to the tubeplate, and the

sixth under the firehole ; thus, every particle of good matter in the coal may be burned up and the fire may be worked to the highest point of economy. I have heard drivers explain that a concave fire should be formed and so kept up, of a form almost resembling the inside of a tea saucer, shallow and concave, the thinnest part of the fire being in the centre, the fire being made up from time to time in the manner I have just mentioned against the walls of the firebox and in actual contact with the heating surface ; and it is said for this class of firing that the centre of the fire is then self-feeding, for, by the action of the blast, and the shaking of the engine, the lumps in the corners are caused to roll or fall towards the centre. On this system, the centre is the thinnest part of the fire, quite free from ash or clinker, the dirt falling down by the sides of the copper plates and tending to prevent the cold air from touching the plates ; also, with a fire of this class, the oxygen can only get into the firebox and into the neighbourhood of the tubes through the centre of the fire and mingles with the flame, even when a portion of the air is taken in from the firehole, if the deflector plate is in position, which leads the air down under the brick arch and so mingles it with the flame, it then becoming instantly heated to a very high temperature before entering the tubes, which are thereby assisted to, as far as possible, maintain an even pressure in the boiler. Bad firing, however, is to be much deplored, for, by it, much fuel is lost by its falling through the bars and being, consequently, thrown away with the ashes. This more often takes place with good fuel, owing to its brittleness, but may, in some cases, however, be due to bad design of the fire grate. Again, sometimes, the fireman will allow his fire to get in holes and, at once, the cold air is rushing into the firebox without mingling with the flame, with the result that trouble arises from leaking stays and tubes. Too much care cannot be taken with the firing, as the best designed or made boiler may prove inefficient from this cause.

In criticising Mr. Maitland's paper, however, I am only seeking for information, the ethics of our Institution being that we are incorporated for the dissemination of knowledge, and the wider the discussion that takes place, the more information we shall all obtain.

Mr. Lawford H. Fry : I think the Institution is to be congratulated on the suggestive paper that we have had on the subject of coal, without which no locomotive can

move unless it is burning liquid fuel, of which we do not get very much here.

I am much interested in what Mr. Maitland says with regard to the two locomotives, one of which burnt under the tubeplate and the other at the back of the firebox. I should be very much inclined to suspect that there was a difference in the smokeboxes of these two engines; probably one had a higher blast-pipe than the other, which would tend to make this difference. The blast-pipe, of course, is of vital importance in connection with the combustion of the fuel as it is on the blast that the air depends.

Mr. Maitland speaks of 20 lbs. of air per lb. of coal. I am inclined to think that that is a counsel of perfection. I have examined a good many analyses of smokebox gases, and I find that when the grate is burning about 100 or 124 lbs. of coal per square foot of area, that is to say when it is being pushed to its maximum, that it is extremely difficult to get more than 10 lbs. of air for each pound of coal fired. That, of course, is insufficient for the complete combustion of the coal, and I find that each pound of coal burned only gets about 12 to 15 lbs. of air. It would be very advantageous for the combustion if we could get more air through the grate, but the draught makes heavy demands on the back-pressure, and at high speeds there is very considerable loss due to the back-pressure necessary for the draught.

In designing the diameter of the blast-pipe, to which Mr. Maitland refers, I think there are three elements to be considered. The air has to be taken into the ashpan, it then has to be taken through the fire—there are four elements—the ashpan, the fire, through the tubes and then through the spark arrester if there is one. If one measures the draught in the ashpan, fire, smokebox, and then in front of the blast-pipe, it is possible to see how the resistances vary, and one finds with the spark arrester, which is necessary at the high rates of combustion in countries where there is liability to fire, that it will take 20 per cent. of the whole draught simply to get the gases through the spark arrester.

Mr. Maitland's paper dealt mainly with the coal from the point of view of the railway company, and each railway company has a comparatively narrow range of coal. It is the locomotive builders that have the most difficulty, owing to the varying conditions of coal. A builder must be prepared to build a locomotive, either one locomotive to burn

Anthracite, which, as Mr. Bennett tells us, will have something like 7 per cent. of volatile matter, and he must also be prepared to build a locomotive to burn Lignite, which will have over 50 per cent. volatile, and this gives the builder some very interesting problems to meet all these varying conditions.

The Wootton firebox has been largely developed to burn the fine Anthracite Coal. I have here a record of a special Wootton boiler which was built to burn a coal of the following analysis: This coal was "Screenings" and contained 33 per cent. of volatile matter, 23 per cent. of fixed carbon and 41 per cent. of ash. It was a very poor coal and consequently could only be burnt very slowly; it was also a very fine coal and therefore required a very light draught. The boiler was provided with a Wootton firebox and burnt that coal quite successfully. The Wootton fireboxes burning fine Anthracite coal have grates some of them about 10ft. long and 8½ft. wide, in some cases 9ft. wide. I have seen engines with 96 square feet of grate area. The fact that they are burning Anthracite coal enables these boxes to be very shallow. You have a small amount of volatile matter, and therefore you do not need very much volume above the firehole; if you are trying to burn soft coal in the Wootton box, you are liable to have difficulty because you bring your hot gases so close up to your top sheets; there is not enough room for the gases to burn. In conclusion, I might quote an experience from an engineer who was in the West with the Wootton firebox—a "Consolidation" engine with Wootton firebox on trial on several Western railways. He says the Union Pacific was one of the railways on which the engine was tried. "At Laramie, Wyo., the directors and Mr. Adams met the engine to look her over. She had then been in service on the road some five or six weeks, using only the slack or refuse coal from the mines. The assistant superintendent of motive power, with a clerk, had been with the engine all the time, keeping record of her performance. Mr. Adams asked me my opinion of the engine's ability to burn their refuse coal. I told him in reply I had none to offer; that I would prefer he should take the reports of his own people. He said he had them and they were surprising. Mr. Adams then turned to the directors and said: "Gentlemen, the question seems to resolve itself into this: Shall we adopt a type of engine that will do our work with fuel that costs us money to throw away, or continue to use those that require fuel worth to us in the market seven dollars per ton?" showing

the great advantage of designing an engine to burn a low grade of coal; and later on this same engineer, Mr. E. G. Rauch, of the Manhattan Railway Company, says: "I used some coal that was as fine as Scotch snuff. It was called the Grass Creek coal, and on account of its light character, could not be used in engines. That which I used had been sifted several times to get it fine enough to pack around the water pipes at Green River, to protect them from frost. It was not intended for any other use. I insisted on trying it—did not want it said there was any fuel the engine could not do her work with, unless it were the fact. She steamed well with it, and only yielded 29 pounds of ash to a ton of fuel."

Mr. Bassett: I am very sorry I was here so late that I have missed the major portion of Mr. Maitland's paper, and also I may say that my experience with coals is only in the direction of gas manufacture—that is to say that such coals as Anthracite and Welsh Steam Coal and so on are entirely ruled out. The gas engineer generally has now given up the use of Cannel entirely, and divides coal into the two rough classes of "coking" and "non-coking" coals, namely, those which fuse or melt practically as soon as they are heated, and if they were only carbonised they would leave a shapeless mass of coke, having no relation to the original coal; and "non-coking" coals which give off their gas, leaving coke practically the same shape as the original lump. These, of course, would be the two main varieties of ordinary coal, and I have no doubt Mr. Maitland has dealt with the difference required in the design of the grate and the firebox to use either of these kinds of coal. There is one point of view from which I generally consider a firebox. Every firebox must be to a large extent in its action a producer or gas generator, that is to say, that, although the heated coal is giving off gas during the first period of the time it is put into the firebox, yet also during that first period and also for a long while afterwards, you have the air gas or water gas reaction going on, from which the air that is coming through the grate forms carbon monoxide, to a large extent, an inflammable gas which will burn on top of the coal; and therefore you want a certain amount of adjustment of the volume of air that will come in below the grate bars and the volume that can come through the firehole door—you want to get the right proportion; and that proportion must necessarily vary during the period between firing, that is to say, when coal is first put on, and when it is giving off its gas, you want to get more air

through the firehole door to burn that gas ; and when the gas represented by the volatile matter in the coal has ceased to be given off, you want less air ; you simply want the constant proportion between the air coming in at the top and the air coming in at the bottom, and according to the grade of coal used, the locomotive engineer must so design his firebox that he can get those proportions of air, allowing, of course, a reasonable amount of adjustment.

There is only one thing—I do not know whether Mr. Maitland has mentioned it—whether he has ever found any difficulties in the storage of coal. It is a point that might be dealt with ; it has been gone into very thoroughly in the gas industry, where the space at disposal is very limited, and the question has come up this year particularly owing to the coal strike. Stocks in hand now are sometimes four or five times as great as they were last year.

Mr. Wolford : It is rather difficult to criticise Mr. Maitland's paper because it opens up practically everything in the design of locomotives from one end to the other ; but although I have not noticed a great difference in the firing of similar engines, there is a great difference in firing different classes. An engine with a very sloping box would require a different method of firing to one with a deep box, and I have very often noticed that a deep box requires a deep fire and a shallow box a shallow fire ; and one with very tapering firebars also requires rather more at the back because there is a strong tendency for the fuel to shake forward, and I have seen engines fired with fuel right up to the door, not thrown in but simply put in, whereas with a deep box, you would have to throw it forward, especially when the bars are level.

Then there are one or two other little points about coal itself. We know—Mr. Bennett has told us, and Mr. Maitland also, but Mr. Bennett more particularly—that there are several different sorts of coal. There is the Anthracite, the Bituminous and the Lignite, and the other coals. I have read somewhere that the older formation of coal is the Anthracite, and it has lost its lighter constituents due to the extra weight imposed upon it since the ages when it was formed. That seems very reasonable, probably right, but one thing strikes me as rather difficult to understand ; it is that although that might be so, yet the deepest coal is found in the Lancashire district, which is not Welsh coal at all. Anthracite coal from Wales lies considerably nearer the surface than the coals round the Manchester district. I have

read somewhere that the deepest coalmine—the Pendleton Dip—is about 3,474 feet. It struck me as rather peculiar that if the weight of the surface above had squeezed out the lighter constituents of the coal, how it is that the deepest coal is not Welsh or Anthracite coal.

Some coals will form what we call “bird’s nests” on the tubes and studs of roof bars and other parts. That might be explained, and what the effect of watering coals would be, and so on. There are many things which might be dealt with in coal rather than the actual design of the engine.

Of course, I know that the position of the blast-pipe does far more than anything else in the engine. By raising or lowering the blast-pipe and providing a petticoat pipe it is possible to make coal burn anywhere in the firebox within limits.

Spark arresters have a great influence, although there is one—a sort of Venetian blind arrangement on the smoke box—that gives no back-pressure at all.

But there was one point I wanted to mention, about putting a “Jimmy” across the top of the blast pipe. A good many people complain of that because it increases back-pressure. I really cannot see that a small bar can really have any appreciable effect in increasing the back-pressure. I believe myself the great objection is that it has to be done in a hurry and there is a great liability of putting something in that will drop down the blast-pipe. I think there is more damage from that than actual losses due to back-pressure. I know that it will “wake up” an engine very much; and so will a rough-topped blast-pipe—one with a ragged edge will give a better blast.

Mr. S. H. Whitelegg: I have been deeply interested in Mr. Maitland’s very interesting paper and also in the discussion that has taken place since. After the many ways in which this paper has been criticised, there are, I think, very few points left to be discussed. I quite agree with Mr. Wolford when he says that the actual bar in the blast-pipe has not so much effect as the state of the surface. I have experimented in various types of blast-pipes, and latterly I have tried a blast pipe with a lip formed on the top; and the effect of this lip is to considerably increase the steaming power of the locomotive and without increasing the back-pressure.

There is one other point I should like to raise, and that

is that Mr. Maitland does not mention much about the load or speed of trains, and this, undoubtedly, has a very great effect on the consumption, and also affects the various fuels that are used for the particular engine.

I think it is rather a waste of time to take too much care with the design of blast-pipes, as after an engine has been running a few months, the diameter of the blast-pipe may be altered by as much as a quarter of an inch, due to the sediment forming on the cap; and as you know, a quarter of an inch in a five-inch blast-pipe makes a great difference to the area.

Mr. Wolford, again speaking, said: There is one little point I meant to have mentioned. Speaking of Mr. Bennett's theory—or rather, somebody else's theory—he mentioned about burning the coal saucer-shaped. I remember noticing the drawing of a North London engine a good many years ago with curved firebars with all the space round covered with dead plate—firebars the complete length of the firebox bellied up in the middle a matter of six inches and all round the sides—four or five inches—dead plate to keep the air from coming in. That will give the same effect as the practice of throwing the coals at the sides.

Mr. McKie: There was one statement made—Mr. Maitland mentioned that an engine fitted with a superheater could develop a greater tractive force. I think he was rather wrong in that statement. I believe it is thought by some people that it can develop a greater tractive force than an ordinary engine. There might be more coal saved, but there is no more tractive force developed.

Mr. Nethercott: I was much interested in Mr. Maitland's description of two engines of the same class so totally different. It seemed to me there must be something wrong with the fire or the fireman to require firing of that description. Certainly, I believe in the fire being kept even as far as possible, and the less holes there are, so much better for the fire and the firebox and certainly it must be so much better for the engine.

Mr. Long: My comments will not take the form of criticism, but I should like to put to Mr. Maitland a question, and that is, whether he really regards seriously the tests in regard to fuel burnt. I think it is between the superheater and non-superheater. It is all very well to say that under a test with picked coal, that a superheater engine is burning say, 26, and a non-superheater say, 40 lbs.

per mile, but what are they doing in the ordinary course of their work? We heard a good deal years ago of the advantages of compounding as expounded at Crewe. Those engines, I believe, were represented as burning something like 24 to 25 lbs. per mile, but I believe it is a notorious fact that they were the most expensive engines that any railway company in this country possessed. Of course, it is on this all-important question of consumption that the reputations of locomotive engineers stand or fall, and each locomotive engineer undoubtedly has a reputation to make and he seeks it first of all on this question of coal consumption; but when we talk of figures in connection with coal consumption, I think it is fair that the general figures and not figures of special tests with picked coal should be brought forward as examples.

Mr. Dearberg: There is one question I should like to ask Mr. Maitland. Could he give me any information about the "Galloway-Hill" furnace? I should like some rather exact details. Mr. Whitelegg has spoken on the subject of blast-pipes, could he give me any information as to how that arrangement is working on the Tilbury in connection with the reversing shaft? It seems to me, from a theoretical point of view, a very good idea.

Mr. Chrimes: There is just one question I should like to ask about Briquettes. They were used on the Brighton Line at the period of the coal strike, and at the end of a fifty-mile run the tubes in the firebox, which on an "Atlantic" class are 2½ in., were filled up until there was only ¾ in. space left for the air to go through to draw the fire. I should just like to know how they deal with that on the Continent and in America.

Mr. Burt: There is not very much left for me to say after the remarks that have been made. There is one point I am rather keen on, although, perhaps, it is somewhat outside the paper, and that is with regard to the amount of Welsh steam coal which is continually going abroad, and especially to a certain powerful foreign navy, with which we may have further acquaintance later on. I think myself that it ought to be more confined to this country, especially as it is becoming a limited quantity, it ought to be kept here.

With regard to composition, I find that a good average coal consists of about 80 per cent. of carbon, 6 per cent. of

hydrogen, 1 per cent. of nitrogen, 7 per cent. of oxygen, $1\frac{1}{4}$ per cent. sulphur, and ash about 4.13.

Mr. Maitland also remarked that in the case of Belpaire fireboxes, the tendency of the blast was to take the fire from under the tubeplate. Personally, I cannot see what influence the outside casing of the boiler can have on the fire.

With regard to briquettes, it is somewhat surprising, I think, that they are not more extensively used in this country. They surely must be cheaper, and an enormous amount of waste could be utilised.

Regarding the storage of coal, it has been proved that coal is of very little use for locomotive purposes after it has been kept for two years if it has been exposed to the air, but I believe recently some experiments have been made by keeping coal under water. I should think it would be rather an expensive job to provide accommodation for storing thousands of tons under water.

Referring to Briquettes, I should like Mr. Maitland to have told us more about them. I have been given to understand that their preservative power is considerably greater than that of coal, probably owing to the action of the pitch. Perhaps he will also give us the component parts of Briquettes? During the time they were used in England, I believe that many of the men did not get on very well with them, but that, probably, was owing to the fact that they were not much used to that kind of fuel. Of course, it is almost universal in France and Belgium, practically no coal at all being used there, although I believe that a certain amount of Welsh coal is used on the Paris, Lyons and Mediterranean on their express engines—they are in a position to buy that luxury.

The **Chairman** then called upon Mr. Maitland to reply.

Mr. Maitland: I have before me a rather numerous list of criticisms which have been most welcomely received by myself. I am sure they have been instructive to us all with regard to the paper which has just been read. I will endeavour to deal with them in rotation.

Mr. Bennett spoke, or rather enlarged, upon my remarks as to the geological formation of coal. This question, like many other scientific questions, is one which has evoked many divergent opinions and theories, and even the greatest scientists themselves are not wholly agreed as to

the precise and specific conditions under which coal was formed. But of the many theories which at present find favour to a great extent with modern scientists, I quoted two, and I am very grateful to Mr. Bennett for having brought to your notice one or two more. There is no doubt that, as he says, coal does contain a certain amount of fossilised material, and, although it is less apparent in some coals than in others, yet I myself have very often come across—I should say more in regard to Yorkshire coal than in any other coal—remains of fossilised animals or animal substances. I do not think, however, that their presence is of sufficient importance in any coal which is consumed on locomotives in this country to command very serious attention.

Now Mr. Bennett inferred that my remarks—which have caused a certain amount of criticism—as to the peculiarities between two engines of similar class and under similar conditions were obtained from drivers and were therefore the personal opinions of those men. I assure you that such is not the case. Those remarks were made upon my own personal experience with those two engines, and I can assure you that I was just in the same degree of health on the one day as the other, so it was not the case that the fireman was tired. I can give you a few dimensions which perhaps may be interesting:—

Internal width of box	...	...	3ft. 5in.
Internal length of box	...	...	5ft. 6in.
Depth through the box,	1ft. 3½in.	greater at	
the front end under the tube-plate than			
under the fire-hole door.			

So it was a very sloping box indeed for its length. From the bottom of the firehole door to the firebars was 1ft. 6in. It was a shallow box and I can assure you that nothing surprised me more than to find this remarkable difference between the two engines; but I am very much obliged, I believe it was to Mr. Whitelegg, for his remark that possibly the blast pipe in the one might have been rougher and might have become more corroded than the blast pipe of the other. That may be the explanation.

Mr. Fry has brought before our notice a very interesting case indeed of a locomotive designed to burn low grade coal. In these days, when the locomotives have so many competitors in the form of automobiles and electricity, it is of the utmost importance that the locomotive should be

built to burn the same kind of fuel—or nearly the same kind of fuel—as the stationary boiler in the electric generating station. We have often had it said to us that the stationary engine was a far more efficient machine than a locomotive; be that as it may, the great point which I have endeavoured to bring to your notice in my paper has been the expense of good coal for locomotives. The case Mr. Fry brought before your notice is most interesting, as it shows that a locomotive can be designed to burn satisfactorily even the cast-off refuse from the coal pit. It is a most satisfactory case and I am sure it reflects very great credit on the enterprising engineers who insisted upon producing such a machine.

Mr. Bassett made a remark about the storage and stacking of coal. This question I referred to briefly and I should like to say one or two more words upon it. I am afraid that not only were certain gas and electrical industries “caught napping” at the time of the great coal strike, but, if the reduction of the train services is any data to go upon, the railways of Britain were “caught napping” too, simply through not having provided themselves with an adequate stock of coal to meet such an emergency. Now that enforces upon us the desirability of having a large stack of coal, and we must also consider that that stack of coal, if exposed to the weather for any length of time will rapidly deteriorate. It will lose its valuable qualities and they will evaporate and pass off into the air. I therefore mentioned a rule, which I believe obtains on a good many railways, of renewing and using up the old coal stacks every two or three years. The usual method of stacking coal is to place it on the ground in a heap and to build a wall of some very hard coal, or, in some cases, briquettes, round this stack and so to provide an outer surface which would afford a greater resistance to the weather than would perhaps some of the softer coal which forms the interior. As to stacking coal under sheds, I have never heard of it being done.

Mr. Wolford referred to the question of the kind of fire which was most economical to have in a locomotive. Now, he said that, on the whole, a deep box required a deep fire and a shallow box a shallow fire. With this I am absolutely in agreement. I have noticed in many cases that a deep box requires a deep fire, but also I would say that in these same cases the deep box required firing under the firehole door and very little down at the front end, whereas the

shallow box required much more in comparison down at the front end and less at the back of the firehole door.

There is one question that he raised about the deposits of coal being found at a greater depth in Lancashire and neighbourhood than in Wales. I was already aware that such was the case, and I have had the explanation given to me that, at a time when the coal had become for some centuries buried in the ground, one of those violent seismological disturbances, to which I have referred, took place, with the result that there was a great displacement of the earth, which covered up the coal quicker than would have been done had the natural course of events been allowed to continue. I have had that explanation given to me, but I do not think myself that it quite solves the difficulty. There is one thing I wish to say, that although the coal perhaps in another part of the country is not at so great a depth, it perhaps has suffered more from these violent disturbances through perhaps a more acute earthquake shock or other means.

Mr. Wolford remarked upon the very "illegal" use of "jimmies" in blast pipes. Now I am aware it is illegal, but many things that are not legal are very often done. I am informed it is a thing which *is* very often done; but be that as it may, I have known of cases where that has been carried out, and I really do not think that there was very much difference, if any, in the back-pressure. It may make a little, but I agree with Mr. Wolford in his remarks, and also with Mr. Whitelegg, that it does not have the deleterious effect which is very often attributed to it. But I do thoroughly agree with him in this, that except when the said "jimmy" is properly fixed, there is every danger of its dropping down into the cylinders and causing very serious damage. I am informed on the highest authority that one day an engine was seen on one of our main lines proceeding with steam shut off and the driver and the fireman going for a fishing expedition into the blast pipe. I was not a witness of that myself, but I can assure you that my informant is a most reliable person and I do not think he would have informed me of that had it not been true. Eventually the article was found and the journey proceeded with.

Mr. Whitelegg very briefly drew my attention to the fact that I had not fully considered or brought to your notice the influence of loads and speeds on coal consumption. Well, I did mention that, but I regret that I did not

do so more clearly. The increase of coal consumption which has gone on—which is going up by leaps and bounds—is due to that alone. The demand of the public now is to get to their destination as quickly as possible, and it is surprising the amount of extra coal which it is necessary to burn even when five minutes is knocked off a journey, of say, 60 or 70 miles.

Again, with the competitive strain of electricity, there has been a greater demand for rapid acceleration, which brings in its train additional coal consumption in order that the engine might get away with its train in as short a time as possible. A great amount is blown out of the chimney by the heavy blast and not consumed, and is therefore unable to give off its rich gases and so adds to the coal consumption of the engine. Another thing, too, is the heavy loads now obtaining on so many of our express trains. The G.W.R. furnish us with many examples of over-loaded trains, or what some people call over-loaded trains—17 bogies and so on are sometimes to be seen. Well, that, of course, is bound to tell, not only on the coal consumption, but also on the locomotive itself, and a locomotive must be in a very good trim indeed to be able to deal adequately with such loads as that. I have a case before me of a high official of one of our railway companies—one of the northern companies—who was travelling by train the other day and they had only 10 bogies on a four-coupled bogie engine. It was not his own line. He said to the driver, "You have been punishing your engine to-day." "Well," he said, "we had to do it to get here to time." "Yes," he said, "and how much coal have you burnt?" "Oh," he said, "we have burnt a tender full." "Why," he said to the driver, "why didn't you have a more powerful engine?" "Well," he said, "we have not got them to have. If we had we should not have blown 15 cwt. up the chimney, which should have been still in our tender." That might be somewhat of an exaggerated statement, but, undoubtedly, a big engine on a heavy train is far more economical than a smaller one.

Mr. Long criticised my remarks upon tests. Well, indeed, I am very much of his way of thinking. I adduced these figures to form concrete examples, but I can assure Mr. Long that these tests, of which I gave figures, took place under practical and ordinary working conditions. They were not carried out on special trains doing a special day's work. They worked their ordinary daily working through. If they had to work a local train they took it.

If the engine was required to go to bring an empty train in it did so. All this went down in the day's work, and so the trials of which I gave you the figures are not so much the trials of special cases, but they are trials which extended over a long period and in ordinary and average practice and work. So, therefore, I think that that will put a little different complexion on the matter than, perhaps, my previous statement would otherwise have done.

As regards the coal consumption of superheated and non-superheated engines, I am informed that the advantage of the L. and N.W. 4-6-0 superheaters over the non-superheaters is something like from 40 to 50%. These figures are not authoritative official returns, but I am certain of this, that very great economy has been experienced by the employment of superheaters on the L. and N.W. expresses.

As regards Mr. Dearberg's remarks on the Galloway Hill furnace, I do not think I can do better than state that a paper will be read upon that interesting subject at an early date, and I therefore would prefer, with your permission, to leave the discussion of that subject until that evening.

Mr. Chrimes drew my attention to the fact of which I was not aware previously, that an "Atlantic" engine was found to have plastered up its tubes at the end of 50 miles with the use of briquettes. Now I can assure you I have never seen such a thing on the Continent at all. I have seen people sweeping tubes, but I have never seen tubes plastered up in that way. I have been for many runs on French engines and the tubes at the end of the journey were as clean—or almost as clean—as they were at the commencement. There is, of course, a far heavier blast employed on French locomotives, as a general rule, than on English ones, and that, in itself, would serve in a great measure to mitigate the formation of scale upon the tube ends; and another thing which I drew your attention to and which perhaps would have something to do with it, is the cutting away of semi-circular pieces of the brick arch in the proximity of the tubeplate.

With regard to Mr. Burt's remarks about the Belpaire firebox, I am afraid that a little misunderstanding has arisen as to my method of expression. I referred to that type of firebox (see diagram), and almost in the same words I was speaking of a type of firebox in contra-distinction to the Wootton type of firebox, and that is one which lies

between the frames and not one which spreads over and beyond the width of them, and I did not mean to convey the impression that the action of the blast upon a Belpaire firebox would have an effect in any way different to the action of the blast on a round-top firebox, and to convey such an impression was absolutely foreign to my intention.

As to stacking coal under water, I regret to say that I have no knowledge of any such methods being adopted.

What I had in my mind was this. I have known the case, or heard of the case—many cases—of coal being conveyed in barges and ships and a hose pipe being “accidentally” left in the coal place and the water turned on. I think you will be thoroughly aware of the increase of weight which would take place in the coal on arrival at its destination. That is the action which I was referring to, and which I had in my mind, which caused Mr. Burt to infer that I was alluding to the storage of coal under water.

He also referred to the use of briquettes. Now briquettes are made of a combination of coal dust and pitch, which are put into a mould and compressed together under hydraulic pressure. In some cases I have heard of very raw and impure oil being used for the purpose, but the usual substance which is used to bind it together is, as I have said before, pitch. These briquettes show no tendency to expand in the firebox and fill up the spaces which are constantly occurring through the thick blast, and it is therefore necessary to use coal dust to put between them to fill up these spaces and occasionally to get down the “pricker” and to stir up your fire in the box from time to time; and, with that, and if these precautions, which certainly are very troublesome and irksome in a good many cases, if these precautions are taken, I do not think that anybody will have reason to complain that they have been short of steam. As regards the use of briquettes on the French railways, I am aware that on the fast trains of the Paris, Lyons and Mediterranean Railway, they are not employed. Their engines are absolutely suited for the purpose. They are “Pacifiques,” most of them—they have just constructed 30 “Pacifiques”—but Welsh coal has been found on the fastest trains—what they call the “Extra Rapide”—to be far more satisfactory and economical. Of course, you are aware that the fares charged on these trains are abnormally high, and, of course, would justify to a certain extent the additional expenditure in coal owing to the Company’s determination to maintain the speed of these trains

to their present booking; and this speed itself necessitates a high-grade fuel being employed, which goes to add additional weight to Mr. Whitelegg's statement about the loads and speeds.

There is just one thing I should like to mention about briquettes. I can assure you that I did not feel anything very serious happen to me through the use of briquettes, but several men found their eyesight attacked in a very peculiar way. I was informed that the pitch—which was ignited on the shovel before being put into the firebox—gave off gases which came up and got right into their eyes, and made them very sore and, in many cases, rendered them almost unable to see. That only happened to a few men and perhaps their eyesight was particularly susceptible to the impurities which were contained in the pitch.

In reply to Mr. McKie, I would state that as it is possible to supply a much larger diameter of cylinder to a superheater engine than to a non-superheater one of the same boiler capacity, a much greater amount of tractive force is available from this cause alone, and which would substantiate my remarks as to the greater tractive force of the engine using superheated steam.

I think I have dealt with most of my critics' remarks, and I am sure I must thank you all, gentlemen, for the very kind and attentive manner in which you have listened to my paper and also for the very cordial way in which you have responded to it by your criticisms and remarks.

A vote of thanks to Mr. Maitland for his paper, proposed by the Chairman and seconded by Mr. Burt, was carried with acclamation, and Mr. Maitland suitably responded.