COAL.

COAL—the subject of my paper,—is one of vital importance to the world at large, especially so to the engineering world, as it is through the medium of the said commodity that we are enabled to extract the heat necessary to produce the energy, force, or power, developed by our various engines.

The Science of Geology,—a science which seldom, if ever, errs, and a knowledge of which is of the greatest importance in mining operations,—is one full of interest, embracing, as it does, the structure and formation of the earth beneath its surface, as to its rocks, strata, soil, minerals, organic remains, the changes it has undergone, and the causes of those changes. I propose to confine myself, first to what I may term the historical, and afterwards to the practical side of the subject, as opposed to the scientific, if indeed they are separable. I must crave your indulgence in this, my first, attempt at addressing so distinguished an assembly, and can only apologise for adopting such a course as not being one of those who delve into the bowels of the earth in search of our "Black Diamonds," but rather one of those poor mortals "Who go down into the sea in ships."

The most remote references which we find on record regarding coal, cannot, I think, be assumed to apply to *coal* of the present day, but simply charcoal or wood-fuel.

That it was known to most nations may be inferred from each having a name for it—the Hebrew "Gahal," Greek "Anthrax," Latin "Carbo," German "Kohle,", Saxon "Coll," and the ancient Briton "Glo." But these terms were not used in their present sense until wood and charcoal were superseded by our coal or fossil-fuel of the present day.

So far as I have been able to learn, there does not seem to be any other meaning or definition of the word "coal" other than "That which burns, giving out heat and flame."

The definition seems rather vague, but several legal trials that have taken place in connection with coal, and the duties expected from it, leave us with no better or suitable explanation. True, we may expect it to be of a black or dark-brown colour, capable of being burnt in furnaces, fire-places, &c.; brittle, and not soluble, like the bitumens, in ether, oil of turpentine, or benzole.

The ancients were fully alive to the presence of certain varieties of coal, but appear to have had little or no idea of the extensive application which it was capable of being put to. A pupil of Aristotle (Theophrastus, 300 B.C.) describes it as "a fossil or stone coal, of an earthy character, capable of burning like charcoal, and used by smiths."

Stone axe found at Craig-y-Parc, in Monmouthshire.

It has also been recorded that the early Britons worked coal. A stone axe, stated by PENNANT to have been found in the out-crop of a coal-seam in Wales, had been well-nigh worn out in the service—but there are no satisfactory records previous to the Romans, and not even then until their later days, when roads had been constructed.

In the 13th century (1239) a charter was granted by Henry III. to the Townsmen of Newcastle-upon-Tyne, giving them liberty to work coal, and at this time commenced the raising of coal systematically; it was not long ere the same coal found its way to London, as the beginning of the next century finds "Ye good citizens of London complaining as to the great injury done to their health by the coal smoke," and it appears that Edward I. (1306) prohibited by royal proclamation the use of coal, and commanded all persons to make their fires of wood.

Up to 1565 the out-put of coal in North Wales was considerably in excess of the South Wales coalfields.

Iron and coal were worked at Neath, S.W., in the 13th century. The Monks of Margam are said to have utilised it at this period also.

But a few years had elapsed, however, ere the scarcity of wood asserted itself, and ships laden with "Sea Coale" once more sailed up the Thames, and the trade has since grown with the growth of the population. The yearly consumption of London alone is now upwards of 5,000,000 tons, or more than the entire out-put of Great Britain during the earlier years of George III. (1714-27).

Sept., 1704, 18 chaldrons of coal Tenby to Cardiff, Duty £5 15s. chaldron, 36 bushels.

Mention is made of coal-mining in Scotland in 1291, when a grant was made in favour of the Abbot and Convent of Dunfermline, and coal was probably marked in several of the English and Welsh Districts at this time.

In the beginning of the 18th century steam was introduced, and soon developed; its strength lay in the coal, and through that same strength made the raising of our coal and the pumping of our mines comparatively easy as compared with the past, we also find at this time coal was being sent from Pembrokeshire to Cardiff, a quiet reminder this of the "old-time saying" of sending coals to Newcastle. It is also on record that Bristol accommodated Newport, Monmouth, in the same manner at a later period (1730-35). Iron smelting became a success by means of coal converted into coke; the iron trade of Great Britain had got to a very low ebb at this time, but has ever since been on the increase.

Then followed various forms or contrivances for the best mechanical effect to be obtained from the heat stored up in our coals. James Watt bringing forth his admirable contrivance for the condensation of steam in a separate vessel, followed soon after by Boulton and Watt's engines, which soon became known the world over, and many other improvements by Stephenson, Newcomen, Trevithick, and several others, not a few of the improvements having their origin in the Cornish copper and tin mines, success in mining operations depending greatly upon the economising of coal. In 1792, Murdock (an engineer employed in the erection of Boulton and Watt's engines), suggested that coal-gas might be conveyed through tubes, as a substitute for lamps and candles, and it was said that he caused considerable alarm amongst some of the more superstitious of the country folk, as it was his wont to light himself homeward at night over the Cornish Downs, having a bag of gas under his arm, the neck of which when pressed made the flame shoot forth like a tongue of fire, and, in 1803, we find gas practically applied, and our coal became a factor in another great industry:—the production of light. In 1830, Nelson brought forth his great scheme for applying hot blast in the smelting of iron in the Scotch works, the result being an enormous increase in our coal consumption, with, as in all other cases, a great gain from a commercial point of view, as by its application the same amount of fuel, reduced three times as much iron, whilst the same amount of blast did twice as much work as previously. The invention and improvements of the past had for their aim precisely the same object as at the present day, "the economising of fuel," but the result is an enormously increased consumption of fuel, but with a far greater ratio in the increase of the work done, and every advance which cheapens the produce of manufactures gives so much more scope to operations, that coal, being, as it is, the basis of them, has a greater demand than ever. And now I would have

To the escape of gas from a colliery in the North of England, about 1750, is attributed the idea of lighting our towns, but nothing in a practical form was done until 1792, when Wm. Murdock applied gas for the lighting of his house and offices at Redruth, in Cornwall.

One ton of pig iron, in 1829, required the coke of over 8 tons of coal; whilst, by the application of air heated to 300° fahr., a trifle over 5 tons did the same amount of work.

The growth of the coal trade was enormously increased also by the great discovery made by Dr. Mushet, of the *Black Band, in Scotland.* Discovered in Glamorganshire by De la Beche, in a brook at Nantyfyrth near Maesteg.

According to Sir W. T. Lewis, the greatest thickness of coal in the S. Wales Basin is found in the Neath Valley.

you follow me to the coalfields of South Wales, they being comparatively young, as far as their development is concerned, as compared to the coalfields of the North of England. Briefly they may be said to consist of the greater portion of Glamorganshire, a considerable portion of Monmouthshire, and a portion of Carmarthen, Brecon, and Pembrokeshire.

According to Sir Robt. Murchison, in the Memoirs of Geological Survey of Gt. Britain, the S. Wales coalfield is larger than any in England; containing 25 seams, 2ft. being the minimum thickness, having a vertical thickness of 84 feet of workable coal.

Nine miles in length, by two and one-half miles in breadth, are covered by the Swansea Bay; nine miles in length, by five miles in breadth, are covered by the Estuary of the Burry and Llwehwr Rivers; Kidwelly to Carmarthen Bay, covers a tract 15 miles in length, with a breadth of six miles, various authorities estimating the field to contain 1,000 square miles, approximately divided as follows: Glamorgan, 518 square miles; Carmarthen, 228 square miles; Monmouth, 104 square miles; Pembroke, 76 square miles; and Breconshire, 74 square miles. A vast field, when the total area of the Principality is taken into consideration.

Total coal of Europe, as per Geographical maps, stands in the ratio of 1 to 21 as compared with America.

Upon the authority of Sir Hussey Vivian, America has 186,000 square miles, or about 44 times more than we possess, the coal fields of Northern France and Belgium cover 1,200 square miles; Rhenish Prussia, 900 square miles; Westphalia 900 square miles; and Russian coal fields, 11,000 square miles; every country indeed, having its coal, more or less. However, it is gratifying to find that, when such a dismal view was taken some years ago (1860) as to the probable duration of our coal fields, the same authority asserted in the House of Commons that, in his opinion, we had sufficient coal to last for more than 500 years, allowing our coal-fields an area of 640,000 acres, the seams being in one place, say 31 feet thick, and at another, 75ft.; then, taking 60ft. as being the mean thickness, or 1,500 tons per acre, brings up our total in Wales alone to 54 billion tons of coals, which he computed to be sufficient, allowing for waste, bad working, faults, &c., to keep England going, at the then consumption, for over 500 years, but it must be borne in mind that our out-put has increased enormously since this statement was made, but it upset the discouraging rumours of the day, being the conviction of one who could boldly say that he was as well acquainted with the field, as he was with the floor of the House.†

1 cubic yard of coal = 1 Ton.

The Report made by Royal Commissioners on duration of Welsh coal fields in 1865, allowing annual consumption to be 13½ million tons, is even far more encouraging than this.

Horsman's

This is not in harmony with the orthodox belief of Geologists, but it is not im-

I may also state that he believes in coal being found at still greater depths, on the assumption of other rocks under-

† See Mr. Macfarlane Gray's Remarks as to this.

lying our present system (carboniferous) beneath which coal may yet be discovered, believing that many other stratifications, besides the carboniferous, represent an age, more or less lengthy, in the history of the world; that each stratum had its flora and fern, its deep woods and vegetation of various forms, swept down by torrent, or buried beneath the wreck caused by the tornado, or indeed, perchance, by the upheaval of the earth itself, there to lie, and, as the land sank, to be covered at times by water and successive layers of rock, clay, and sediment, there subjected to the *pressure*, *temperature*, and *moisture* which were needed in its decomposition to convert it after ages of preparation, into that condensed form of fuel which we now use, the disturbances of the earth itself bringing portions of the coal formation so as to be accessible to man; thus the sunbeams which had in the primœval world exerted their force upon the jungle and swamp are again liberated, when we, by burning, decompose those compounds which had been called into existence by the solar light and heat. Regarding the manner in which coal was obtained in the early days, tradition has it that it was cut in a ravine or gulley where the coal "cropped," and, when its value became more known, levels or drifts were cut in the mountain side; the mine being of the simplest order, a hole to get in and another to get out, with barely sufficient room to stand erect, the coal being passed through several hands in easy stages; no air doors, or fires, in fact no provision being made for ventilation, although the danger attending the coal mining was well known, as may be inferred from the frequent accidents. When work was resumed on Monday mornings, the only means then adopted to clear the mine of the accumulation of "fire-damp," which had taken place in the interval, was to dust it out with their jackets.*

possible that the Permian, Lias, & Oolite stratifications may yet turn out to be coal producers.

(Carboniferous Limestone period).

It has been stated that at this period carbonic acid gas must have existed in the air to the extent of 8 per cent.

"Coal measures"

Shales or slatey clay of various colours, and in nearly all cases a bed of dense clay underlie the seams of coal.

The highest elevation at which coal is worked in Wales is at Carn Moeson, 1971 feet above the level of the Sea. The lowest on the Aberavon Burrows, where the Messrs. Vivian work the Morfa pits beneath the low water mark of the Swansea Bay.

Deepest Pit in Wales, Harris's "Deep Navigation" 700 yards, or nearly one half-mile.

What a contrast this to the present time, with machinery capable of bringing up 18 to 20 tons in a few seconds from some of our deepest pits, with ventilation we may say almost perfect as far as danger is concerned, provided the printed rules posted at all collieries are strictly attended to by the miners themselves; they are now even adopting the electric light in some collieries, some of our larger mines sending 10,000 tons of coal per week to the surface, 1,500 tons per day being no unusual occurrence and considered quite insignificant.

A pair of Winding Engines by Nasmyth, capable of bringing up 3,000 tons per day, have been recently erected for the Ebbw Vale Company.

* Since writing the above I was sorry to find per cable news to *New York Herald*, that 190 lives had been lost through an explosion of fire-damp at a coalmine in Abersychan. The mortality in Welsh coal mines is greatly in excess of those of the North of England, caused to a great extent by the fragile nature of the roof.

The earliest record of the sale of steam coal from Glamorganshire is in 1828, from the celebrated "four feet" vein or seam, and obtained near Abercanaid, and it was from the "Graig" in the same locality that, in 1830, 414 tons of "Waun Wyllt" coal, per "Mars" of Shields, was sent to London, but it was so little appreciated, that it scarcely realized sufficient to pay its freight, but four years later 700 to 800 tons per week was being sent to London, the demand being due, no doubt, to the determined cry that was made for smokeless coal, brought about by the "London Smoke Act."

From Aberdare westward the coal of the south outcrop remains bituminous as far as Llanelly, where the northern side of the field changes to anthracite, the only kind of coal found in seams rising northward in Carmarthenshire, and by all those of Pembrokeshire. Even within distance of a few hundred yards the Llanelly beds are seen to be bituminous when they rise to the south, and anthracitic on the opposite side of the trough, or where rising to the northward.

Anthracite, a burning stone coal, a hard compact mineral coal.

Greek *Anthray* a burning coal, and *Lithos* a stone.

The different varieties of coal may be said to consist of Anthracite (hard), Bituminous (soft), Cannel, Torbanite, Brown Coal, or Lignite. Those in general use are recognised as free-burning, steam, or smokeless coal, and non-caking coals. A single bed or seam may contain different varieties of coal, and in some instances may be divided from one another and sold separately.

Good specimen of Anthracite contains 97 per of carbon, but generally less pure than the carbon contained in bituminous coal.

Impurities principally iron, silica, and alumine.

Anthracite coal is of a bright black colour, does not soil the fingers, and is not so readily kindled as most other kinds of coal, and to a certain extent decripitates in burning. Specific gravity 1·3 to 1·75, it contains carbon to the extent of 90 to 95 per cent., the proportion of hydrogen, oxygen, and nitrogen being small. Various theories are advanced as to the cause of the changes in the Welsh coal. Why should it be anthracite in one place and bituminous in another? Some suggest that at one time it was all bituminous, the change being ascribed to the action of the igneous rocks which run from Ireland to Cornwall and on to Brittany. Others explain that the anthracitic character is due to the great pressure to which the coals have been subjected; many of the seams underlie 10,000 to 12,000 feet of strata, which would be sufficient to raise the internal temperature above the boiling point of water. That heat of an intense character has at one time been in close proximity with our coal seams, may be inferred from the extent to which the interior of some of the iron stone has become crystallized. Others attribute the change to "Faults."

Then follows bituminous coal, being black, of various shades, sometimes having a greyish black streak, specific gravity. 1·25 to 1·4, containing generally from 73 to 90 per cent. of carbon, 8 to 22 of oxygen, hydrogen, and nitrogen; earthy matter same as anthracite, 3 to 30 per cent. (ash). Some specimens will coke, but the smalls do not readily unite. It should be borne in mind that the term bituminous, as applied to our soft coals, does not really mean that they contain bitumen (*i.e.* mineral pitch, soluble in ether, oil of turpentine, and benzole), but that they contain a higher per centage of the gases, oxygen, hydrogen, and nitrogen, principally hydrogen, than the anthracite, or hard coal, giving it a more flaming character in burning. Caking coals emit jets of gas and generally give off a greater amount of flame and smoke, are in great demand as household coal, and are valued for their low per centage of ash. The small of the same when duly heated becomes fused together, and are converted into coke for iron-smelting, and also for burning in locomotives. This contains on an average 5½ per cent. of hydrogen, it being the main element in the evolved gas and by the combustion of which flame is produced.

Pure coal consists of carbon, and the elements of water, viz.: Oxygen and hydrogen.

Carbon 84·9 per cent Hydrogen 3·23 Oxygen 11·78

Bituminous impurities.

Bisulphuret of iron (iron pyrites), of brass like appearance, making it dangerous to keep in a moist state, as the decomposition of this causes spontaneous combustion.

Bituminous.

Next, we have Cannel Coal, the name of which is supposed to have originated from "Cannoyll"—a candle—from its readiness to light, and it is largely used in the manufacture of illuminating or coal gas. The teeth and scales of fishes in their fossil state are oftentimes found embedded in it; some of our leading microscopists stating that it may be known by the general absence of vegetable structure, and it would seem to be a moot question whether it should be classified, scientifically considered, with our coals proper.

Then follows Torbanite or "Boghead Mineral," and Lignite, the former containing about 9 % carbon, 60 to 69 % volatile, the ash being abundant, and being so equably diffused throughout the mass, that, after the process of combustion has taken place, it remains blanched in color, but retaining the same volume as formerly. It is a great gas-producer, one ton is said to be equal to the giving out of 15,400 cubic feet, which is considerably in excess of Cannel; some authors class it as a distinct mineral species, others again, as a "bituminous shale." Lignite or "Brown Coal," as it is sometimes called, often resembles wood in appearance

Volatile—wasting away easily passing into the æriform state, as hartshorn, ether, &c.

—in its undecomposed state. It burns easily, giving forth an unpleasant odour, specific gravity 0·5 to 1·5, contains 50 to 70 per cent. carbon, 8 to 22 per cent. of hydrogen and nitrogen, but contains an excess of oxygen, and generally a large amount of water. Some of the best examples of lignite closely resemble our good bituminous coals, there are as many varieties of it as there are of the coal proper ; but it is usual to give the name Lignite or Brown Coal to all the more recent formations, that is to say, more recent than the true carboniferous or coal. And, lastly, I may refer to our artificial or compound coal, commonly called Patent Fuel, and if the computation be correct that in Great Britain alone the quantity of coal dust remaining unemployed annually amounts to 28,000,000 tons, it seem a pity that the demand for Patent Fuel is not greater, consisting as it does, of a mixture of coal dust and tarry or bituminous matter, water, and sometimes other ingredients for cementing the compound, but the less foreign matter the better, as it only produces a larger quantity of clinker and ash. This mixture has a high evaporation of 10·36lbs. of water at 212° per lb. of coal ; the rate of evaporation per hour being 457·84lbs.

Containing on an average 1 ton of Coal Dust, 16 gallons water, intimately mixed with 16 gal. of *Coal Tar.*

Carboniferous : Latin *Carbo*, and *Fero*, to produce.

Carbon : pure Charcoal, an elemementary substance, bright brittle, and inodorous.

Bitumen—a mineral, pitchy, inflammable substance.

It, however, emits much smoke, gives off a great amount of soot, and is not readily kindled. Some years ago an attempt was made to remedy these defects, working on the principle that the value of coal for steam uses depended greatly upon the amount of fixed carbon that it contained. Experiments were made by the Admiralty Officials, at Swansea Patent Fuel Works, anthracite being mixed with more bituminous coals, but it was found that the tar being so much more combustible than the slowly-igniting anthracite, the latter remained after the combustion of the former, accumulating on the bars, or falling through the grate, escaped combustion. It might be said that the stowing qualities of this fuel deserve some consideration, being made up in the form of bricks; they are very convenient for packing, their specific gravity being as low as 1·15 to 1·302, but, unless carefully packed, they occupy even more space than ordinary fuel. During the last quarter-of-a-century, vast strides have been made to secure a greater efficiency of power for the amount of coal consumed, or, in other words, to secure the maximum amount of power at a minimum consumption of fuel.

The great improvement made in our steam engines and boilers have all been made with this object in view, and we have got thus far, that at the present time we are enabled to produce three-fold the power for a given quantity of coal than was the case 30 or 35 years ago, as the consumption of coal per I. H. P. was in 1855 nearly three times what it is at present, and we are now working at "pressures" so high, that I feel convinced were hardly thought practicable, if indeed, possible, by a majority not many years ago, and it is my opinion that ere we accomplish many further economic improvements in our engines, we will have to work to even higher pressures still, and therefore will in the first place have to look to our boilers, provided we are to keep to the same factor of safety, which I, for one, hope we do. Of late years great improvements have been made in the lighting of our great cities and towns, our factories, harbours, ships, and even our mines, both at home and abroad, by means of the electric light; but here again we are met face to face with the same problem as to power, and the means of obtaining the same, and, therefore, be the power either steam, gas, hot, or compressed air, the fact remains, and the necessary amount of coal has to be consumed. True, we achieve greater results, but, apparently, without coal nearly all our great inventions and improvements would be of little or no avail. On the other hand, it must be admitted that liquid fuel seems destined for a great future, and has already been adopted with great success in some instances, its use being rapidly increasing, seeing that we now possess a considerable number of ships, built specially for the carrying of petroleum in "bulk," indeed, the latest addition to the ships of this class being so adapted as to be enabled to carry liquid fuel in their present (coal) bunkers, evidently anticipating the probability of petroleum being the future fuel of our steamships. On a small scale it is already doing excellent service, the Messrs. YARROW having been very successful in its adoption as a fuel in some recently-build steam launches, giving remarkable economic results, and, lately, the vapour generated by heating petroleum spirit has been doing good service in the place of steam as the "prime mover." Nevertheless great improvements remain yet to be made ere liquid fuel can be so manipulated as to supersede "coal," even were the supply equal to the demand, but it cannot be denied Nature has already bestowed upon us another powerful heat-producing agent, it having excellent recommendations as such, also as a good luminant and lubricant. What more it may prove

If all Board of Trade requirements are not fully complied with, the factor may be increased

With cylindrical Boilers, when made of such material and construction as to comply with the Board of Trade, the factor 5—6 is allowed.

Tensile strength of the iron to be equal to 47,000lbs per square inch with the grain, and 10,000lbs. per square in. across the grain.

Boilers to be tested by hydraulic press to twice the working pressure, to the satisfaction and in presence of the Board's Surveyors

S.S. 'Petrolea, launched Nov. 23rd, 1889.

itself to be it would be hard to foresee, but, doubtless, many other good qualities will become developed when the liquid becomes more fully known.

> I consider myself justified in making this remark, seeing *vide* daily papers, that we have actually had ships put back to port being unable to proceed to sea, owing to the inferiority of the fuel supplied them.

To return to my subject, I must say with regard to coal, that my experience as an engineer has convinced me that the best coals, or coal of a fairly good quality, are the cheapest. No doubt it would be difficult to convey this idea to the uninitiated, or to those whom the price per ton is the only criterion adhered to, no allowance being made for the greater efficiency of the superior coal, and, indeed, no thought whatever as to the evil effect oftentimes to the boilers through the using of bad coal; leaks occur, which, if not serious in themselves, are of such a nature as to materially affect the efficiency of the boiler as a steam generator, to say nothing of the deterioration caused by the same, the excessive cooling down of some of its most vital parts, caused to a certain extent by the prolonged space of time that elapses, ere the fire, after having been cleaned out, is once more in a perfect (or as near that as can be obtained) state of combustion, and doing its portion of the useful work of the boiler, bearing in mind that, with inferior coal, this process has to be repeated as often as three and sometimes four to one as compared to the duty done by superior or indeed fairly good samples of fuel, and while this has been going on the speed of the engines has become reduced, a loss that cannot be regained, assuming that at all other periods of time you are developing all the power possible with the means at your disposal. Another object, which should not be overlooked when space on board ships has become so precious, is the greater amount of work done weight for weight with the superior, as compared to the inferior coal, and oftentimes (although this cannot be counted upon as a "constant") the space gained in stowing the same, which must be a considerable item in itself, more especially in some of our larger steamships running long distances, and without the facilities for coaling. Having described our coals, and given their average value from different localities, it now remains for me to say a few words regarding the same. Taking into consideration their stowing qualities, or the space occupied by a given weight, they may be said to vary greatly, even to the extent of 40, and, in some instances 60 per cent. Coals of equal evaporative power are known to vary as high as 18 to 20 per cent. in this respect, their specific gravity giving no reliable data as to their bulk or stowing qualities, as one variety may take up less space for a given weight than another, although the latter may be of a higher density, this being due to the structure or mechanical formation of the coal, and such coals as are of a loose structure, and therefore lacking in cohesive power, become greatly reduced in value, caused by breakage in handling, and by attrition caused by the motion of the ship, and therefore the selecting of coals giving the best results requires considerable thought and attention, seeing how they vary as to evaporative power, rate of evaporation, bulk, ash, &c. The state of the coal with regard to the moisture and exposure it has been subjected to previous to being put on board ship, has a considerable effect upon its economy also, as, although combustion may truly be said to be the chemical union of the coal with oxygen at a certain high temperature, it is equally true also that the "wasting away," or decay of coals, is simply a mild form of combustion, caused to a great extent by the action of the sun's rays and the rain absorbed by the coal; the water, becoming decomposed, gives forth its gases (hydrogen and oxygen), the oxygen uniting with the carbon of the coal, heat is generated and unless allowed the means to escape in its inception, will soon become spread throughout the mass, each particle conveying it from one to another; the excessive quantity of hydrogen contained in it, due to the added amount of water, causing it to burst forth into a blaze when air is admitted to it, or as soon as an attempt is made to subdue it, hence spontaneous combustion, which, if not discovered at its early stages soon developes itself into a form of combustion anything but "mild." Coals being subjected to high temperatures are very liable to the foregoing, more especially such as contain a high per-centage of sulphur or iron pyrites, which may readily be recognised from its "brass-like" appearance, the gases evolved during the changes that take place while the process of decay is going are also very dangerous. While considering the economy of different varieties of coal it will be found that while one is possessed of high evaporative power, and therefore rapid in its action in raising steam, another variety, superior in this respect, or having a low evaporative power, is still able to convert a greater quantity of water into steam, and, consequently, more valuable as a force producer.

The Oxygen necessary for complete combustion of 1 lb. of coal is contained in 12 lbs. of air, but in practice (*i.e.*, natural draught) twice that quantity is usually required. With forced draught 18 lbs. of air does the same work.

A compound of sulphur & iron, commonly called iron pyrites.

In conclusion, let me thank you, gentlemen, for the patient manner in which you have listened to the reading of my paper. My thanks are also due for the benefit derived from the perusal of a little work on coal mining by Professor W. W. Smyth, of the Royal School of Mines;

and also for much useful information from the reading of a work on the South Wales Coal Trade, by Charles Wilkins, Esq., F.G.S. Hoping that at least my efforts will be appreciated and of benefit to our younger members; for my own part I cannot say that I have attained my object, namely, the selection of the most economical fuel: as I have invariably found that coal which possessed pre-eminent qualities in one respect were sadly deficient in another, and, indeed, it would be difficult with the object in view, unless supplied with the price per ton, to compare with other data. Our advance as to future economy will, in my humble opinion, be derived not so much from enormously increased boiler pressure, but rather as to good circulation and perfect combustion, our boilers thereby becoming greater heat absorbents by virtue of a better system, which will embrace to a greater extent the heat of our "present" waste gases. Then our fast steam-ships will not be the beasts of burden, which, figuratively at least, they may be said to be at present, carrying little else other than their living freight of passengers and the amount of fuel to accomplish their journey. When this has been achieved, then we may proudly say that we are obtaining economic results, and justly claim to be manipulating in a thoroughly efficient manner that *black, brittle, inodorous,* and *unprepossessing substance* called "*Coal.*"

CHAIRMAN'S REMARKS.

(Mr. J. Macfarlane Gray.)

I think the members of the Institute ought to be proud that such a paper as this has been produced by one of our sea-going engineers. Papers like that by Mr. Sommerville, and this by Mr. Morgan are just what this Institute was designed to bring to light and to encourage. Mr. Morgan has given us the result of extensive reading and of much thought. I draw your attention to a numerical statement in the paper, one about which there is a serious misunderstanding. The author states that in one coal-field in Wales the available supply is still 54 billons of tons. Now, the word billion has two meanings, the one is a thousand times the other, and I am in doubt which is meant here. On the continent and also in America the names in numeration change every three figures, while in the works by British authors, the names change only every six figures after millions. I think it must be French billions which are meant in the paper.

Mr. S. C. SAGE'S Remarks.

I have listened with much interest to the able and instructive paper just read by Mr. Morgan, and respecting the subject of it, I may say that I have had to burn many kinds of coal during my experience, English, Welsh, Scotch, Australian, Chinese, Japanese, and Belgian, and the coal that in my opinion best fulfils the purpose of a steam generator for the class of ships that I have been accustomed to—in spite of the fact that it is bituminous, and not quite of so high a specific gravity as the best Welsh—is the best hard Yorkshire steam coal, as it keeps its power under exposure to heat much longer than Welsh, and does not disintegrate so rapidly.

I have also had experience of a Belgian patent fuel—the "Moncean Fontaine" Brand, which is, I believe, made from the coals out of a pit that are peculiarly fireable, and not by themselves available for steam generation. In consequence of this peculiarity the coal fresh from the pit is at once made up into blocks, and the result is that the consumption is in two ships that I can vouch for, the same as Welsh coals. The reason in my opinion why so little patent fuel is used in the English Mercantile Marine, is that it is too frequently made from small coal that has already lost its combustible properties, and very often through carelessness contains other and less combustible imgredients than coal and pitch. When you consider the stowage advantages of patent fuel, it seems to me indeed a wonder that a really good kind is not made and placed on the market for use in our steamers, it being a fact, I believe, that most of the patent fuel made in this country is exported.

Mr. J. H. THOMSON'S Remarks.

For my part I always prefer good South Wales coal for a long voyage, and I consider the advantages of patent fuel in bricks, as regards stowage are sometimes over estimated, as it is seldom that there is time to stow them in the bunkers of the regular merchant steam ship. There is a gentleman with us to-night, who has succeeded in solidifying petroleum, and then mixing it with coal by which means he produces a very good fuel, it will be very interesting if he will kindly give us some information on this new combination.

Mr. C. LUNGLEY'S Remarks.

I have listened with great pleasure to the interesting and instructive paper on "Coal" just read by Mr. Morgan.

Being myself interested in a patent fuel I followed him on that branch of the lecture very closely, and as MR. THOMSON has kindly alluded to my being the patentee of a new kind of fuel, I will, with your permission make a few remarks upon it, which must necessarily be brief, as I came here quite unprepared to speak.

My fuel, which I have described as "Solidified Petroleum Patent Fuel," contains as its name would imply solidified petroleum as its principal ingredient, with which other substances such as coal, sawdust, peat, and in fact almost any kind of vegetable refuse can be utilized.

As you are probably aware, it is no new thing to be able to solidify petroleum, but as far as I know no one as yet been able to apply heat to it when so solidified, without it again liquifying.

This I am happy to say I have been successful in accomplishing and therefore am now able to place before you a patent fuel which is far superior to any other at present in the market, and which will I think compare very favourably with the best kinds of coal now used for steaming purposes.

I intend to introduce it in the block-form as being the most convenient for handling and packing. The size will of course vary according to the quantity of oil used in each block.

As an intense and active heat can be instantly obtained from it, it will I am sure be especially suitable wherever rapidity in generating steam is of great importance, as for example, in the case of torpedo boats and swift cruisers.

The great saving of space attending its use would also be an undoubted advantage to such vessels.

Another of its many advantages is the small amount of smoke which it gives off as compared with other patent fuels, in fact little more than is produced by the coal which it contains.

I also find that there is little or no clinker left after burning.

When we think of the enormous vessels which are now built, and know what a large proportion of the space in them is required for the stowage of coal for steaming purposes, the advantage of using a fuel capable of doing the same amount of work that is now done by coal, and which would at the same time not occupy one half the space now perforce given up to the bunkers, is at once apparent and need not be enlarged upon.

I will not trespass further on your time, but will conclude by thanking you for the kind attention you have shown me, which encourages me to hope that at no very distant date I may have the pleasure of reading a paper before your society on "Solidified Petroleum Patent Fuel."

Mr. M. B. TAYLOR'S Remarks.

I have listened with great interest to Mr. Morgan's excellent paper, and consider the subject one of the greatest importance to us, as Marine Engineers, when we know what the item of coal expenditure means to our owners, and that it greatly depends upon the forethought and ability of the engineers in charge, for the economic and successful voyage of the ship in which he may be on board.

As a rule the engineer has no choice as to what class of coal he will take, other than what comes alongside, therefore it becomes his duty to do his very best in manipulating fire-bars and bridges, also to adopt the best method in working fires, to get the greatest result and efficiency from whatever class of coal he may require to use.

I fully concur with several other members who have spoken before me, in that Mr. Morgan's paper is of such interest, that a very useful paper could be written upon each of its several headings.

Of course, each of the gentlemen present have had considerable experience, with different kinds of coal, and evidently are partial to, or prefer, a certain class of coal. But I must say from my own experience, there are a great many considerations to be studied, such as length of voyage about to be undertaken, along with bunker space provided, and lasting quality of coal supplied; also capacity of boilers for having a good command of steam.

With easy steaming boilers we know that a slow burning coal would undoubtedly give the best results, while with boilers which are hard pressed for steam a quick burning flaming coal would be preferable, but very often it is impossible to carry sufficient of the latter for long voyages, such as that to Australia and New Zealand, by the Cape route.

Therefore (taking everything into consideration), I must say that (from my own experience) I must prefer good "Welsh" before any other class of coal, for its lasting and efficient qualities.

In our sea experience most of us have encountered the usual annoyance and detentions accompanying the cleaning of fires, with boilers short of steaming power, and I must here add my testimony to the benefit derived from the use of mechanical fire-bars for such boilers. I do not consider it the proper thing, that we should advocate any particular patent in our discussion here, unless the relative merits of such are the subject matter before us, so I will say mechanical bars generally.

But I think those working independently of the stokers are undoubtedly to be preferred. As to my experience with them, I have gone a voyage of forty-four days, and never cleaned a single fire, therefore avoiding all loss of revolutions and time, also the char usually thrown overboard with the ashes, and at the same time escaping injurious effects of cold air in furnaces, combustion chambers and tubes. I have found them very efficient with our British coal, but they are of even more value where you have a large percentage of ash, such as the Australian coal for which in my opinion they are specially adapted.

Our British coal is generally of excellent quality, and is suited for different purposes according to the locality obtained, that of Scotland for gas, of Durham for coke, and of South Wales for steam coal, varying of course in quality, according to the locality of mine, and very often in the same seam, where it is worked from.

As the subject of Mr. Morgan's paper is of such interest to us, and especially as we often draw our supplies from other countries when in foreign parts, I will give (with the Chairman's and Author's permission) a few approximate analyses of coal from the different districts of this and other countries, including some of our Colonies, selecting those which I consider most useful to us as Marine Engineers, and with a good percentage of fixed carbon.

I now conclude my remarks by complimenting MR. MORGAN on the manner in which his paper has been written and delivered.

COMPOSITION OF COALS.

	Water.	Volatile Hydro-Carbons	Fixed Carbon.	Ash.	Sulphur	Coke.
BRITISH ANTHRACITE.						
"Prollfaron" Colliery, Glamorganshire, nine foot seam ..	1·29	5·23	90·71	1·95	0·82	92·66
"Capel Ifan" Colliery, Caermarthenshire, ash red	1·25	3·69	92·10	1·20	1·06	94·00
BRITISH BITUMINIOUS NON-CAKING.						
"Bute" Pit, Horwain, Glamorganshire, ash light red ..	0·89	8·97	87·61	1·75	0·78	89·36
"Blaen Rhondda," upper four foot seam, flame smokeless, ash red	1·08	8·75	84·51	4·75	0·91	89·26
"Rushley Park" seam, St. Helens, Lancashire, slightly caking	3·23	30·37	60·50	5·00	0·90	68·5
South Staffordshire, "Ten yard coal," near Wolverhampton, ash light, bulky, and yellowish grey	11·29	31·11	56·18	1·03	0·39	57·21
BRITISH BITUMINIOUS CAKING COAL.						
"Dunraven" Colliery, Pontypridd, Glamorganshire, coke lustrous, firm and coherent, ash pinkish grey	0·78	15·81	78·26	3·40	1·75	82·66
"Duffryn Seam," Synvi, coke slightly swollen, ash greyish pink	0·87	21·45	73·00	3·92	0·76	76·92
"Best Arley" coal, near Bolton, Lancashire, coke firm and coherent, ash dark red ..	1·88	32·67	60·45	2·87	2·13	63·32
Northumberland, or Newcastle coal, "Bowden Close" ..	29·66		67·41	2·28	0·65	69·69
"West Hartley" Main ..	39·67		56·69	2·51	1·13	59·20
SCOTLAND.						
"Wellwood"	39·28		56·26	2·89	1·57	59·15
"Dalkeith" Coronation seam ..	46·12		50·40	3·10	0·38	53·50
Kilmarnoch, "Sherrington" ..	49·81		48·05	1·25	0·89	49·30

Coal from Various Sources.

	Water.	Volatile Hydro-Carbons	Fixed Carbon.	Ash.	Sulphur	Coke.
Vancouvers Island.						
Ash reddish brown	3·20	35·98	50·38	9·70	0·74	60·08
Chile.						
From near Coronel, 250 miles South of Valparaiso, coal, hard and black	3·82	34·62	50·49	10·07	1·00	60·56
Labuau.						
Labuau Coal Company, fine black colour, not unlike Wigan Cannel, contains particles and sometimes lumps of light brown resin, ash buff	6·10	37·50	54·25	1·85	0·30	56·10
Borneo.						
From near Sarawak, coal black with considerable lustre ash reddish yellow	48·69		47·00	3·60	0·71	50·60
Sumatra.						
From Vanti, coal, hard homogeneous, black lustrous, ash red	5·22	39·71	53·75	0·83	0·49	54·58
India.						
From Hyderbad, coal, black firm (ash buff)	9·12	35·33	45·19	9·55	0·81	54·74
China.						
From "Tientsin" Anthracite, ash gray and sandy ..	2·90	7·14	70·55	1[illegible]·00	0·41	89·55
"From hills" to the West of Peking, coal burns clearly and without smoke, equal in all respects to the best Welsh ..	0·53	15·60	77·65	5·82	0·40	83·49
Japan.						
From "Takasima," in Nifou, red	1·50	40·38	53·50	4·51	0·11	58·01
"Matzie," Provence of Hizen ..	2·08	41·96	41·70	11·00	3·26	52·70
Queensland, Australia.						
"Watertown" Mine, Ipswich..	25·2		62·00	12·8		74·8
"Barreme" Mine, Maryborough	31·5		64·00	4·5		68·5
Tasmania.						
Gardener's Bay Coal Mining Association	2·9	15·7	63·5	17·9		81·4
New Zealand.						
"Jenkin's Mine, Nelson ..	14·40	13·46	62·40	1·80		
"Kaitangata" Mine, Otago ..	19·61	37·25	39·41	3·73		

Coal from Various Sources—*Continued.*

	Water.	Volatile Hydro-Carbons	Fixed Carbon.	Ash.	Sulphur	Coke.
"Malvern Hill," Canterbury ..	4·15	19·89	68·54	7·42		
New South Wales—Northern District. The coals of this district are all very similar in appearance, being firm, and show a bright laminated structure with traces of mineral charcoal; they are all highly bituminous, cake strongly in the fire, and yield bright, hard, sonorous coke.						
Newcastle Wallsend Colliery (ash, reddish)	2·29	34·21	58·60	4·28	0·62	62·88
Greta Colliery (ash, buff coloured)	2·25	39·21	54·41	2·72	1·41	57·13
Southern District. The coals of this district are characterised by a somewhat dull colour, but are firm and strong; they may be classed as free-burning bituminous coal, as although they do not cake in the fire, they are readily coked in an oven.						
"Mount Keenbla" Colliery, ash white	1·50	19·74	67·18	10·72	0·86	
"Illawarra" Coal Company, ash grey	0·70	22·04	68·08	8·76	0·42	76·84
"Coal Cliff" Colliery, ash grey	1·61	19·68	68·08	10·28	0·35	78·36
"Bulli" Colliery, ash grey ..	0·65	21·65	65·86	11·28	0·74	76·96

Mr. W. W. WILSON'S Remarks.

Mr. Sage tells us that he has found that in some ships under his supervision, Belgian Patent Fuel has been found to give better results than average Welsh Coal, but this does not coincide with my experience of it.

A few months ago a sample of this fuel was brought from Antwerp in one of our ships, and I was deputed to make a comparative trial in one of our donkey boilers, between it and some Harris' Deep Navigation Welsh Coal. This trial was conducted as carefully as possible, under perfectly similar conditions, the coal being weighed and water measured in both cases in a similar manner.

The actual result as to the amount of water evaporated per pound of coal, was found to be 24% better for the Welsh Coal than for the Patent Fuel.

The Patent Fuel was much slower to get properly lit up, and required a little more working to give anything like a fair result, but, after the fire was properly under weigh and steam raised, the result as to rate of evaporation was nearer equal, although it was still in favour of the coal. I cannot therefore agree with Mr. Sage in his assertions.

Mr. F. W. SHOREY'S Remarks.

Our Chairman appears determined that everyone present shall say something, but I do not know that I can add much to what has already been said.

I was pleased to hear one of the gentlemen present speak of the new patent fuel, which is made from solidified petroleum mixed with sawdust, for it is the first time one has heard of such fuel.

We know there are a number of patent fuels in the market, but the question is, how do they compare in price against coal. Doubtless there are many combustile substances that would generate a given quantity of water into steam much quicker than coal. What we want to arrive at is, which is the most economical kind of fuel to use? For instance, supposing one hundred-weight of coal costing one shilling would generate 200 lbs. of water into steam, and one hundred-weight of patent fuel costing two shillings would generate 300 lbs. of water into steam, in the same time, then from a commercial point of view, the saving would be in favour of coal.

Until their relative values have been proved, one would not like to venture an opinion, time and testing will soon show which is the best for loading and stowing our bunkers with.

Mr. W. WHITE'S Remarks.

I have followed Mr. Morgan's interesting and exhaustive paper on 'Coal,' with much pleasure, and I do not know that after the lucid and able manner in which he has dealt with his subject, I can add anything to what as been already said.

I noticed that when he touched upon the question of patent fuels, he stated that the evaporative power of the best kinds, was from 10 to 12 lbs. of water per 1 lb. of fuel.

I may here mention that I was present at the testing of Mr. Lungley's Patent Fuel some two months ago. After experiencing some little difficulty at first, which, as Mr. Thomson who had kindly undertaken the experiments, I am sure will readily agree with me, was entirely owing to our ignorance of the proper way in which to treat it, we obtained as may be seen by referring to our log, the excellent result of 16·83 lbs. of water evaporated per pound of fuel.

This result I need hardly say, places Mr. Lungley's Patent Fuel far ahead of all others at present in use, and in my opinion warrants his assertion, that it is the coming fuel for steaming purposes.

Mr. ROBERT BRUCE'S Remarks.

One has difficulty in speaking from a critical point of view on this paper. It suggests thoughts and ideas, however, on many subjects of importance to Marine Engineers, and, which may take a correct form in some future paper.

The Author has confined his remarks to Welsh and English Coal, no doubt because his experience has been obtained in dealing with these coals, but it is in my recollection that some of the Scotch coal-fields, produce a very superior anthracite coal. As yet, however, the Admiralty officials have not given any report upon the recent tests, but, it is a fact that with a proper draught, the Scotch Smokeless Navigation Steam Coal is as smokeless as any other anthracite coal in use, and its evaporative power is certainly *high.*

I give an analysis by a very competent authority of the No. 1 Steam Coal from Longrigg Collieries, Slamanan:—

Volatile Matters	Gas, Tar, etc. ..	17·21	19·92
	Sulphur	·33	
	Water at 212° F.	2·38	
Coke	Fixed Carbon ..	76·82	80·08
	Sulphur	·41	
	Ash	2·85	
			100·00

Coke per ton of Coals, 1794 lbs., or 16cwts. 0qrs. 2lbs.
Specific Gravity, 1·304
Weight of a cubic foot in lbs., 81
Space required for storage, cubic feet per ton, 41½
Heating or evaporative power .... *Practical*, in pounds of water, at 212° F., evaporated by combustion of 1 lb. of coal } 10·52 lbs.

This analysis will compare very favourably with the best Welsh Coal, and it is established by the experience of large Shipowners and Engineers, who have used the Longrigg Navigation Coal regularly, the former at sea in ordinary work, and the latter for special purposes of trial trips.

I believe I am correct in stating that there is no condition of anthracite coal, which Scotland cannot produce, and it is to be hoped that ere long those in authority at the Admiralty, will see their way to adopt the Scotch Navigation Smokeless Coal. In Engineering and Shipbuilding, Scotland is in the van, and there is in the face of the above facts, no reason why she should not at least be in the front rank for the supply of the propelling commodity.

PREFACE.

THE LANGTHORNE ROOMS,

BROADWAY, STRATFORD, E.

April 15*th*, 1890.

A Meeting of the Institute was held this evening, presided over by Mr. G. W. MANUEL (President).

Two Papers were read in the course of the evening. One by MR. JOSEPH THOMAS (Honorary Member), the other by MR. G. W. BUCKWELL (Member)

The subject-matter of the former Paper is of great interest as showing the precision with which work such as is described can be undertaken and carried into effect.

Several questions were asked by members at the conclusion of the Paper, the replies given by MR. THOMAS are appended.

The Paper by MR. BUCKWELL deals with results tabulated from experiments tried in cross-channel steamers, under varying conditions of weather.

The remarks which followed on the reading of MR. BUCKWELL'S Paper and his reply will be found after the Paper by Mr. THOMAS.

The tables, as well as the notes on the various trips are very interesting, the deductions made and the conclusions drawn from them admit of further analyzing with the additional information given by MR. BUCKWELL in his reply. It would be interesting to have a companion Paper with a series of results taken from screw steamers of different proportions, in varying conditions as to weather, draft, revolutions, &c.

The current half of Session 1890-91 will terminate with a Paper on Ventilation, by MR. G. D. HOEY (Honorary Member), on Tuesday, May 27th; the second half will commence on or about Monday, 1st September.

JAS. ADAMSON,

Honorary Secretary.