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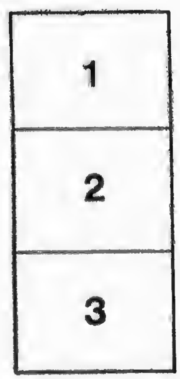

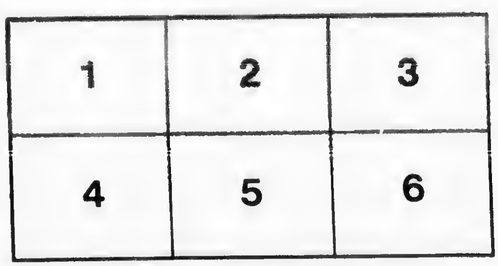

THE
COAL TRADE OF BRITISH AMERICA,

WITH

RESEARCHES

ON THE

CHARACTERS AND PRACTICAL VALUES

OF

AMERICAN AND FOREIGN COALS.

BY WALTER R. JOHNSON,
CIVIL AND MINING ENGINEER AND CHEMIST, WASHINGTON, D. C.

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PREFACE.

A wide spread interest is involved in supplying mineral coal to the markets of the world, and for the multiplied uses of modern civilization.

While employed, as in former times, almost solely for domestic consumption, its value was little understood, except by those who inhabited countries exhausted of other fuel, or subjected to the severity of a rigorous climate. But since the discovery of its great advantages in many metallurgic processes—since its vast utility for the production of steam became known, and especially since the practicability of navigating the ocean by steam was discovered—COAL has assumed for all nations, in all climates, an importance which, a century ago, had not entered into the conceptions of men.

As an article of commerce it is not even in our own time estimated as its real importance should seem to warrant.

Of other bulky articles in which commerce is carried on, manufacturing industry commonly returns to us some part of the identical substance which it had received as a raw material, something visible and tangible of which our senses can still take cognizance—something which arrests our attention and challenges notice or admiration, recalling our minds to the original condition of those materials by which our wants are supplied or our senses gratified. Thus the garments we wear constantly remind us of the flax, cotton, silk, wool, hemp, fur, down, leather, &c., which may chance to enter into their composition. The ornaments of our persons, our dwellings, or our furniture, recall the precious metals, the gems, the paints, the dye stuffs, employed in the decorative arts. The needle which embroiders, the lancet which punctures, the hair spring which so delicately balances and regulates—no less than the ploughshare which turns our soil, the anchor which moors our battle ship, or the chain, or the monster tube which bear us safely, in mid air, over the chasm of Niagara, or the strait of Menai—admonishes us, at every step, of the obligations which we owe to the metal of which they are all composed. The cereal grains return from the manufacturer in the form of flour, bread, starch, or fermented liquors, all indicating the materials to which they owe their origin.

On the contrary, the material which furnishes *motive power*, is either wholly overlooked, or soon forgotten. The evanescent movement of machinery, which transports materials from place to place, or transforms them from one shape to another, leaves nothing visible or tangible on which our senses can dwell. The corn, it is true, has been ground, but no trace of the grinding power is seen in the bread, or the starch. Cotton, flax, and wool have been spun; iron and steel forged; copper, zinc, gold, and silver melted; drugs and dye stuffs pulverized; but they show no external signs of the coal, or fire, or steam, by the agency of which these transformations have been effected. We see around us the fabrics which were ordered from Manchester a short month ago, and we handle the yellow bars and dust which left San Francisco within the last forty days; but of the miraculous power which has winged their way hither, we see no traces on the surface, and are prone to forget the useful labor of the black masses by which we are so largely benefitted. A piratical act has been committed, or a hostile invasion is attempted or intended, and the arm of our national power is stretched forth to thwart the designs of wicked men, but without the aid of this dark, forbidding mineral, the interposition of that arm would be all too tardy—its efforts altogether unavailing.

It is but a few years since foreigners began to understand that coal existed extensively in our country. The quiet manner in which the development of a few detached coal fields near the Atlantic border had been carried on, gave the impression, that if coal existed at all in the United States, it must be small in quantity, and of doubtful quality, and, therefore, the less said about it the better. Since, however, we have begun to make known by official and authoritative documents the numerous varieties and the high qualities of American coals, the attention of capitalists has been turned in the direction of our coal fields, and money has flowed into the country to be invested in lands and mining operations, and in the rail roads and canals intended for conveying coal, or in ocean steam ships to be propelled by American coals, or in manufactories to be actuated by the same material.

To make known our mineral districts and the value of their products, is, therefore, one of the most effective means of securing the investment of whatever capital may be necessary, not only for their development, but also for the construction of the public works which facilitate their transportation. The Chesapeake and Ohio Canal has remained many years incomplete, and might probably have continued so much longer, had it not been clearly established that its extension would bring it to a coal field, affording fuel of the most valuable kind, and in the greatest abundance.

In respect to the comparison which we have instituted between the results of experiments on American and foreign coals, it may be stated, that their purpose is to make the American reader acquainted with a more extensive series than our own researches had been able to embrace of the celebrated coals of England, Scotland, Ireland, and Wales.

It is creditable to our own Government that it took the initiative in researches respecting so important a subject as the value of coals. Should it continue the same to completion, both the interest and the credit of the nation will doubtless be largely benefitted; but without such completion it must stand in the attitude of one listlessly neglecting the advantages of his own position.

One highly important question to be practically determined by further experiments on American coals, especially on those of the West, is their relation in value to the several kinds of wood for which, both in steamboats and on shore, they are likely to be extensively substituted. The necessity of this branch of inquiry being carried on where the wood can be procured in all the conditions in which it is habitually used, would indicate that the experiments should be performed at the West, where both the woods and the coals, still awaiting trials, are mostly found.

Following the discussion of the able and important Report on British coals, will be found accounts of certain characters and habitudes of coal in general, regarded as a mineral body.

The present volume embraces, moreover, accounts of analyses, made by the writer, on American and foreign coals not embraced in his report to the Navy Department in 1844, and of certain coal fields visited and explored, with a view to the extent and character of their minerals. The most recent of these explorations is that of the limited but exceedingly interesting and valuable coal field found in the centre of North Carolina, affording a curious illustration of the causes which have operated to produce the various kinds of coal ranging from highly bituminous, through semi-bituminous, and anthracite, to perfect plumbago.

In regard to the information contained in these pages respecting the New Brunswick, Nova Scotia, and Cape Breton coal fields, the writer takes great pleasure in acknowledging his obligations to Richard Brown, Esq., of Sydney, to Henry Poole, Esq., of Albion mines; to J. W. Dawson, Esq., of Pictou; to Joseph Smith, Esq., of Amherst; to Moses H. Perley, Esq., of St. Johns; and to Messrs. Archibald, Bracket, and Andrews, American Consuls at Sydney, Pictou, and St. Johns, respectively, for much valuable assistance. He would also testify to the uniform courtesy and kindness with which, throughout his tour in the Provinces, he was treated by all with whom it was his good fortune to become acquainted, or from whom he had occasion to make inquiries.

WASHINGTON, *December* 20, 1849.

COAL MINES AND COAL TRADE

OF

NEW BRUNSWICK AND NOVA SCOTIA.

The following statements of facts and observations contain the result of a personal examination of the several mining districts of the Northeastern British Provinces made during the summer of 1846. The coals of those provinces having been tested by the author, during his research on American coals, and the coal fields from which they were derived, having been to some extent made known by the labors of Messrs. Jackson and Alger, Dr. Gesner, Richard Brown, Esq., and Mr. Lyell, the writer felt much interest and curiosity in making a comparison between the advantages and capabilities of those mines, and many which he had professionally examined in various parts of the United States.

These statements are believed to possess an interest for all who are concerned in the ownership or management of mines in the United States, and with this view are submitted to the public, together with the accompanying documents, which will, perhaps, in some degree, enable the American reader to estimate the value of those treasures of mineral fuel which yet lie unexplored in various parts of our extended territory. The citations may show with what fostering care the authorities of the provinces, as well as of the parent country, have watched over the mining interests of Nova Scotia, and of the enterprising Association by whose skill and perseverance so valuable a trade has been secured in the United States.

I.—Situation of the Mining Districts.

The principal mining districts where operations are at present carried on, are those of Pictou and Sydney. The former is situated in the northeastern part of the peninsula of Nova Scotia, one hundred and six miles by the road from Halifax, and eighty miles by the course of navigation, in a due west direction from the northern entrance of the gut of Canso. The latter is on the eastern part of the Island of Cape Breton, distant from Pictou, by the usual route of travel, about one hundred and eighty miles.

As to the extent of these two districts I may observe, that the entire area af the field in which the coal-bearing strata of Pictou occur, has been estimated by Messrs. Brown and Smith at *twenty-eight square miles*, but owing to numerous faults and dislocations, the space actually available for mining purposes is far less than that. Indeed the only seam now worked, is, by Mr. Brown's estimate, *known* to underlie not more than three square miles.

The Sydney district is much more extensive. It reaches from the north side of Cow Bay to the northerly division of Mirê Bay, to the northern part of Boulardrie Island, a distance of thirty-five miles. An average of four or five miles in width may be assigned to this district. But this includes numerous bays and indentations of the coast.

From the authority just cited it appears that, after deducting the water surface, this coal field contains "*one hundred and twenty square miles of land containing workable veins of coal.*" The most important mines in this district are situated about nine miles distant, in a direction nearly due north from the ancient town of Sydney.

About nine-and-a-half miles east-southeast from the above mines, and near the entrance of Bridgeport basin, at the head of Lingan Bay, are the Bridgeport mines, not now in operation.

About three-and-three-fourths miles in a west-northwest course from the Sydney mines, are those of Little Bras d'Or, situated on the channel of that name. At this locality, also, operations are for the present suspended.

At the south end of this coal field, nearly on a line with the above three collieries, and on the northern side of Cow Bay, is an ancient mine said to have been worked by the French for the supply of Louisburg, while they held possession of this island some ninety or one hundred years ago.

Besides the above districts, there is a third near the northernmost part of the peninsula of Nova Scotia, a few miles from the isthmus connecting it with New Brunswick. In this district two small collieries have been commenced—one on the shore of the Cumberland Basin, the easterly division of the west branch of the Bay of Fundy, at a place well known as the "South Joggins," about ninety miles from St. John, and about one hundred and fifty from Eastport, the border town of the State of Maine; the other, seventeen-and-a-half miles inland, from the same point at the Joggins, in a southeasterly direction, at a place called Spring Hill.

Thus we find in Nova Scotia, including Cape Breton, seven points at which the mining of coal for commercial purposes has been more or less extensively prosecuted.

In the Province of New Brunswick are several small coal mining establishments, five or six of which are on the waters or tributaries of Grand Lake, which opens into the St. John's river by a navigable passage called the Jemseg. Near the head waters of the Oromuctoo river, another tributary of the St. John's, falling into it from the southwest, ten miles below Fredericton, is an opening from which coal has been taken to supply blacksmiths in the neighborhood.

The mines on Grand Lake are, by the course of navigation, from sixty to seventy miles above the city of St. John. Coasting vessels of one hundred tons burden may approach within a few hundred yards of the drifts by which they are worked.

On New Castle river, Salmon river, and Coal Creek, are openings where a few hundred chaldrons are annually mined. St. John and Eastport are probably the most distant markets to which this coal has hitherto found its way.

The breadth of the coal formation in this part of New Brunswick is by the course of the St. John's river, from the mouth of the Washadamoak to that of the Keswick, a few miles above Frederickton, something more than fifty miles. But neither in this nor in any other part of New Brunswick, could I learn that workable seams of more than twenty or thirty inches in thickness have yet been opened. I saw none over twenty-two inches thick, but was informed that on Salmon river a drift had been carried four hundred feet in a bed of twenty-four or twenty-five inches. About eight miles from one of the mines on Grand Lake, an exploration was made some years ago, by boring to the depth of four hundred and three feet, but nothing was discovered of more importance than the seam of twenty-two inches. This bed, where it is worked on the borders of the lake, is nearly horizontal, and its covering very light, not generally exceeding ten or fifteen feet in thickness.

Besides the above districts, in which active mining operations have been carried on, it may not be improper to refer to other portions of both provinces which are known to contain coal.

1. On Inhabitants river, a little to the east of the Gut of Canso, in the Island of Cape Breton, extending some miles up that river, and believed to continue southeastwardly to its opening into Inhabitants Bay, is a narrow coal district, in

which one or two openings, to supply coal for domestic use, have been made by the owners of the soil. According to my estimate, the district, at the part traversed, has a breadth of about three miles; and it may, in all probability, be from seven to ten miles in length. This is inferred from information received relative to points where coal has actually been opened.

2. The northwest part of the Island of Cape Breton, extending from Port Hood, on St. George's Bay, along the coast northeastwardly to Mabou, and thence to Broad Cove and Chimney Corner, contains a coal field, of which the limits inland, are as yet undetermined, and in which the thickness and value of the seams are yet to be ascertained. The coal is represented to crop out in the steep bluffs of the sea coast, as in other parts of this island, and to have been occasionally procured for use by the inhabitants.* The length of this district is about forty miles.

3. Thin seams of coal are found within fourteen miles of the town of Truro, on the road from Pictou to that place. One bed of two-and-a-half feet thickness has been worked by a resident on the ground, at a depth of thirty feet. The coal was judged to be of inferior quality.

4. A seam, said to be five feet in thickness, of impure coal and slate intermixed, has been opened between the Debert and Folly rivers, on the north side of Cobequid Bay, sixteen or seventeen miles north-northwest from Truro. The pit being filled with water at the time of my visit, the character of the seam could be judged of only by information from the propietor, and the nature of the materials thrown out. They concurred in proving that the seam, thus far pursued, had not developed any thing to warrant extensive operations.

5. In the county of Westmoreland, New Brunswick, adjoining Nova Scotia, is an irregular district of country containing coal measures, the limits of which have been described with some minuteness by Dr. Abraham Gesner, who made a Geological survey of that province. He has referred to points where coal has been discovered on Trout Creek, Pollet River, Coverdale River, and other tributaries of the Petit Codiac. On passing through this district, from Amherst to St. John, I was

* In relation to this coal field, Richard Brown, Esq., in his paper on the Geology of Cape Breton, (Quarterly Journal of Geology, No. 2, May, 1845,) remarks that, "On the western shore of Cape Breton the millstone grit commences at the northern end of the Gut of Canso, and it underlies the coal measures which extend in a narrow belt from Port Hood to Chimney Corner, near Margarie. I have not visited this part of the Island, but am credibly informed that valuable seams of coal exist at both extremities of this coal field."

unable to learn that any openings of good workable coal have yet been made.

As the researches, by boring, made by Moses H. Perley, Esq., on Salmon River, in 1840, above referred to, are cited at large by Dr. Gesner, I made inquiries of that gentleman, relative to the success of any investigations since that period, in discovering valuable seams of coal, but was assured that, to the best of his knowledge, no bed containing more than twenty or twenty-two inches of *good coal* is yet known to exist in New Brunswick. Mr. Perley, however, among other facts which he obligingly communicated, stated that a wealthy English capitalist had recently purchased some forty thousand acres of land near Bathurst, on the Bay of Chaleurs, with a view to mining operations in *coal* and other minerals. Should any beds worth working be found at that locality, they could scarcely compete in the American markets with the coals of Nova Scotia, unless a ship canal should afford a communication between the Gulf of St. Lawrence and the Bay of Fundy.

II.—Position of Coal Seams in respect to Water Level.

1. The lowest part of the present workings at Pictou are four hundred and fifty-one feet, vertically, below the surface of the ground, and four hundred and twenty-seven feet below tide water, distant about half a mile.

2. At Sydney, the greatest depth of working below the surface is three hundred and fifteen feet, and below tide level two hundred and twenty-five feet, distant about one-third of a mile.

3. At Bridgeport, Little Bras d'Or, and the South Joggins, the mines have thus far been drained by horizontal drifts. At the last mentioned point, the coal is also carried out on the same level, and put on board of vessels, laid up at high tide, directly at the mouth of the drift.

4. At Spring Hill, the workings have hitherto been carried only along the out-crop, and the water has been kept out by hand pumps. But at this, as well as at the three preceding localities, vertical pits, descending below water level, will doubtless be resorted to in case of any considerable extension of the works.

III.—Thickness and Inclination of Beds.

At Pictou, the great seam is twelve feet thick, with an inclination to N. 41° E. of 17°. It is worked in long, parallel level boards eighteen feet wide, by means of four pits, along the line of the main "board gate," and from the bottom of each pit runs a horse gate or road in opposite directions along the level or *strike* of the bed. Each road takes the coal, not only of its own excavation, but also that of the five boards next above it, brought in by branch roads cut obliquely upward through the walls of coal left between the boards.

At Sydney, the thickness of the bed is six feet, inclined in an angle of about 7°, at the *northern* end, toward the N. 65° E., and at the *southern* end, to the N. 80° E., showing a slight curvature of the stratification. This bed is worked by driving oblique headways from the main horse gate or level, rising in an angle of about 3°, and *breaking off* or turning out from this with the rooms sixteen and a half feet wide, and leaving pillars of the same breadth.

At Bridgeport, the thickness of seam is nine feet, divided into three equal portions by two plies of slate, at first only a few inches thick, but which on pursuing the bed to some distance became much heavier, and still further on had grown to several feet, rendering it impossible longer to work the coal in a single level. The inclination is *one in fourteen*, or from 4 to 5°, and the available breast or "*rise*" 1,200 to 1,500 feet.

At Little Bras d'Or, the thickness is four feet, and the inclination in a northeasterly direction 7°. The coal is raised by a horse gin.

At the South Joggins, the thickest bed is four feet. It dips to the S. 28 W. in an angle of 23°.

At Spring Hill, the bed is said to be fifteen feet thick, but only eleven feet are regarded as workable. The inclination is to the N. 30 W. 31°.

IV.—Situation with respect to Navigable Waters.

The *Pictou* mines are six miles by railroad from the loading ground at the mouth of East river, which is three miles by the course of the channel above the town of Pictou. This railroad has an inclination towards the harbor of one foot per mile. It is laid with edge rails, and cost, together with three locomotives, $280,000. Except at a passing place two miles below the mines, the road is laid with but a single track. The locomotives at present in use are able to make about five trips each per day over the road, conveying about ninety tons of coal in a train of thirty cars. Though really on navigable waters, the loading ground is not reached with ease and safety at all stages of tide and states of weather. For greater security and dispatch, many avail themselves of the services of a steam-tug owned by the Association, for which a rate of towage according to tonnage is demanded. This, as well as pilotage, light money, consular fees, and port charges, becomes a charge upon the *freight*, and ultimately upon the coal.

The Sydney mines are within three-eighths of a mile of the sea shore, but as the coast is there too much exposed, and the water too shallow for large vessels, a railroad about three miles in length* has been constructed to reach a suitable loading ground, at a point just within the mouth of Sydney harbor, called the "Bar," where vessels ride in safety at all times during the shipping season.

The Bridgeport mines are almost directly on the sea shore, at which is an old wharf formerly used by the colliers. But a railroad one and three-fourth miles in length, mostly constructed on a natural embankment of sand, now connects them with the loading ground at Bridgeport basin. Want of time compelled me to forego a visit to these mines.

The Little Bras d'Or mine is but a few hundred feet from the channel of that name and about four miles above its mouth. The loading ground has but a single shute, and is adapted only to small vessels. But little coal has yet been taken from this mine, and that cheifly for smiths' use.

Preparations are made, and an engine house is erected, for sinking a new pit during the ensuing winter, on a seam of coal four feet eight inches thick, which underlies the six feet seam now worked at Sydney colliery, by a vertical distance estimated by Mr. Brown at three hundred and ninety feet. This pit is to be near the line of the level part of the railroad, and but two miles from the loading ground. The coal will probably be reached at a depth of less than three hundred feet. The seam is said to be free from slate and of a very pure quality.

At the South Joggins district, the pit proposed to be sunk for working the four feet seam will, it is supposed, be one and

*This road is a somewhat interrupted or broken line, employing various kinds of power. The coal put upon the road from the pit's mouth, first descends an inclined plane four hundred or five hundred feet long, drawing up ballast cars, which in turn descend and draw up the empty cars. It is then taken up by stationary power, over an inclined plane, twelve hundred feet in length, to the commencement of a level section of road one and one-fourth mile in length, over which it is drawn by horse power. It then arrives at the head of a descending plane one and a fourth mile in length, with an inclination of thirty-six feet to the mile, over which the cars descend by gravity, accompanied by horses riding in appropriate cars to take back those which are empty. It finally passes over a self acting inclined plane, one thousand feet in length, with an inclination of *one* in *thirty* or one hundred and seventy-six feet per mile, drawing up the empty cars, and thus arrives at a wharf on which are the loading shutes, sixteen feet above high water level. Transportation costs more here than at Pictou.

a half miles from the loading ground near the mouth of the river Hebert, about three miles above Minudie.

To bring the coal of Spring Hill to tide-water, either on the Macan basin or at the mouth of the Hebert, will require a railroad of more than twelve, and in the latter case, probably sixteen miles in length. Could a trade of forty or fifty thousand chaldrons per annum be relied on, the Association would doubtless feel warranted in at once incurring the expense of this road.

From all the above statements it may be inferred that few mining districts in any country present facilities for reaching navigable tide waters, equal to those of Nova Scotia and especially of Cape Breton.

The distance of Pictou and Sydney from Boston is nearly the same, or about six hundred and twenty-five miles; that from Minudie to Boston will not exceed four hundred and fifty miles, which is rather less than the distance from Boston to Philadelphia.

V.—Cost of Mining, Transporting, and Loading Coal.

At *Pictou*, coal is mined by the cubic yard, the miner finding his own lights and powder. To the end of July last, I learned that the price paid per cubic yard, excavated in the regular *boards*, eighteen feet wide and twelve high, was twenty-six and two-third cents; in headings only nine feet high, thirty-one and two-third cents; in seven feet gangways, thirty-three and a half cents; and for passages or openings of still less heighth, thirty-six and two-third cents. Far the greatest part of the coal is paid for at the first named rate.

From *two* cubic yards excavated is obtained, on an average, one chaldron of coarse marketable coal, and one-fifth of a chaldron of slack. Of the former the *Pictou chaldron* weighs 1.575, and of the latter 1.75 tons. Consequently 1.92 tons of the mixed coals cost fifty-three and a third cents.

At the first	of the above rates	the *ton*	costs	28.8	cents.
"	second	"	"	33.0	"
"	third	"	"	34.9	"
"	fourth	"	"	38.2	"

Considering the large quantity mined at the lowest rate, it is probably very near the truth to regard the whole as costing thirty cents per ton. This charge covers the expense of putting the *coal* into skips, as well as the slate and stone, of which one or two thin plies exist in the bed of coal.

To convey the skips to the pit's bottom, now about sixteen hundred feet in each direction from the workings, one boy at forty cents per day, and one horse costing thirty-seven and a half cents per day, may be sufficient for each two cutters. They send up the produce of four and a half cubic yards each per day, or 8,6 tons, showing an expense of nine cents per ton for this part of the mine charges, which is doubtless a *large* allowance. Propping may cost two cents per ton; firemen of upcast pit, watchmen, and road cleaners, two cents per ton; salaries of overseer and two assistants or "oversmen," engineers, and the requisite firemen at pit's mouth, three and a half cents per ton; tools, materials, and sundries, eight cents; salaries to managers, bailiffs, and clerks, nine cents. These items, which of course I offer only as approximations to the cost from such data and observations as I could obtain, will increase the cost from thirty cents on the skips, to sixty-three and a half cents per ton of 2,240 lbs. at the pit's mouth. The calculations are predicated on a business of about ninety thousand tons, or sixty thousand Pictou chaldrons annually.

Screening and loading cost eight and a half cents per chaldron, or 5.4 cents per *ton*, each laborer screening and filling eight chaldrons per day for sixty-eight cents wages.

Transportation and loading on ship board, independent of trimming in the hold, (which is at the expense of the ship,) cost about five cents per ton. In this service are employed three locomotives, of which two only are running while the third has its turn in the "hospital." The number of road cars used is one hundred and fifty-seven, of which thirty constitute a train. In a full day's work in midsummer, each locomotive makes five trips, or performs a service equal to hauling ninety tons thirty miles, over a descent of one foot in a mile, and taking back the empty cars. These locomotives have six driving wheels, with vertical cylinders; the fire, of bitumenous coal, at one end of the boiler, and the engine at the other. Including an extra return flue, they cost eight thousand dollars each. A small passenger car accompanies every train, paying its own way from the fares collected by the conductor.

The above estimates, amounting, for current expense, to seventy-five cents per ton on board, do not include the repair of road, wear and tear of machinery, interest on capital, or rent and royalty to the Government. If ten cents per ton be added for *repairs*, it ought, in my judgment, to cover every expense of that nature, whether to road, cars, locomotives, or other machinery. The very slow rate of travel secures the road and its furniture from much deterioration. The use of flat wire ropes, at the winding pits, renders the cost of renewal very light. With this addition the cost is eighty-five cents per ton.

At *Sydney*, the mining of coal is paid for at so much by the tub, sent to the bank. The "tubs" are sheet iron boxes thirty-seven and a half inches long, thirty inches wide, and twenty-six and a half inches deep, and contain, when even full, sixteen and a quarter cubic feet, and when heaped, as they usually come from the pit, are computed and called at the mines *nine bushels*, but they actually contain, when even full, 10.3, and when heaped, fully eleven *coal* bushels.

In one end of the workings, the price paid is thirteen and a third cents, and in the other, owing to greater difficulty in working, fifteen cents per tub; consequently, the average cost of a tub is fourteen and a sixth cents or 1.28 cents per bushel. Eight of these tubs make a car load, or "New Castle chaldron," as taken by the Association. When first taken from the mines, one ninth part of the whole is separated by the screens in the state of slack, so that nine tubs must be taken out to afford one car load, and will cost one dollar and twenty-seven and a half cents for cutting and filling into tubs. As the slack coal of this colliery is unsaleable, its cost becomes chargeable on that part of the coal which is actually shipped. Three-fifths of all the coal mined during the year is laid upon the bank, while shipping is suspended. On this portion of coal the amount of slack is double of that taken directly from the pit; consequently ten and two-sevenths tubs must have come from the mine to afford a car load, after some months of repose upon the banks. The cost of this number of tubs is $1 45.5. Hence the average cost of mining a car load through the year's operations is $1 38.3, and that of one gross ton, forty-five and a half cents.

In this mine a single main road is made to answer for all the transportation to the pit's bottom, one winding engine takes out the whole of the coal, a much less number of under ground drivers and horses is required; nearly thirty per cent. of the matter cut, being in the state of slack, is thrown into the gobbings, instead of the whole being drawn up as at Pictou. For these reasons, I conceive that the remaining "mine charges," besides cutting and filling into tubs, may be at least eight cents per ton less than above calculated for that place. This would bring it to the bank for seventy-one cents per ton.

Screening and loading into cars costs but half as much at Sydney as at Pictou, but the transportation costs proportionally more. The two are computed by Mr. Brown to cost nine pence currency (fifteen cents) per chaldron, or say ten cents per ton. This, with an equal allowance for wear and tear, brings the expense on board, independent of interest and royalty, to ninety-one cents per ton.

It is evident that many of the charges against the ton of coal, as at present mined, will diminish with the extension of business. Thus the salaries of resident manager, viewers, oversmen, engineers, firemen, clerks, and various other persons permanently attached to the mines, will remain very nearly the same as at present, even though the supposed amount of business should be doubled.

From a report of a committee of the House of Assembly of Nova Scotia, dated March 2d, 1839, it appears that the working charges at the Albion Mines, (Pictou,) in September, 1838, were as follows:

Pit charges - -	£0 s 8 d $7\frac{1}{2}$	\$1 $72\frac{1}{2}$
Sundries - -	10	$16\frac{2}{3}$
Materials - - -	4	$6\frac{2}{3}$
Salaries - - -	8	$13\frac{1}{3}$
Carriage - - -	$9\frac{1}{2}$	$15\frac{5}{6}$
	s 11 d $2\frac{3}{4}$	\$2 25

exclusive of duty, interest, or wear and tear.

The report does not state explicitly on what amount of coal the above charges were computed; but as the Association are in the practice of reducing their returns to New Castle chaldrons, I suppose these charges to refer to that measure, which, being in fact 3.15 tons, will give the cost of the above items on one ton, 71.4 cents. Unless operations were then conducted on a vastly more expensive scale than at present, I cannot suppose them to refer to the chaldron by which coal is now *sold* in Pictou. At sixty thousand chaldrons per annum, there will be taken out every day during three hundred working days of the year, two hundred chaldrons, which was, very nearly, the quantity daily extracted both at Pictou and at Sydney at the time of my visit. The cost of mining near the head of Grand Lake, in New Brunswick, is from seventy-five to eighty cents per chaldron, or from fifty to fifty-three cents per ton.

VI.—Wages earned by Miners and others.

At Pictou, I was informed by Henry Poole, Esq., the resident manager of the works, that miners cut four and a half cubic yards per day, which, at twenty-six and two-thirds cents, the lowest price per cubic yard, gave him \$1 20.

At Sydney, a miner sends up from one end of the workings eight tubs per day at fifteen cents each; and from the other end, nine tubs at thirteen and a third cents per tub. Both, therefore, earn the same wages as the miner at Pictou, viz: $1 20 cents per day.

At both places miners pay for their own lights and powder, which cost them about ten cents per day.

For the services of the resident physician, miners with families pay forty cents, and those without families twenty-six and two-thirds cents per month, or on the average thirty-three and a third cents per month, which for twenty-five working days is one and a third cents per day.

One ninety-sixth part of their clear earnings, or 1.1 cent per day, is reserved for the services of school teachers.

After these three deductions, the clear daily earnings are $1 07.6 per day, equal to $322 30 per annum. Adding the free ues of a house worth $320, and a supply of fuel, which must cost not *less* than $20 for the season, the annual amount of his receipts may be set down at $366 30.

Laborers above ground, both at Pictou and Sydney, receive from sixty-five to seventy cents per day.

During my visit to Nova Scotia, an attempt was made on the part of the operatives, both miners and laborers, at Pictou, to obtain an advance of wages. The Association granted to the latter an increase of five or six cents per day; but they declined altogether to increase the rates allowed for mining.

Of *salaries*, the total amount paid at the Albion mines (Pictou) in 1838 was, according to the report above cited, $7,625. The document from which this information is derived does not specify the distribution of this sum; but as there were raised and sold in that year 32,584 chaldrons of coal (Pictou measure) it is evident that every *ton* became chargeable on this account with 14.9 cents. On 90,000 tons it would have been 8.46 cents.

The mine overseers receive, both at Pictou and Sydney, $720 per annum, besides house and fuel. The "oversmen" or assistant overseers $360 per annum, with like privileges. The train conductors on the road receive $36 per month, engineers from eighty cents to one hundred cents per day.

It was stated to me that a former agent received a salary of £1,000 currency, or $4,000 per annum, but that this had been somewhat reduced. I suppose, however, that gentlemen as accomplished and well qualified to act in that capacity as those whom I had the pleasure of meeting at Sydney, Pictou, and Amherst, would, if perquisites be included, scarcely be offered less than the sum above named.

VII.—Origin and stability of Mining population.

A great part of the miners in Nova Scotia are from Scotland; some from the north of England, and a few from other parts of Britain. Small numbers of native Nova Scotians are engaged about the mines, chiefly as fillers and other laborers above ground.

The arrangements of the Association for the comfortable accommodation of miners, for their supply of fuel, for the medical attendance of themselves and families, and for the education of their children, together with their prompt monthly payment of all dues in *cash*, have probably secured as much stability and permanency among this class of their operatives as are to be found among that class of persons in any other mining district. I met with a few miners who had worked in our anthracite regions, and in other parts of the United States, but such instances appeared to be rare, and migration from the Provinces to the States more frequent than in the reverse direction.

The Association, I understand, give little encouragement to return, to those who have once left their works for the United States, and decline to employ such, unless in urgent want of hands. I was several times asked by laboring men, miners, and others, if I thought working people could get a "chance" now "in the States,'" meaning of course *good wages*.

I may add, that in the present state of our mining interests, I did not feel warranted in answering such inquiries in a way to excite undue hopes, or to induce a desire of change among those who were already obtaining a comfortable livelihood.

The *climate* of Nova Scotia does not, probably, differ so widely from that of their native country as of itself to urge the Scotish miners to seek a more southern region. A few emigrants are understood to arrive every year from Great Britain, but I did not learn that much effort was made by the Association to introduce them. A native mining population is gradually growing up on the spot, superseding, in a degree, the necessity for a foreign supply.

VIII.—Length of the Season for shipping Coal.

The shipping season at Pictou, commences, sometimes, as early as the first of May, but, in general, the trade cannot be said to be established before the fifteenth of that month. On the average of seasons, it terminates by the middle of November.

This statement is made on the concurrent testimony of navigators, residents at Pictou, and merchants engaged in the trade in Boston.

The length of the season is consequently *six months.* Later than the middle of November, the occurrence of sudden and violent storms, the prevalence of fogs, and the freezing up of the harbor, oppose serious obstacles to navigation. When winter has fairly set in, the formation of ice on the Northumberland Straits, and its complete jamming up in the Gut of Canso, render the passage of ships physically impossible. At Sydney, the harbor opens on the broad Atlantic, and is accessible both earlier and later than that of Pictou. From the middle of April to the middle of December vessels *may* enter and depart; but *seven months* will generally be found the practical shipping time.

In point of fact, the active season at Sydney commences much later than at Pictou. This is mainly owing to the more general application of Sydney coal to domestic purposes than to that of manufactures. The season for its consumption begins only with the approach of winter, while the uses to which Pictou coal is applied, namely, manufacturing and steam navigation, extend more equally throughout the year.

Should mining operations be carried on extensively near the head of the Bay of Fundy, a season not probably exceeding six and a half months could be relied on for shipping. The storms of spring and the fogs of autumn, with the enormous tides of all seasons, (rising sixty or seventy feet near the head of that Bay,) conspire to render early and late navigation uncertain and hazardous. The distance, it is true, to the ports of the United States, would be much less than from either of the other points, and in favorable seasons might involve fewer delays than from Pictou or Sydney.

Insurance on vessels navigating the Gulf of St. Lawrence is effected for the *season*, terminating generally with the first of October.

IX.—Price of Coal for Home Consumption, and for Export.

At Pictou, the *large coal* is sold by the small quantity, or by single cargoes, at $3 30 per chaldron. When one thousand or more chaldrons are taken, a deduction of thirty cents per chaldron is made at the end of the year.

The *slack* or fine coal is delivered on board at $1 50 per chaldron, with a deduction of three per cent for cash payment.

By the weights above stated, of the chaldrons of coarse and fine coal respectively, the former costs $1 90.4, and the latter 83.1 cents per *ton* on board.

At Sydney, the coarse coal alone is sent to market. It is put on board at $3 60 for the small quantity, or single cargo, and at $3 30 where one thousand or more chaldrons are taken by a single customer during the season. As this coal weighs 1.53 tons per chaldron, the *ton* costs by retail $2 37, and by wholesale $2 16.

X.—Weight of a chaldron at Pictou and Sydney.

The weight of a chaldron, Nova Scotia measure, has been derived from several independent sources, including different methods of determination. Among them are, 1st. The measurement of the cars in which the coal is transported to the loading ground, and the weighing of given bulks of the coal in different states and sizes of lumps, from both mining districts; 2d. Weighing of the car loads, by the former agent of the Pictou mines; 3d. A comparison between the weight and number of chaldrons, delivered at the custom houses, and the number of chaldrons put on board at the mines; 4th. A statement by the general agent of the mining association, of the relation in price between a *chaldron* and a *ton*.

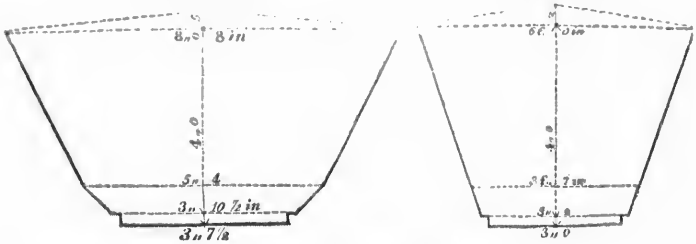
1. In 1843, I found by actual weighing, in a box containing two cubic feet, that the average weight of a cubic foot in the marketable state is 52.08 pounds, and by carefully measuring the cars both at Pictou and Sydney, that they hold, when heaped to the height of five inches in the centre, 136.64 cubic feet.* This gives the weight of one chaldron three thousand five hundred and fifty-eight pounds.

2. In 1835, Joseph Smith, Esq., found by the average of twenty-four trials of the weight of a car load, that the chaldron weighed three thousand four hundred any ninety-seven pounds.

* The following sketches exhibit the form and dimensions of the cars on a scale of one-quarter of an inch to the foot, together with the amount of heaping by the average of a great number of observations. They are called two chaldron cars.

Sections of car bodies used at Pictou and Sydney.

Longitudinal. Transverse.



Contents, when heaped five inches, 136.64 cubic feet.

3. In 1838, he weighed twenty car loads, from the average of which, the weight of a chaldron is three thousand four hundred and sixty pounds. The cars weighed, held *one* chaldron each.

4. Captain Brouard, of the Pictou and Boston Packet, taking on board ninety chaldrons in Pictou, delivers one hundred and ten in Wareham, and, as in the latter place, the chaldron weighs two thousand nine hundred and forty pounds, (as in Boston,) in the former, it must have weighed three thousand six hundred and five.

5. In 1846, the Matilda's cargo, in Pictou, measured one hundred and thirty-two chaldrons when put on board, and one hundred and sixty-one were delivered in Wareham, showing the chaldron, in Pictou, to have weighed three thousand six hundred and one pounds.

6. In 1843, Samuel Cunard, Esq. stated in his letter to Lord Faulkland, hereto appended, that at the rate of eighteen shillings currency per *chaldron*, the cost of a *ton* of Pictou coal would be nine shillings and six pence sterling, or the weights are as $2.33\frac{1}{3}$ to 3.60, which makes the chaldron weigh three thousand four hundred and fifty-six pounds.

The above six independent determinations give an average weight of *three thousand five hundred and twenty-eight pounds* to the Pictou chaldron.

I will only add that, in 1843, Mr. Joseph Hall, measurer in the Boston Custom House, measured and weighed eighty cargoes of Pictou coal, by which he ascertained that the average weight of a chaldron, in *Boston*, is *two thousand nine hundred and forty pounds;* and that Thomas Tremlett, Esq., of that city, who deals extensively in Nova Scotia coals, handed me a memorandum of which the following is a copy:

"Pictou coal overruns in measure, on the average, twenty per cent. so that one hundred chaldrons at Pictou, will measure out, United States measure, one hundred and twenty chaldrons."

From these two statements resulting from operations on the largest scale, we have the proportion 100:2,940::120:3,528, giving the weight of the Pictou chaldron precisely equal to the average of the six preceding calculations.

In 1843 and 1844, Mr. Hall measured, at Boston, one hundred and forty-three cargoes of *Sydney* coal, and the mean result of the whole gives the weight of a Boston chaldron of that coal two thousand eight hundred and sixty-two pounds. This gives the weight of the chaldron at Sydney three thousand four hundred and thirty-four pounds or 1.53 tons. Mr.

Smith found the slack coal at Pictou to weigh three thousand nine hundred and thirty-five pounds per chaldron.

XI.—Use to which the Fine or "Slack" Coal is applied.

The slack coal at Pictou is readily disposed of for blacksmiths' use at the price above stated, it being preferred to the coarse coal for their purposes. A ply of superior purity falls, in great part, into slack in mining, and this, doubtless, causes it to be in request. Vessels of three hundred or four hundred tons burden were receiving cargoes of it at the time I left Pictou. As I have computed above, that the total cost of mining and delivering on board is eighty-five cents, and as the rate at which the slack is sold is eighty-three cents per ton, it is evident that this part of the product of the mine nearly pays its own cost, a great advantage, when compared with many mining districts where it is either wholly wasted or becomes a source of positive expense. Adding thirty per cent. for duty, and one dollar fifty-seven cents per ton freight to Boston, the importer there gets it at 83.1+24.9+1.57=$2 65 per ton delivered.

At Sydney *one*-ninth part of all the coal which goes directly from the pit to be prepared for the loading ground, is as above mentioned, in the state of slack; and also *two*-ninths of that which is taken from the bank. In passing over screens with three-quarter inch gratings, the slack is about equally divided into *nut coal* for the domestic use of miners and others about the works, and *dust*, which being received in a separate car, is conveyed to the "duff heap," where it is allowed to take fire spontaneously. This it does in the space of a few months, and in the course of eight or ten years becomes wholly consumed. The duff heap or ridge of each year is kept separate. Those of 1838 and '39 were pointed out to me in a still smouldering condition; but the small amount of ashes left from the heaps entirely extinct, indicated the small quantity of earthy impurity (five or five and a half per cent) in the coal; while the deep red color proved the presence of no inconsiderable quantity of oxide of iron, resulting from the decomposition of the sulphuret which had caused its spontaneous ignition. *Pictou* coal leaves from twelve to thirteen per cent. of earthy residue.

XII.—Freights to Boston and other American Ports.

The freight on a *Boston* chaldron, weighing as above, two thousand nine hundred and forty pounds is stated by Mr.

Tremlett at $2 75; or on the gross ton $2 09.5. During a part of the present season, freights have been taken as low as $2 50 per chaldron, or 1 90.4 per ton.

From *Sydney* to Boston, the freights are very nearly the same as from Pictou. The only instances particularly ascertained were at the former rate, or $2 50 per chaldron of two thousand eight hundred and sixty-two pounds, equal to $1 95.7 per ton.

From Pictou to *Providence* freights have varied from $2 87½ to $3 00 per *chaldron at the latter place*, and as the chaldron there in use is the London chaldron of twenty-five and a half cwt. or two thousand eight hundred and six pounds, the freight per gross ton is $2 39.6; showing that at $2 75 to Boston and $3 00 per chaldron to Providence, the *ton* costs 30.1 cents more freight to the latter place than to the former.

From Pictou to *New York* also, freights have been about $3 00 per chaldron; but as the chaldron there weighs but two thousand five hundred pounds, the gross ton costs $2 69, or 59½ cents more than to Boston, and 29.4 cents more than to Providence.

XIII.—Difference of Freights at Boston between Nova Scotia and Philadelphia, and its causes.

From a careful examination of the bill of lading book of a respectable commercial house, largely engaged in the shipment of coal from Philadelphia to Boston and to Providence, I have ascertained that the average of freight paid for two hundred and forty-five cargoes to Boston, during the seven years from 1839 to 1845 inclusive, was at the rate of $1 74.8 per gross ton; and that on two hundred and eleven cargoes sent to Providence, they paid $1 45.3 per ton, showing the difference between those two places to be twenty-nine and a half cents per ton; which, as will be seen, is almost identical with the difference in the Pictou rates for the two places.

From another house extensively engaged in exporting coal from this city, I learn that they paid, in 1844, $1 71½, and in 1845, $1 79 per ton, freight to Boston, or $1 75¼ as the mean of the two years. In 1845, they paid $1 24 to New York.

During the present season, freights have been something lower than the average of several preceding years, having varied from $1 40 to $2 18 per ton. But as the close of the season generally finds them considerably above the average of the year, the final average may still approximate those above given. Hence we may institute for the above three ports, the following comparison, viz, per ton:

	To Boston.	To Providence.	To New York.
Freight from Pictou is	$2 09.5	$2 39.6	$2 69
" from Philadelphia	1 75	1 45.3	1 24
Differences	34½	94.3	$1 45

The first and most obvious reason for the difference of freight between Boston and Philadelphia, and Boston and Pictou, is the greater *distance* of the two latter places. The distances are nearly in the ratio of thirty-eight to twenty-eight, or in miles as six hundred and twenty-five to four hundred and eighty-seven.

The second cause is mainly but not altogether dependent on the first. It is the greater length of time required to make the round trip, in the one case, than in the other. Thus, from Pictou to Boston and back, trips have been made by four vessels, viz: the Grey Hound, the Pique, the Brothers, and the Elizabeth, of which the average duration was thirty-nine days.

From the records of one of our large coal companies, I find that twenty-four round trips, between Philadelphia and Boston, occupied in all seven hundred and eight days, or twenty-nine and a half days each trip. These were made by eleven different vessels.

In the months of July, August, and September, of the present year, twenty-five single passages were made by different vessels from Pictou to Boston in three hundred and seventy-one days, or, on an average, each *passage* took 14.7 days.

Eight days are probably a full average allowance of time to come from Boston to Philadelphia during the same season of the year.

By vessels exclusively engaged in the coal trade, the above time of twenty-nine and a half days is more than an average duration of a round trip from Philadelphia to Boston. During the favorable season, trips are often made in from twenty to twenty-six days. Should steam propellers be employed as colliers, the absolute, but I apprehend not the relative duration of trips, will be affected by their general adoption.

The third cause why freights are higher at Pictou than at Philadelphia is the shorter season for shipping. While six months, at Pictou, are all that can be safely counted on, from eight to eight and a half months may be generally found available at Philadelphia.

A fourth cause is, that while Pictou has but little trade except in coal, Philadelphia has an extensive commerce in other articles rendering vessels often very abundant. Thus, while vessels habitually engaged in the West India trade are withdrawn, during the hurricane season, from the tropical seas, instead of remaining, as in former times, idle at our wharves, they take coal freights to the North and return in time to resume their usual routes as soon as the dangerous period is past. Vessels which bring return freights, doubtless make longer trips than if they came in ballast, and were confined to the coal trade. But they can afford to take coal freights at lower rates than would otherwise be obtained for them.

A fifth reason, but one which is connected with the duration of the round trip, is the fact that, *under existing arrangements*, considerable detention is liable to occur at Pictou during the active season, owing to a want of facilities for despatching vessels, especially those of the larger class. Only seven vessels, of all classes, can there be loading at the same time; and of that number, only two can be of the larger size. Five of the berths have a depth of water sufficient only for the smaller craft. At Sydney only three vessels can load at a time.

At Richmond, above this city, I am informed by J. Tucker, Esq., President of the Reading Railroad Company, that it is *possible* for seventy-five vessels to be loaded at the same time, though a much less number is generally found at the berths.

When twenty-five or thirty vessels are at Pictou together, the detention, after they announce themselves "*ready*," and before they are admitted to the berths, is sometimes eight or ten days, while at Philadelphia it seldom exceeds half that time. It is true that, as there are at Pictou but two kinds of coal, "*coarse*" and "*slack*," there is not the detention at the shutes, which results from a vessel's waiting at the Richmond wharves till a sufficient quantity of the particular kind of coal which she has been ordered to take on board, can arrive by railroad to the particular house to which she may have been consigned. I may here add that, between the first and the twelfth of August last, eight passages from *Sydney* to Boston took an average of thirteen days, and that five passages from Pictou, in the same period, took exactly the same number of days each.

From Pictou to *Fall River*, I may also state that, commencing with the first of June last, the bark E. Churchill made three round trips in one hundred and eleven days, or took thirty-seven days per trip. Captain Jones, of the Bark Lucretia, who has been three years in the coal trade between Pictou and *Providence*, stated to me that he had been able to make no more than four trips during the season of six months, in which the navigation remains practicable and safe. Five and a half or six weeks may be sufficient time for a trip, but a *fifth* trip cannot be ventured upon at so late a season as would have arrived after completing the *four*.

XIV.—Number and Class of Vessels employed in the Coal trade.

To the obliging attention of Luther Bracket, Esq., Americar Consul at Pictou, I am indebted for some interesting facts relative to the American tonnage employed in the Pictou trade, and to the increase in number and size of vessels during the present season, (1846.)

The first arrival of American vessels for coal, in 1846, was on the twenty-first of May. From that time the arrivals were as follows, viz:

In the month of May, nine; June, thirteen; July, thirty-nine; August, fifty-seven; to sixteenth of September, twenty-three.—Total in a hundred and nineteen days, one hundred and forty one. Of this number, two were ships; sixteen barks; eighty-one brigs; forty-two schooners, one hundred and forty one.

In the early part of August there arrived at Boston eleven vessels, mostly British, laden with coal, bringing an aggregate of seven hundred and ninety-seven chaldrons, or an average of seventy-two chaldrons per cargo. Between July twenty-seventh and August twelvth, twenty-seven vessels of the United States, received an aggregate of four thousand and one chaldrons, Pictou measure, or one hundred and forty-eight chaldrons each. Between August twelfth and twenty-ninth, twenty-seven vessels received in all five thousand two hundred and forty-six chaldrons, or one hundred and fifty-seven chaldrons per cargo. Between August twenty-ninth and September twelfth, twenty-three vessels took three thousand seven hundred and eleven chaldrons, being one hundred and sixty-one chaldrons per cargo. Not included in the preceding number of vessels, there had arrived previous to September sixteenth, one ship with a tonnage of three hundred and twenty-one; six barks averaging three hundred and seventeen tons; and four brigs of one hundred and seventy-four tons each. Several of these had come directly from Europe, in ballast, where they had been chartered, as was understood, by the Association, to carry coal to the United States, with a view of being stored under the recent Warehousing act.

Hence it appears that, with the increased briskness of the trade, observed since the act to repeal the existing tariff was passed, the size of vessels employed in it has been progressively and pretty rapidly increasing.

The number of cargoes of coal exported from Pictou in American bottoms, for a number of years past, as furnished by the authentic records of the American Consulate at that place, has been as follows:

In 1839,	237 cargoes.		In 1843,	71 cargoes.	
1840,	107 "		1844,	53 "	
1841,	199 "	to September 1,	1845,	44* "	
1842,	140 "	and to August 25,	1846,	110 "	

XV.—Importation of Nova Scotia and other Coals into the United States.

With a view to present authentic information as to the extent and value of the coal trade of the British Provinces with this country, both absolutely, and as compared with the trade in the same article from other parts of the world, the following statements have, at my request, been obligingly furnished by the Register of the Treasury.

It appears from the figures, that, in 1848, out of one hundred and ninety-six thousand two hundred and fifty tons of coal imported, one hundred and fifty-three thousand one hundred and twenty-two tons, or seventy-eight per cent. came from the British North American Provinces, at a cost of $312,295.

It also appears that, since 1843, the importations of coal, from all quarters, have increased from forty-one thousand one hundred and sixty-three to one hundred and ninety-six thousand two hundred and fifty-one tons, or the increase is three hundred and seventy-six per cent. over the former quantity; while from the British North American Provinces alone, the augmentation has been from thirteen thousand one hundred and sighty-five tons, in 1843, to one hundred ond fifty-three thousand one hundredand twenty-two in 1848, or the increase is one thousand and sixty-one, or say *one thousand and sixty-one per cent.* The modification of the American tariff, in 1846, the release of the Mining Association, as above stated, from all but a nominal rent for Crown dues, the passage of our Warehousing act, which enables

* The records of the last part of this year were carried to Washington by the late Consul, where he died, and that portion of the account is, therefore, wanting. There is, no doubt, a great increase in the trade this year, over the last.

the importers to store their coal and await favorable turns of the market for bringing it forward, together with the favorable action of the British Government, in granting a favorable charter of incorporation to the Association, and using its influence to settle all controversies between it and other claimants to the Cape Breton Mines—all these acts concurrently performed on the two sides of the Atlantic, have evidently given a vitality and energy to the mining operations in Nova Scotia, which, without such a combination of favoring circumstances, they could scarcely have expected to attain.

Statement, exhibiting the quantity and value of Coal imported under the tariff of 1842 *and* 1846, *together with the amount of duty which accrued on the same, prepared under resolution of the House of Representatives, of the* 14*th December,* 1848.

Period of importation.	Coal Imported.		Rate of duty.	Duties.
	Tons.	Value.		
From 1st Oct. 1842, to 30th June, '43	41,163	116,312	1 75 per ton	$72,035 25
Year ending 30th June, 1844 -	87,073	236,963	"	152,377 75
Year ending 30th June, 1845 -	85,774	223,919	"	150,108 00
Year ending 30th June, 1846 -	156,853	378,597	"	274,492 75
From July 1, to 30th Nov. 1846 -	65,272	157,636	"	114,226 00
From Dec. 1, 1846, to June 30, 1847	82,749	213,349	30 per cent.	64,004 70
Year ending 30th June, 1848 -	196,251	461,140	"	138,342 00

Coal Imported into the United States from 1843, to

Years ending.	COAL IMPORTED FROM											
	England.		Scotland.		Ireland.		British N. American Colonies.		Other Places.		Total.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
30th June, 1843	25,072	$78,210	1,606	$4,272	451	$1,436	13,185	$28,734	846	$3,660	41,163	$116,312
1844	32,637	110,691	1,688	3,860	558	2,027	51,196	115,906	742	3,437	87,073	236,963
1845	26,004	96,427	1,062	2,869	228	422	58,297	122,975	275	1,226	85,776	223,919
1846	57,903	173,290	1,457	3,243	24	63	95,330	195,452	2,139	6,549	156,853	378,697
1847	51,149	163,041	2,577	7,582	1,308	4,336	92,186	194,173	801	1,853	148,021	370,985
1848	39,685	138,768	884	2,136	1,789	4,885	153,122	312,294	771	3,057	196,251	461,140

Treasury Department,
Register's Office, *July* 9, 1848.

XVI.—Facilities for increasing Mining Operations.

It is probable that, by increasing the force at present employed, the Pictou mines might send out about fifty per cent. more coal than is at present mined per day. I observed that one of the four winding pits was used only to convey persons to and from the works, though capable of being employed in the same manner as the other three. This pit is intended to serve the upper tier of *boards*, which are as yet carried right and left to a considerably less distance than those in the deeper part of the mine. It was, doubtless, sound policy to work the lower boards forward faster than the upper, on account of the greater facility which this arrangement gives for getting rid of the fire damp, so abundant in that part of the works, and because it holds in reserve a large body of coal which can at any time be relied upon to meet an increased demand. It also stands, in some degree, in the place of a stock of coal upon the bank, to hold in check any unreasonable demand on the part of laborers, as it might, if necessary, be let out and mined by contract at very reasonable rates. Should any accident occur to the pumps, or any unusual influx of water take place, the temporary abandonment of the lowest level would not, necessarily, suspend mining operations in the upper board.

Besides filling all the boards, it would be possible to work with two turns of hands, and greatly to increase the quantity of coal extracted; but, as a permanent arrangement, this would, doubtless, be objectionable, and would involve immediately considerable permanent outlays for accommodations to miners.

A proof tunnel has been driven nine hundred and thirty feet across the Albion measures, cutting several underlying seams, thinner than the one now worked. Some of these, from three and a half to seven feet thick, may be found profitable in working. I did not learn that any active operation on these beds is at present contemplated. I suppose the present works may, if urged, send forth ninety thousand chaldrons, or one hundred and thirty-five thousand tons next year. Railroad and loading facilities must be considerably increased to get this quantity *on board* in six months of the shipping season.

The Sydney mines, worked by the present pit, could probably furnish sixty or seventy thousand chaldrons, if in using the winding pit, recourse be had to two cages on each rope instead of one, for which I perceived provision was being made at the time of my visit. The new pit at Sydney, just commenced on the underlying bed above-mentioned, may probably not send to market a large quantity of coal during the next season, but will be ready to supply, perhaps, twenty thousand chaldrons within two years from this time. The operations at Bridgeport, and at Little Bras d'Or, may be resumed at any time when the prospect of a sufficient market in the United States shall seem to warrant the enlargement of a supply from that quarter.

The examinations in progress on the Bay of Fundy will probably lead during the next year to the opening of mines of capacity to furnish annually twenty thousand chaldrons of coal.

The much larger expenditure which would be required to bring the more important Spring Hill seam into activity, will doubtless induce the Association to proceed with due deliberation in that quarter, as all their hopes of a market depend on retaining and improving their present advantages and facilities for competing with American coals in the markets of the United States. Even the neighboring province of New Brunswick, situated on the opposite side of the Bay, would not become to any considerable extent a customer of the Mining Association of Nova Scotia, both because that province has mines of its own, and because its immense timber trade brings annually to St. John a vast number of vessels from England in *ballast*. As this costs from twenty-five to fifty cents per ton, besides the expense of taking in and discharging, it will, as often as possible, be substituted by English coal, provided the latter can be sold in St. John at a trifling advance on the price and export duty at Liverpool. If a certainty of obtaining immediately a market for fifty thousand chaldrons per annum were felt by the Association, I learned that they would proceed at once with works on the Spring Hill seam.

XVII.—Nova Scotia Coals compared with Anthracite.

During my experiments at Washington in 1843, I made trial of *two* samples of Pictou, *one* of Sydney coals, and *eight* of Pennsylvania anthracites. Pictou coal was burned for six days, during which were consumed 6,116½ pounds, evaporating 46,212 pounds of water from initial temperature, which, being reduced to the standard temperature of 212°, gave 8.455 pounds of water evaporated by one pound of coal.

Of Sydney coal, I burned in two days 1,601⅛ pounds, evaporating from initial temperature 11,325 pounds of water, which, being reduced in like manner to 212°, gives 7.99 parts of water evaporated by one of coal.*

The burning of eight samples of anthracite occupied thirty-one days, during which 31,696 pounds were consumed, and 276,070 pounds of water evaporated, giving, when reduced to standard temperature, an average of 9.565 pounds of water to one of coal. Hence, making anthracite the standard, we have the relative efficiences as follows:

Anthracite, - - - - - - -	100
Pictou coal, - - - - - - -	88.4
Sydney " - - - - - - - -	83.4

I have seen a published statement to the effect that a sugar refiner had, in 1843, made trials of Lehigh, Beaver Meadow, and Lackawanna anthracite, obtaining a mean of 9.19 pounds of water evaporated by one pound of anthracite; and also of Pictou and Sydney coals, obtaining only 4.47 pounds of steam for one of those coals. I hesitate not to say that this latter number is wholly unworthy of reliance. I have been informed that the trial referred to was made with the *bituminous coals* under a simple cylindrical boiler without return flues, or any means of economizing the heat, while the *anthracites* were burned under an improved boiler of the best construction. If this was really the unfair mode of treating the two kinds of fuel, it is easy to account for the difference, but it will not be easy to persuade any one who understands the subject, to rely on the results thus obtained as any standards of comparison.† No one, I presume, would pretend that less steam would be obtained by Pictou coal than by an equal weight of *pine wood*. And yet by a very careful experiment, I evaporated 4.69 pounds of water, from 212°, by the consumption of one pound of that material.

Assuming the correctness of the data above given, it will be easy to institute comparisons of value, and to determine what ought to be the price of the one when that of the other is given.

*From examining the coal in all parts of the Sydney seam *now worked*, I am fully satisfied that the sample sent to Washington in 1843, of which specimens still remain in my possession, was not taken from that bed. Its foliated structure, firm texture, and little liability to fall into slack, ally it much more nearly to the splent and cannel coals. From samples which I have seen and used from Bridgeport, I am disposed to think it came from that place, and not from the Sydney colliery.

†Note. Feb. 4, 1847. I have this day been again informed, by a gentleman of Boston, that the experiments were in fact made in the manner I have indicated, by the sugar refiner in question. Yet these *results* have been paraded in the newspapers of Philadelphia as data for computing the relative value of coals!

Thus at \$3 per chaldron in Pictou, the price of one gross ton is - - - - - - - - -	\$1 90.4
At 30 per cent, the *duty* is - - - - - - -	57
And at \$2 75 per chaldron, the *freight* on one ton will be - - - - - - - - - -	2 09.5
	4 56.9

Or say \$4 57. Hence \$4 57 $\times \frac{100}{88.4}$ = \$5 17 ought to be the contemporaneous price of a ton of anthracite. But as at Boston the Pictou coal is sold not by the gross ton, but by the chaldron of 2,940 pounds, while anthracite is sold by the ton of 2,000 pounds, it is proper, in order to decide in cases which have occurred and been referred to in the prices current of the day, to compare together the relative values of these two quantities. The comparison shows that at \$4 57 per *ton*, Pictou coal is \$6 00 per chaldron; the gross ton of anthracite \$5 17; and the ton of 2,000 pounds ought to command at the same rate \$4 61.6.

Should anthracite be put on board at Philadelphia at \$3 00 per *gross ton*, and pay \$1 75 per ton freight, the *ton of* 2,000 *pounds* would cost in Boston \$4 24. The value of 2,000 pounds of Pictou coal would *then* be $\frac{88.4}{100} \times$ \$4 24 = \$3 75, and a chaldron of 2,940 pounds would at the same rate cost \$3 75 $\times \frac{2940}{2000}$ = \$5 51¼. From this number, if we take \$2 75, the price of freight on the Boston chaldron, from Pictou, there is left \$2 76½ to cover the *cost* and *duty*. The latter being supposed thirty per cent., the former will be \$2 11, at which rate the *Pictou* chaldron would cost \$2 11 $\times \frac{3528}{2940}$ = \$2 53.2 or about forty-seven cents per chaldron less than the present selling rates.

Again, as we have seen that at the present selling price in Pictou, anthracite is worth \$5 17 per gross ton in Boston, deducting freight, \$1 75, it is worth \$3 42 *on board*, in Philadelphia.

An impression appears to have prevailed, that in our Eastern cities, Nova Scotia coal has borne a price higher than its relative value would warrant. The above method of determination will prove whether the supposition be correct. Thus the Boston Courier of September 21, 1846, gives the price of

Pictou coal per chaldron, new duty, -	\$5 75 a 6 00
Schuylkill, white ash, per *ton*, - -	5 75 a 6 00
Schuylkill, red ash, " - - - -	6 00 a 6 25

Making the average for anthracite \$6 00 per ton of 2,000 lbs.
Do. for Pictou 5 87½ per chal. of 2,940 lbs.

As the 2,000 pounds anthracite are equal in heating power to $\frac{100}{88.4}\times 2{,}000=2{,}260$ pounds of Pictou coal, the price of 2,000 pounds of anthracite ought to have been to that of a chaldron of Pictou coal as 2,260 to 2,940, or as $4 52 to $5 87½. This proves that the Nova Scotia coal was sold much lower than the anthracite, the latter being $1 48 above its relative value.* Nova Scotia then *undersold* Philadelphia.

Again: The New York Shipping and Commercial List of of September 16 quotes Pictou and Sydney at $6 00 to $6 50 per chaldron, and anthracite $5 00 to $6 00 per 2,000 pounds.

The average superiority of anthracite over *Pictou and Sydney* coals is such that 2,000 pounds of the former equal 2,328 of the latter in mixture; and as 2,500 make a *chaldron at New York*, therefore 2,500 : 2,328 : : 6.25 : 5.82=the relative value of the ton of anthracite. As it was actually selling at from "five to six dollars" the calculation shows that its relative value was much nearer to the highest than to the lowest quoted rate.

As Pictou coal has been sold this season at $3 00 per chaldron of 3,528 pounds, one ton costs $1 90.4. The *present* duty is $1 75 per ton. In December next it will be fifty-seven cents per ton. The difference is $1 18 per ton, and $1 55 per Boston chaldron.†

I cannot omit here to call attention to the great misapprehensions which must inevitably exist in the public mind in regard to the true values of coals, so long as they continue to be bought and sold by *measure*. This evil would still be felt even were the bushel or the chaldron everywhere the same, inasmuch as coals vary so widely in the weight and value of a given bulk, according to the sizes of lumps and to the specific gravity of the mineral. But the confusion becomes much greater when the standard of measure itself varies from place to place, and when even in the *same* place coal is bought and mined by one measure, and sold by another, as in Nova Scotia; when, for example, we have the New Castle chaldron of 53 cwt. or 5,936 pounds, the Nova Scotia chaldron, as above proved, of

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*It is *possible* that the Courier's quotation referred to the price *on board* of the Philadelphia ton of anthracite, in which case the calculation would be 100-88.4× 2,240=2,534 and 2,940 : 2,534 : : 5.87½ : 5.06, which shows that even under that supposition, the ruling price of $6 00 for anthracite, was ninety-four cents higher than its relative economical value.

†A Boston Prices Current of November 4, quotes Pictou and Sydney coals ("duty $1 75 per ton") at $7 a $7 25. Anthracite, per "ton," $6 00, and for retail, per 2,000 pounds, $6 50. This proves that the cargo price of anthracite was fourteen cents per ton too low, and the retail price $1 03 too high, as compared with the average price of $7 12½ per chaldron for Nova Scotia coal.

3,528 pounds; the *so called* "New Castle" chaldron of Nova Scotia, double of the preceding, and forming one car-load of 7,056 pounds; the London chaldron by act of Parliament 25½ cwt. or 2,806 pounds; the Boston chaldron, (by custom-house practice,) of twelve tubs containing each four even bushels, and weighing as above shown 2,940 pounds of *Pictou*, and 2,862 pounds of *Sydney* coal; the New York chaldron of 2,500 pounds; and finally the Providence and Philadelphia chaldrons, containing twelve tubs of three *heaped* bushels each, and weighing, (as it happens,) of Pictou coal, almost exactly the same as the statute London chaldron, or 2,805 pounds.

I see no probability that this confusion will cease until manufacturers, navigators, domestic and other consumers, as well as mine owners, transporters, and dealers in coal, shall come to an understanding and determination to buy and sell coal solely by weight.

As the ton of 2,000 pounds has been almost universally adopted in the retail coal markets; as the State of Pennsylvania has abandoned the ancient denominations of *tons, hundred weights, &c.*, and charges tolls on her public works solely by the thousand pounds; and, as when transported about a city, two thousand pounds form a more suitable load than the gross ton, I can conceive no adequate reason why this weight should not supersede both the old gross ton and the multitudinous *chaldrons* above referred to. It is applicable to sales from the mines as well as to those from the coal-yard, and to governmental as well as to individual purposes.

XVIII.—Absolute and variable Density of Pictou Coal.

As the organic matter in bituminous coal is, in general, a less dense material than the inorganic or mineral substances, such as silex, alumina, oxide of iron, lime, &c., which constitute its earthy portions, and which appear as its ashes after combustion—the less amount of these latter materials there are in a specimen of coal, from a given coal seam, the less may we expect to find the relative weight or specific gravity of the coal; and by converse reasoning, the greater is the density of a specimen, the greater amount of impurity may we expect to find in it.

This principle will, with some modifications, apply to the coals of different coal districts, but is not to be implicitly relied upon to indicate the amount of combustible matter in coals from remote localities, since it is well known that in such cases the composition of the *organic* part of the coal, as well as the nature and amount of its *mineral* impurities, is liable to vary.

The main coal seam at Pictou is nearly thirty-five feet in thickness, but only about twelve feet near the upper part are regarded as profitable for present working. In order to obtain a correct section, and to determine approximately the values of the subordinate divisions, a cut was some time since formed diametrically across the whole seam, the thickness of each ply carefully noted, and the specific gravity of the materials ascertained both by Mr. Poole and the writer. The plies are numbered from above downwards. The cut was made about the middle of the mine, between the upper and lower "boards."

SECTION OF THE MAIN COAL BAND, ALBION MINES.

No	Description of Material Cut.	Thickness.		Total depth from roof		Specific Gravity.		
		Ft.	In	Ft.	In.	By Mr. Poole.	By Mr. Johnson.	Average.
1	Roof Coal........................	1	5	1	5	1.442	1.440	1.441
2	*Fall Coal, mined*..............	2	0	3	5	1.282	1.300	1.291
3	*Holing Stone*, do	0	6	3	11	2.822	2.508	2.660
4	*Top Bench Coal*, do..........	4	3	8	2	1.318	1.308	1.313
5	*Stone, not regular*, do.......	0	1	8	3	2.362	2.371	2.366
6	*Bottom Bench Coal*, do.......	4	9	13	0	1.323	1.334	1.328
7	14 feet Stone Parting.........	1	0	14	0	1.546	1.465	1.505
8	15 feet *Coal*.....................	2	3	16	3	1.407	1.418	1.412
9	Iron Stone, not regular.......	0	3	16	6	3.200	3.288	3.244
10	17 feet *Coal*.	3	6	20	0	1.471	1.487	1.479
11	Bat (slatey matter)............	1	2	21	2	2.136	2.175	2.155
12	*Coal*.............................	3	4	24	6	1.467	1.524	1.495
13	"	1	6	26	0	1.314	1.307	1.310
14	"	1	6	27	6	1.483	1.564	1.523
15	"	1	2	28	8	1.547	1.610	1.578
16	"	1	4	30	0	1.423	1.432	1.427
17	"	1	8	31	8	1.462	1.602	1.532
18	"	0	10	32	6	1.671	1.825	1.748
19	"	1	6	34	0	1.800	1.854	1.827
29	Pavement Rock................	0	6	34	6	2.090	2.105	2 097
X	Below Floor.....................					2.231	2.194	2.222

Experiments made by Mr. Poole, at six different parts of the mine remote from each other, gave an average specific gravity of the "Fall coal" (No. 2) of 1.279; the "top bench" (No. 4) 1.345; and the "bottom bench" (No. 6) 1.334, the general average of which is 1.321. But as the three plies of coal are of different thicknesses, the true average specific gravity of the eleven feet of coal worked is 1.328, which corresponds to exactly eighty-three pounds per cubic foot, or 2,241 pounds (one gross ton) per cubic yard.

From an inspection of the numbers in the table, it is evident that, with an unimportant exception, no other coal in this thick seam has so low a specific gravity as the three plies above designated, and particularly that the massive body, thirteen feet four inches thick, from No. 12 to No. 19 inclusive, has but a single ply (No. 13) of one and a half foot thick, which has so low a specific gravity as 1.31. The rest evidently belong as properly to the class of *bituminous* shales as to that of *coals*.

When broke up into lumps of the size usually given to the lump coal in the market, experiment proves that Pictou coal weighs 52.08 pounds per cubic foot, as above stated. If the coal be broken up so fine that no piece shall weigh more than one pound, the cubic foot will weigh fifty-five pounds, and the gross ton would then require only 40.72 cubic feet of space for its stowage on ship board. The anthracite of Beaver Meadow, Pa., broken to egg size, weighs fifty-seven and one-fourth pounds per cubic foot, and the stowage space per ton is then 39.12 cubic feet.

As the Pictou chaldron is forty-eight bushels, each bushel weighs seventy-three and a half pounds when reduced only to the ordinary marketable condition of average coarse and fine coal.

XIX.—Control, Management, and Rent of Mines.

I have already referred to a mine of coal, said to have been worked by the French near Miré Bay, prior to their surrender of the celebrated fortress of Louisburg in 1758. At Swivel Point also, about one mile southeast of the present Sydney mines, is seen in the base of the perpendicular cliff at high water level a very ancient opening—the mouth of a horizontal drift—on a five feet bed of coal, which overlies the six feet seam now worked.

The cliff having been washed away to a considerable distance since the work was abandoned, the wooden props of the ancient gangway stand in the open air and are washed by the surf during the prevalence of easterly storms. More and more of the props are exposed every year by the gradual falling of the overhanging cliff.

As the coal formation is exposed to the open day all along the eastern part of this island, from the Miré Bay to the Great Bras d'Or entrance, a distance, following the sinuosities of the coast, of nearly seventy-five miles, it was impossible for even the earliest navigators, to remain ignorant of the existence of coal on that coast. But mining operations conducted in drifts from above tide level, could extend to limited distances only before they reached the outcrop, because the land rises only from eighty to two hundred feet above the sea. Hence the trade never assumed any great importance until a more efficient system, one to extend below tide level, had been introduced.

By Messrs. Smith & Brown's statement in Haliburton's History of Nova Scotia, it appears that prior to 1828 the Sydney mines were worked by horse power, and yielded in a few of the preceding years an average of about eight thousand five hundred chaldrons annually. They now yield about forty thousand chaldrons.

The mines of Pictou appear to have been first wrought to an important extent in the year 1818. On the first of January of that year two mines, one on the east and the other on the west side of the East river of Pictou, were leased to Edward Mortimer, Esq., for twenty-one years, for an annual *rent* of £370 currency ($1,480,) and a *royalty* of three shillings (sixty cents) per chaldron on every chaldron over one thousand four hundred, raised and *sold* within the year.

On Mr. Mortimer's decease in 1819, the mines were leased on the same terms to Messrs. Smith & Liddell, by whom they were managed till the 1st of January, 1828, when their lease was surrendered to the British Government.

During their lease, it appears that the mines were worked by Adam Carr, who is stated to have sold his coals at 13s. 6d. ($2 70) per chaldron. In 1822 and '23, however, he sold them at the wharves in Pictou at 20s. 9d. ($5 15.) But Carr's operations, agreeably to the statement of Richard Brown, Esq., before a committee of Assembly of the Province of Nova Scotia in 1839, extended to no greater depth than fifty-four feet. He exhausted the seams to water level before leaving them.

The whole quantity of coal taken out before the surrender of Smith & Liddell's lease, viz: from 1818 to 1827 inclusive, was only 23,325 Winchester chaldrons, and the total amount of royalty paid was but £5148 15s. 9d., or $20,595 15.

During the existence of Smith & Liddell's lease, viz: on the 11th of July, 1826, a Royal Grant was made to the late Duke of York, by which he became sole lessee, for sixty years, of all mines and minerals in Nova Scotia, except of course those on lands which had been previously granted by the Crown without a reservation of *royalty*. These latter are believed to comprise but a small portion of the territory of the province.

The grant to the Duke required of him, his heirs or assigns, to pay a rent of one shilling sterling per ton on all coals, the ton being expressly stipulated to weigh twenty-two hundred weight of one hundred and twenty pounds each, or two thousand six hundred and twenty pounds. It also required him to pay four pence (eight and a third cents) for every ton of iron ore or iron stone, and *one twentieth part* of the metals, gold, silver, copper, lead, and all other ores and metals. He was required to prove that searches had been made within two years, and that mines had actually been opened within five years after the date of his grant, in order to render it valid.

Many parties in Nova Scotia have, in my hearing, complained bitterly of this wholesale disposal of the richest treasures of the province. They seemed to concur almost unanimously in the sentiment of Mr. Haliburton, that "this impolitic reservation to the Crown of the most valuable minerals in the grants of land made to the people of the province, has diminished the interest of the owners of the soil to seek for what they could not enjoy; and the exclusive right invested in the persons in England, claiming under his Royal Highness the late Duke of York, to all the mines and minerals in Nova Scotia, not only renders them indifferent about the discovery of minerals, but prevents them from communicating any information they may possess."*

In 1828, Messrs. Rundel, Bridge & Co., assignees of the Duke of York, came into possession of the Pictou mines, and under the authority of their lease, it is understood that the General Mining Association of Nova Scotia, a body established chiefly by capitalists in London, has since been operating.

As to the dues paid by the Association to the Government, they appear to have varied considerably from time to time. On the 25th of November, 1829, G. Murray, of Downing street, wrote to Sir Peregrine Maitland, that the *rent* to be paid by the General Mining Association was £3,333 6s. 8d., Halifax currency, for any quantity of coal not exceeding twenty thousand chaldrons, and *two* shillings per chaldron *royalty* on the excess beyond that quantity.

In his letter to the late Governor of the Province,† Lord Falkland, under date of December 22, 1842, Samuel Cunard, Esq., Agent of the General Mining Association, states "the fixed annual rent for the privilege of raising twenty thousand

*Vide Historical and Statistical account of Nova Scotia, by Thomas C. Haliburton, Esq., Vol. 2, p. 415.

†See the letter at length, appended to this report.

New Castle chaldrons to be £3,000 sterling," (say $15,000,) "and two shillings currency for the excess shipped beyond that quantity."

It appears that down to 1838, the Association took out in all 190,147 chaldrons, understood to be Winchester measure, and that the sales did not in any year amount to twenty thousand New Castle chaldrons. At the rate stated by Mr. Murray to Sir P. Maitland, this would have amounted to $146,663, and at that put down by Mr. Cunard, to $165,000 for the eleven years in which the Association had been operating.

By official returns from the several mining districts, hereto appended, it appears that there were mined and sold by the Association in 1842, a total of 39,333 chaldrons, New Castle measure, which at the rates stated by Mr. Cunard must have paid in rent and royalty $22,733.

In consequence of Mr. Cunard's representations in the letter above referred to, setting forth the difficulty of competing in the American market with the coals of the United States, under the tariff of 1842, Lord Stanley, on the 18th of February, 1843, communicated to Lord Falkland the decision of the Lords of the Treasury, which was to allow the Association for that year only, to raise twenty thousand chaldrons beyond the number stipulated in their lease, free of charge for royalty, thus, in effect, giving them the right to raise forty thousand chaldrons, New Castle measure, for £3,000 sterling. It appears by the annexed certified returns, that they actually raised 33,550 New Castle chaldrons in that year, which was a decrease of 5,783 chaldrons on the preceding year's operations.

Upon urgent representations made, Lord Stanley, on the 31st of January, 1844, again wrote to Lord Falkland, granting him the privilege, if he thought proper to exercise it, of allowing the Association to raise fifty thousand chaldrons, New Castle measure, for a limited period, "say from five to ten years," on the payment of the stipulated rent of £3,000 sterling. In answer, Lord Falkland assigned as reasons for withholding this privilege, that the decision would embarrass the adjustment of the "civil list" question, (a matter which he appears to have considered paramount to all other subjects,) and that the indulgence granted the preceding year had not resulted in an increase of sales, but the contrary.

The *offer*, however, on the part of the Government to grant this large concession, proves the regard which it feels for the interests of the Association, and the liberal aid it was willing to bestow, in fostering its growing enterprise, and sustaining its competition in the American market.

We need not look beyond the direct interest which the Crown has in the ultimate productiveness of the *royalty* to find an adequate commercial motive for affording this important indirect protection to its colonists and other subjects. As an additional evidence of this interest on the part of the Government in the prosperity of the mining operations in Nova Scotia, I may mention that during the present year the Association has for the first time become possessed of a *charter*, having hitherto been compelled to manage its affairs without this advantage.

The possession of the sign manual and broad seal of Her Majesty, together with the settlement of a long pending suit in chancery between the Crown and the assignees of the Duke of York, a settlement which removes all embarrassment arising from that quarter, are advantages on which the Association look doubtless with nearly as much satisfaction as on the recent modification of the American tariff. These advantages are believed to have been due in no small degree to the indomitable energy, skill, perseverance and address of the General Agent of the Association.

This corporation has a capital of £250,000 ($1,250,000) invested in Nova Scotia and Cape Breton. The shares are £20 each, and have lately received a dividend of eight or ten per cent., understood to be the first which has ever been made. After it was paid the shares sold in London at sixty-five per cent., or £13 per share.

In his testimony before the committee of the Provincial Assembly, in 1839, Mr. Brown states that the Association formerly sold coal at 13s. 6d. ($2 70) per chaldron, but subsequently raised it to 15s. and then to 17s. ($3 40); and that at the former price they sold it at a loss, with a view to introduce it into foreign markets. This effect having now been produced, a return is beginning to be received, and the prospective benefit for which this ample capital was long since invested has begun to be realized.

The amount of royalty now paid is computed on the New Castle chaldron, as stated to me by several of the agents, and the *rate* mentioned was eighteen pence sterling. If this statement be correct, and if by the "New Castle chaldron" be meant not the real New Castle chaldron of 53 cwt., but the car load of 63 cwt., then the royalty is a trifle less than twelve cents per ton, (11.9 cents.)

From the foregoing statements, it appears that Pictou coal has at different times been subjected to the following rates of rent and royalty, per ton:

Per Ton

1. Under the first lease from 1818 to 1828, the rent and royalty averaged - - - - - - - 55.4 cts.
2. Under the grant originally made to the Duke of York, at one shilling sterling for two thousand six hundred and twenty pounds, the royalty per ton of two thousand two hundred and forty pounds, was 21.3
3. Under the lease to the Association, from 1828 to 1838, inclusive, it amounted, by Mr. Cunard's statement, on the coal actually mined at Pictou (excluding that of Sydney) to - - - - - - 55.2
4. On the total amount mined in 1842 - - - 18.4
5. On the quantity taken out in 1843, under the special permission of the Lords of the Treasury - 14.2
6. On the total quantity, (forty thousand New Castle chaldrons,) which *might have been* taken out that year, had a market offered, the ton would have paid - - - - - - - - - - - 11.9
7. On fifty thousand chaldrons, proposed to be allowed by Lord Stanley in 1844, for five or ten years, at £3,000 - - - - - - - - - 9.5
8. On one car load at eighteen pence sterling, as stated above - - - - - - - - 11.9

If, therefore, the statements made to me be correct and applicable to the company under its new charter, the rent paid will be 2.4 cents *more* per ton, than would have been paid had Lord Stanley's proposal of 1844 been carried into effect. It is but 2.3 cents per ton *less* than was actually paid in 1843. Had eighteen pence sterling (thirty-seven and a half cents) per *ton*, been the rate, it would probably have nearly corresponded with the "mine leave" obtained by those who own anthracite mines in Pennsylvania. Until the present year, the Association have had a distinct lease of the Cape Breton mines, independent of their engagement with the Duke of York's assignees, not admitting that the Duke's grant covered that island. The settlement of the chancery suit, and the admission of the assignees to a participation in the benefits of all the mines, merging the royalties into one, and co-operating to extend the trade, will, no doubt, be found favorable to the interests of the crown, as well as those of the Association.

From the best information I could obtain, I compute that the whole quantity of coal that has been mined and sent to market from Pictou since 1818, is eight hundred and seventy thousand chaldrons, or one million three hundred and seventy thousand tons. Knowing the cost of mining, the amount of royalty, and the capital invested, it is easy to compare the actual cost with the present selling price.

Thus, at Pictou, are invested £180,000 ($900,000) on which, interest at six per cent. $54,000, and to pay this, ninety thousand tons mined annually, must pay sixty cents per ton.

We have seen that the current expense of mining and delivering on board, is - - - - - $0 85

Royalty, 11.6, or say twelve cents per ton -	0 12
Interest on capital - - - - -	0 60
Making a total of - - - - -	$1 57
Increase this to make the royalty thirty-seven and a half cents, say - - - - - -	0 25½
Then the cost and interest will be - -	$1 82½
As the ton, at *wholesale*, now costs - -	1 90.4
If from this we take - - - -	1 57
We have left as the nett profit - - -	33.4
	$1 90.4
Supposing the royalty to be thirty seven and a half	1 82.5
This would be reduced to - - - -	7.9

which would in that case be left to cover any contingency, such as burning the mines, falling off of trade, or casualties of any other kind.

That the Association do find that they have a margin left, on which they may, if need be, reduce prices below the present rates, and that, in fact, they are not disposed, at least with their American customers, to adhere very rigidly to the rule of charging $3 30 by the *single cargo*, or $3 for large quantities, is evinced by one or two cases which have come to my knowledge, relative to the actual, as compared with the nominal quantities of coal, of which cargoes have been made up.

Thus, the Brig Almira, Captain Tyler, in September last, brought from Pictou to Philadelphia a cargo of coal containing, "per manifest," one hundred and sixty chaldrons, and charged, as registered at the Custom House, $528; which it will be observed is $3 30 per chaldron, on the "manifest" quantity. It measured eight thousand and four bushels, almost exactly fifty bushels to the Pictou chaldron, and was equal to two hundred and twenty-two and a half Philadelphia chaldrons. It weighed six hundred and twenty-two thousand five hundred and thirty-three pounds, which divided by three thousand five hundred and twenty-eight, the true number of pounds in a chaldron at Pictou, gives one hundred and seventy-six as the *true number* of such chaldrons in that cargo, which multiplied by $3 gives $528. This proves that this "single cargo" was sold at the same price as if the purchaser had taken one thousand chaldrons or more.

Again: A cargo of Pictou coal, recently imported into Providence, Rhode Island, is stated to have been invoiced at *one hundred and sixty-two* chaldrons, and charged at $486, which is $3 per chaldron, (being, perhaps, part of a large order,) but it actually weighed six hundred and nine thousand one hundred and twenty pounds, and consequently must have been *one hundred and seventy-two* Pictou chaldrons. It measured seven thousand seven hundred and seventy-six bushels, or two hundred and sixteen Providence chaldrons. Here the sellers in Pictou gave forty-eight bushels for a chaldron; forty-five bushels is their true chaldron. The true selling price was $4.86 \times 172 = \$2\ 82\frac{1}{2}$ per chaldron, ($1 79 per ton.) At three dollars per chaldron, the cargo would have come to $516. The duties, on the first of December, 1846, on the *invoice value* of the cargo will be $145 80, while on the *true value*, if that be $3 per chaldron, it is $151 80, which shows that this *erroneous* manifest will cause a difference to the revenue of $9. If there be no misstatement of the *value*, then it is clear that the Association are furnishing coal to their customers in Providence at $2 82½ per chaldron, or $1 79 per ton. This may have been designed to place a Providence customer more nearly on a level with those in Boston, where I have shown freights cost thirty cents less per *ton* than at Providence. To compare the Pictou coal with anthracite in Providence, at the rate at which this cargo was sold, we have the following statement:

Cost per ton in Pictou,	- - - -	$1 79
Duty, thirty per cent.	- - - -	53.7
Freight, (at three dollars per *chaldron*,)	- -	2 39.6
And the total cost of the ton is	- - -	$4 72.3

A ton of anthracite should, by what has already been seen, cost at the same time and place $4\ 72.3 \times \frac{100}{88.4} = \$5\ 34$; from which deducting freight from Philadelphia to Providence $1 45, and we have $3 89 as the price at which it must be put on board at Philadelphia.

XX.—Appeal of the Mining Association to the Government.

I append to this report the letter of Mr. Cunard, to which I have more than once referred, and also a copy of the return, made by the several collieries at the end of 1843. These documents, and the other correspondence which I have had occasion to cite, are interesting, as they convey, in an authentic form, information as to the effect of the tariff of 1842, in impeding the introduction of Nova Scotia coals into the United States; as they establish the fact that the markets of this country are of vital importance to the mining interests of that province; as they exhibit the persevering efforts made by the enterprising Association which controls those interests to obtain and preserve a footing in our markets; as they admit the hopelessness of inducing those who have adapted their furnaces to the use of anthracite to return to that of bituminous coal; as they assert that at $3 60 per chaldron* no profit had been left to the Association, and that a great reduction must be made in the price of coal to enable it to sustain, under the tariff of 1842, a competition with the American coals in the markets of the United States.

The correspondence which I have cited also, shows that this strong appeal, made to the Home Government, was not without its effect in procuring relief to the Association. Mr. Cunard's letter testifies that for sixteen years those clear-sighted capitalists who are engaged in efforts to create and extend a trade with the United States, were willing to forego all returns upon their investment. It declares that the expense of mining had been reduced to the lowest possible rates, and that the mines must be closed unless the Government would afford relief by reduction of the royalty. Finally, it expresses the confident expectation, in case this favor from the Crown were granted, of inducing manufacturers in the United States to continue, and even extend, their use of Nova Scotia coals, notwithstanding the duty imposed in 1842, and notwithstanding the competition then existing between our two great rival lines of transportation.†

Philadelphia, *November* 14, 1846.

* Compare with this the statements on the preceding page.

† Reading Railroad and Schuylkill Navigation.

APPENDIX.

A.

Letter from Samuel Cunard, Esq., to Lord Viscount Falkland.

HALIFAX, N. S. 22*d December*, 1842.

MY LORD: I have, as Agent of the General Mining Association, to bring under your Lordship's notice, the great decrease which has taken place in the shipments of the coal made from the mines of the province this year, compared with those of last year; and I beg to call your Lordship's particular attention to the causes which have produced this decrease, and to state my conviction of the positive certainty which at present exists, that our trade with the United States will be entirely destroyed, and the coals of this province excluded from that market, unless we can, by a reduction of the cost of the coals, counteract the heavy duties which we have to contend against.

Your Lordship is aware that the Government of the United States have lately imposed a duty of one dollar and seventy-five cents per ton, or two dollars and twenty cents per chaldron upon all coal imported into the United States. This duty alone, (imposed for the purpose of protecting the mines of Pennsylvania and Virginia,) would have been almost prohibitory; but, in addition to this, the mines in Pennsylvania have been able to effect a very great reduction in the cost of their coals, by the competition of the Reading Railroad, by which means they can afford to sell their coals, this year, at one dollar and fifty cents per ton less than last year; and they have now completed a railroad from Cumberland to Baltimore, which will tend to reduce the price of coal still further.

The duty upon coals imported into the United States this year, until the month of July, when the new tariff came into operation, was a little more than one dollar per chaldron, but by the new tariff, the duty levied is very nearly two dollars and one quarter per Winchester chaldron.

Your Lordship will at once see the effect which the additional duty had upon the importation of Pictou coal into the United States, when I inform you that twenty-one thousand and seventy-six chaldrons were shipped from the Pictou mines in the months of May, June, and July, and only eight thousand four hundred and four chaldrons since that period.

Mr. E. Cunard has just returned from a visit to the principal cities and manufacturing districts of the United States, and has in every instance been informed by the manufacturing companies, who have been the principal consumers of our coal, that they will be forced in consequence of the enormous duty which they have to pay on the importation of coal from Nova Scotia, and the low price at which anthracite coal is now offered to them, to make use of the latter instead of Pictou coal, unless we can afford to sell the coal at a much less price than we have hitherto done.

It is necessary before changing from the consumption of bituminous coal to anthracite coal, to make an alteration in the construction of the furnaces, and I cannot conceal from your Lordship the hopelessness of inducing manufacturers to return to the consumption of bituminous coal, after they have once adapted their furnaces for the use of the anthracite.

The establishments at the mines have been reduced to the lowest possible point consistent with any degree of effectiveness, and the strictest economy prevails in every branch of the service. The price of the coals put on board of the vessel at the mines, free of all charge to the purchaser, is at present eighteen shillings currency per chaldron, equivalent to about nine shillings and six pence sterling per ton.

This price has left no profit to the Association for the large capital embarked in the working of the mines, on which no interest or return has ever yet been paid; but as it is quite evident that a great reduction must still be made in the price of the coal, to enable the Association to compete in the United States' market with the American coal, protected by a heavy duty, by the freight from Nova Scotia, and by the strong feeling which exists to encourage the productions of their own country in preference to those of Great Britain or her colonies. I have given my best attention to the only means of effecting this reduction, and am now preparing a reduced scale of wages which I will endeavor to arrange with the colliers, although your Lordship is well aware of the difficulty which attends a measure of this nature.

After effecting a reduction of the colliers' wages, it only remains for me to bring again under your Lordship's consideration, the absolute necessity of assistance from the Government by a modification of the royalty.

I need not call your Lordship's attention to the great benefits which the province has derived from the vast expenditure which the General Mining Association have incurred, or repeat the many arguments which were made use of on former applications to your Lordship, and to Lord John Russell and Lord Stanley.

It is not at the present moment of any importance whether the large expenditure incurred by the Association was injudicious (as has been imputed) or not. Few undertakings of similar magnitude, even in England, have been accomplished within the estimated expense. The difficulties with which the Association had to contend, and the expenses to which they were subject in opening mines in a new country, with the season for active operations limited to the short period of six or seven months, are totally unknown in England. Their works are now, and have been for some time, carried on upon the most economical scale; and after having continued their operations without the smallest return, for a period of sixteen years, in the hope of obtaining an increased trade with the United States, they now find themselves, after an enormous outlay in the construction of railroads to increase the facilities of shipment, and with mines capable of supplying an almost unlimited quantity of coal, threatened with a total destruction of their foreign trade, and with every prospect of the consumption being narrowed to the trifling supply of the province. I have, therefore, earnestly to entreat your Lordship to take the subject into consideration; and I beg to request, that your Lordship will be pleased to report to the Right Honorable the Secretary of State for the colonies, the unfavorable position, and the still more discouraging prospects which await the trade of the mines, with a request that a very great modification may be made in the amount of royalty now paid. Without this aid the Association will be compelled to close the Pictou mines, and to dismiss the colliers, and others employed there, as the Sydney mines alone can furnish twice the quantity which will be required by the province for many years. The Association would resort to this ultimate measure with great reluctance, as it would involve the loss of all their expensive engines and machinery; but they will have no alternative left, if the Government refuse to grant them the assistance prayed for. No one can be better aware than your Lordship of the injury which would result from such a step to the general trade and revenues of the province.

The fixed annual rent of £3,000 sterling for the privilege of raising twenty thousand New Castle chaldrons, equivalent to a duty of three shillings sterling per New Castle chaldron, is a much larger duty than the Association, under existing circumstances, can continue to pay. As they are, however, aware, that this amount has been appropriated by the Government for specific purposes, and it may be inconvenient to Government to reduce it, or interfere with its regular payment, the Association would be willing to pay this amount annually, but would pray that your Lordship would be pleased to recommend, that the number of chaldrons which may be disposed of on the payment of this sum, be extended from twenty thousand to fifty thousand chaldrons. Upon any excess shipped beyond that quantity, the present royalty of two shillings currency per New Castle chaldron be continued.

Should the Government be pleased to accede to this proposition, the Association may be enabled to offer coals to the manufacturers and consumers in the United States at such a price as to induce them to continue their use, and I hope to introduce them also into new markets abroad.

If, however, the Government decline complying with this petition, all foreign trade will be totally destroyed, the Association confined to the trifling supply of the province, and the revenue limited to the fixed rent of £3,000 sterling.

I enclose for your Lordship's information, a statement extracted from the returns in the Miner's Journal, showing the immense increase which has taken place in the production and consumption of anthracite coal. In the year 1820, there were only three hundred and sixty-five tons of anthracite coal sent to market in the United States. In the year 1840, the consumption was estimated at one million of tons; and in the present year the quantity is estimated at nearly one million and a quarter.

The shipments from Nova Scotia in the year 1841, to the United States, were 51,690 Winchester chaldrons. This year, the shipments will be about thirty-three thousand Winchester chaldrons, a decrease of eighteen thousand chaldrons, and since the operation of the new tariff the shipments have nearly ceased.

I think your Lordship will do me the justice to believe that I have not made this application without a pressing necessity. From the knowledge which your Lordship possesses of the subject, and the interest which you have always evinced in the welfare of the province, which is so intimately connected with the prosperity of the mines, I am induced to hope that your Lordship will be pleased to recommend to Her Majesty's Government, to grant the assistance prayed for. As we must now either enter into new agreements with the colliers, or dismiss them, and also endeavor to make arrangements for the supply of the manufacturers in the United States for the next season, I take the liberty of begging that your Lordship will be pleased to request an early reply to this communication.

I have the honor to be, my Lord,

Your Lordship's most obedient servant,

(Signed) S. CUNARD.

His Excellency the Right Honorable Viscount FALKLAND, Lieutenant Governor, &c.

B.

Return of the quantity of Coal raised, sold, and exported, at Her Majesty's Coal Mines at Sydney, and at Little Bras d'Or, in the Island of Cape Breton, and at the Albion Mines, in the County of Pictou, in the year ending 31st December, 1843.

[Extracted from the Journal and Proceedings of the House of Assembly of Nova Scotia, 1844.—Appendix No. 33, page 75.]

	Total quantity of coal raised and sold in chaldrons, Newcastle measure.				Number of Chaldrons sold for home consumption.				Number of Chaldrons exported to the U. States.				Number of Chaldrons exported to the neighboring Colonies.			
	Large Coal.		Siftings or Slack Coal.		Large Coal.		Siftings or Slack Coal.		Large Coal.		Siftings or Slack Coal.		Large Coal.		Siftings or Slack Coal.	
	Chald's.	Bus.	Chal's.	Bus.	Chald's.	Bus.	Chal's.	Bus	Chald's.	Bus.	Chal's.	Bus.	Chald's.	Bus.	Chal's.	Bus.
From Sydney Mines.....	23,432	27	839	13½	9,813	27	454	13½	6,561		223		7,048		162	
From Little Bras d'Or Mines...	35	10	19	16½	11	28	19	16½					23	18		
From Albion Mines.....	11,093	21	2,224		1,287	21	836		7,965		678		901		710	
Total...........	33,860	58	3,082	30	11,111	76	1,309	30	14,466		901		7,972	18	872	

Coals raised and carried from the Mines, New Castle measure:

1842—Sydney Mines........	24,246 chaldrons.	1843—Sydney Mines........	23,422 chaldrons.
Bras d'Or............	562 "	Bras d'Or............	35 "
Albion...............	15,025 "	Albion..............	10,093 "
	39,833		33,550

COMPARISON OF EXPERIMENTS

TO TEST THE

COMPOSITION AND EVAPORATIVE EFFICIENCY

OF

AMERICAN AND FOREIGN COALS.

AMERICAN AND FOREIGN COALS.

Comparison of the Results of Experiments to determine the Evaporative power of American Coals, with those of similar experiments since instituted by the British Admiralty on British Coals.

In reference to the necessity of investigating the various properties of coals, in order rightly to estimate their relative values, the following brief statements from page vi., preliminary report on American coals, express the views of the writer, and may serve to convey an idea of the need which existed in 1843, (and which still exists over a large portion of our coal formations,) for direct trials to establish the worth of their several minerals:

"The question of the value of coals for the purpose of generating steam is, of course, mainly dependent on their heating power; that is, on the weight of water which a given weight of coal, burned under a given evaporating vessel, can convert into steam, while undergoing combustion. But this is not the only circumstance requiring investigation, in order to decide their value, even for the purpose of sea-going steamers.

"The weight of a given bulk of each coal, in its merchantable condition; the manner in which it burns, whether with much or little flame; the amount and character of its combustible ingredients; its facility or difficulty of ignition; the perfection of the combustion, or the proportion of the whole amount consumed to that of the combustible matter placed upon the grate; the concentration or diffusibility of its heat; the proportion of humidity, and that of the sulphur which it may contain, with the consequent liability, under certain circumstances, to undergo spontaneous combustion—are all points requiring attentive consideration. In addition to these, we have the question of the manner in which each coal behaves when coming to the temperature of ignition; its tendency to retain its original form, the nature and extent of change when any occurs, whether by simply cracking and disintegrating into angular fragments, or by enlarging the bulk, rounding away and obliterating the angles, and yet not agglutinating mass to mass; or, finally, by wholly changing its form and consistence, swelling to a great degree, and cohering so as to form a nearly continuous roof, and thus impeding the passage of air through the ignited coal. In some cases the question of the amount of solid matter which accompanies the gaseous products of combustion in the state of smoke, becoming soot upon the flues of the apparatus in which the combustion is conducted, is one of great practical importance. Of these incidental questions, the amount and character of the incombustible ingredients of different coals is a point eminently deserving of notice. It indicates the deduction which must, in all cases, be made from the heating power of an equal weight of the coal, considered as pure combustible matter; it shows the extent and kind of labor requisite in managing the furnace; it warns us what to expect in regard to the durability of grate bars, and the adhesion of scoriæ to those important appendages of the furnace. All these subjects must necessarily engage the attention of engineers and furnace managers, and no little portion of the good or bad character in coal may be considered to depend on these circumstances. The relation of the incombustible ingredients of coal to each other is often such as to render the mixture fusible at the temperature of ordinary furnaces, or at least to be, in a certain proportion, reduced to a pasty coherent mass upon the grate, impeding the passage of air, leaving another portion unvitrified, and capable of passing through the interstices between the bars. For different coals this proportion is very different, even when the combustion is conducted as far as practicable in the same manner, and with the same intensity of heat.

"In fact, there is scarcely an aspect in which this subject can be viewed, which does not open points of inquiry and comparison of the greatest practical importance to the naval service. It is not, however, solely with reference to their evaporative power, or their use under steam boilers, that coals are of importance to the navy of the United States, and of all other maritime nations. The very introduction of steam machinery into the navy has largely augmented the amount of workmanship in metals demanded for that branch of service; and the substitution of iron for wood in the vessels themselves, is destined vastly to increase the demand for such varieties of fuel as are best adapted to the various metallurgic arts. It was, therefore, evidently proper, in directing the investigation of the subject of the evaporative power of coals, that the Department should require (as it did) the researches to be extended to all their applications. By instituting inquiries intended primarily for its own use and benefit, the Navy Department will have incidentally rendered an equal service to many important branches of art in the country. By inviting, as above stated, the proprietors of mines to furnish their respective coals for trial, it afforded to the mining interest an opportunity of ascertaining the relative value of their own products, as compared with those of many other districts and of foreign countries, and especially of having the peculiar adaptedness of each to its specific object clearly designated."

In the preceding account of the coals and coal trade of Nova Scotia, we have had occasion to refer to the results of experiments obtained from those and other varieties of American coals. Those experiments have enabled the writer to compare the market prices at different times with the true calorific values of the anthracites and the Nova Scotia coals respectively. The two samples of English and one of Scotch coals, also tried at Washington in 1843, afforded to a limited extent the means of comparison between some of the varieties more generally imported into this country and the coals *of similar constitution* found in the United States—such for example as those in the neighborhood of Richmond, Va.

We were, however, until very recently, without reliable information respecting the economical values of many British coals which are found extensively in commerce, and much celebrated for their use in steam navigation. Of these the Welsh coals stand conspicuous—and to them reference had been made at pages 212–213 of the report on American coals. A comparison is there presented between about 130 different specimens of coals from seventeen different localities in the great coal field of South Wales, exhibiting their proportions of volatile matter, fixed carbon, and earthy matter, or ash, together with the ratios of their fixed to their volatile combustible materials. The class of free burning bituminous coals of Pennsylvania and Maryland had, upon analysis, yielded ratios of *fixed* to *volatile* combustible matter, varying from 3.65 to 5.97, and these coals had produced some of the highest evaporative effects found during the whole series of trials of American coals.

Among the seventeen varieties of Welsh coals cited from the work of Mr. Mushet, it was found that the ratios varied from 2.56 to 13.95; several of those approaching the latter number being, in fact, true anthracites. The inference was natural, that the Welsh semi-bituminous coals would, when fully and carefully tested, prove, like their American congeners, to be of the highest order of evaporative efficiency. The results of experience on the largest scale had, in fact, justified this inference, for the principal place of shipment (Newport) is known to be generally crowded with shipping, engaged in transporting the Welsh coals to every part of the globe where steam navigation demands their consumption.

The following table from page 213 of the report on American coals, exhibits the characters of Welsh coals above referred to.

Tabular view of the proximate composition of Welsh furnace Coals.

Locality at which each coal is mined or used.	Number of varieties analyzed from each locality to furnish the average composition.	Average composition in			
		Volatile matter.	Fixed carbon.	Earthy matter.	Fixed to 1 of volatile combustible.
(1.) Blaeavon iron works	4	27.122	69.597	3.281	2.56
(2.) Clydach, or Llanelly works	7	21.813	75.598	2.589	3.46
(3.) Nantyglo	4	17.210	79.803	2.687	4.64
(4.) Ebbw vale	7	16.707	79.847	3.446	4.78
(5.) Tredegar	9	15.603	80.056	4.341	5.13
(6.) Bute and Rhymney, Glamorganshire	9	14.797	82.037	3.166	5.54
(7.) Plymouth and Duffryn, near Merthyr Tidvil	8	14.430	82.411	3.159	5.71
(8.) Sir Howy	8	14.149	80.845	5.006	5.71
(9.) Bute	7	13.941	81.937	4.122	5.88
(10.) Dowlais	10	12.176	85.321	2.503	7.01
(11.) Penn-y-darran	8	11.139	86.111	2.750	7.73
(12.) Aberdare, Glamorganshire	9	10.330	85.990	3.680	8.32
(13.) Neath Abbey	6	8.516	87.470	4.014	10.27
(14.) Cyfartha and Ynnis	8	8.091	89.753	2.156	11.09
(15.) Hirwain, Glamorganshire	4	7.982	89.081	2.937	11.17
(16.) Crane's Yniscydwn	3	7.420	89.002	3.578	12.00
(17.) Ystal-y-Fera	9	6.587	91.913	1.500	13.96

General exterior and other characters of the coals.

(1.) Fracture conchoidal; of some of the varieties the structure is cubical, of others the texture is granular and friable.

(2.) Some of the specimens very bituminous in appearance, and all sufficiently so to produce in coking much intumescence and change of form.

(3.) Structure in some cases lamellar, much intersected with planes, and resembling crystallization; other varieties are reedy, and intersected by oblique cross partings.

(4.) In some specimens the structure is cubical, granular, and the consistence friable; in others, the fracture is coarse, rough, and structure amorphous, showing no definite directions of fracture.

(5.) Fractures oblique; structure rhombic, compact, or granular, with sometimes a radio-striated surface; occasionally rising into prisms.

(6.) Bright shining partings oblique to the beds. In some varieties, the appearance is that of glance coal.

(7.) Structure either mixed of reedy and granular, or wholly granular; very bright and shining; concentric circles sometimes are apparent at the fractures.

(8.) Forms general y rhomboidal; structure granular, mineralized charcoal intermixed with reedy laminæ; cross partings more or less irregular.

(9.) Structure variable; reedy and granular intermixed; sometimes crystalloid, specular, glance, or anthracitous.

(10.) Either bright, reedy, in regular laminæ, or intersected at right angles by partings producing brittleness; color sometimes dull black, having no proper cleavage; at others, the aspect is that of beautiful glance, having minute shining laminæ oblique to the surfaces of deposition.

(11.) Structure sometimes compact, minutely laminated. Some varieties have a reediness oblique to the bed; some are graphitic in appearance, and others partly bituminous and partly anthracitous.

(12.) Several of these varieties are entirely anthracitous in character, and undergo no change of form in coking; others have the usual characteristic of dry bituminous coals.

(13.) All these varieties are true anthracites; structure slaty; color brilliant black.

(14.) Some of these are decidedly anthracitous, others contain bituminous cement between the plies, and others still are entirely bituminous. This is, indeed, a *transition* coal.

(15.) Regularly crystalized, granular, or shining, without regular cleavages; surfaces sometimes plumbaginous.

(16.) Bright, shining, pitchy; grows more brilliant by pulverizing.

(17.) All these are true anthracites, with the ordinary characters pertaining to that class.

It appears that when the report on American coals reached England in June, 1845, a copy was sent by Hon. Joseph Hume, M. P., to the Lords of the Admiralty, with a suggestion that a similar examination should be made of the coals of England, Scotland, and Ireland.* Their Lordships promptly responded to this wish, and called on Sir Henry de la Beche and Dr. Lyon Playfair to undertake the investigation. After a labor of two years and six months employed in testing and analyzing the coals, the following report was rendered in January, 1848:

*The following is an extract from the letter of the Right Honorable Joseph Hume, M. P., to the Right Honorable the Lords of the Admiralty:

"The late Mr. A. P. Upham," [Upshur,] "of the United States, was strongly impressed with the importance of determining the nature and qualities of the several coals of the United States, with a view to their use in the steam navy of that country, and in 1842–43 directed a course of experiments to be made on the different kinds of coal of the United States, for the purpose of ascertaining their evaporative powers. I have only this day received from the United States the report of that inquiry, and I have the satisfaction of sending a copy of that report to your Lordships, that you may see the result of that inquiry. They have decided by direct and practical tests the comparative usefulness of American and English coals, as well as the relative value of the former in their numerous varieties; and I submit to your Lordships that a similar inquiry should be instituted into the comparative usefulness of the several kinds of English, Scotch, and Irish coals, with a view of ascertaining the best for the naval steamers of this country."—*Brit. Rept*, *p.* 3.

TO THE RIGHT HON. VISCOUNT MORPETH.

MUSEUM OF PRACTICAL GEOLOGY,
January 5, 1848.

MY LORD:

We have the honor to transmit a First Report on the experiments which, under the sanction of the Earl of Lincoln, your Lordship's predecessor, we were requested by the Lords Commissioners of the Admiralty to superintend, respecting the value of different varieties of British coals, for the purposes of our naval service; and, according to your Lordship's instructions, we have forwarded a copy of this Report to the Admiralty, as the expenses of the investigation were incurred by that establishment.

The utility of such investigations having been fully recognized, both as regards questions of the greatest importance connected with our steam navy and as bearing on various branches of our national industry, in which the right use of our fossil fuel is so requisite, it is unnecessary to dwell on the practical application of the inquiry.

We would, however, observe, that experiments necessary to ascertain the true practical value of coal involve a very large series of observations, extended over a considerable period, and directed to special objects of inquiry. The qualities for which particular kinds of fuel are pre-eminent being so varied, it is impossible to deduce general results from a limited series of observations. Even in the one economical application of coals, their evaporative value, or their power of forming steam, one variety of coal which may be admirably adapted from its quick action for raising steam in a short period, may be far exceeded by another variety, inferior in this respect, but capable of converting a much larger quantity of water into steam, and therefore more valuable in the production of force. A coal uniting these two qualities in a high degree might still be useless for naval purposes, on account of its mechanical structure. If the cohesion of its particles be small, the effect of transport or the attrition of one coal against another by the motion of a vessel might so far pulverize it as materially to reduce its value. Even supposing the three qualities united rapidity and duration of action with considerable resistance to breakage, there are many other properties which should receive attention in the selection of a fuel without the combination of which it might be valueless for our steam navy.

There is an important difference existing between varieties of coals in the bulk or space occupied by a certain weight. For the purposes of stowage room this cannot be ascertained by specific gravity alone, because the mechanical formation of the fragments of coal may enable one of less density to take up a smaller space than that occupied by another of a higher gravity. This is far from an imaginary difference, being sometimes as great as 60 per cent., and not unfrequently 40 per cent. The mere theoretical determination of the density of coals would, therefore, give results useless for practice. The space occupied between two varieties of coals, often equally good as regards their evaporative value, differs occasionally 20 per cent., that is, where 80 tons of one coal could be stowed, 100 tons of another of equal evaporative value might be placed, by selecting it with attention to its mechanical structure. These facts are mentioned merely to show that a hasty generalization should not be made, and to account for our drawing attention to these various points as a means of preventing the selection of a fuel from any one quality. We do not, in the present state of this inquiry, consider it proper to offer any recommendation of our own as to particular kinds of fuel, leaving the experimental facts to decide for themselves.

After preliminary experiments had proved that no practical result could be attained by mere laboratory research, it was determined to test each variety of coal on a scale of sufficient magnitude to check the theoretical views by the practical results. As it was impossible for either of us to devote our whole time to this inquiry, our services being required by other official duties, we appointed assistants to superintend its special parts, under our general direction. On the selection of assistants we have reason to congratulate ourselves, their duties having been conducted with great care and skill. To Mr. Wilson, since appointed Principal of the Royal Agricultural College of Cirencester, whose practical knowledge well fitted him for the task, the superintendence of the economical part of the experiments was first confided. To him and Mr. Phillips is due the erection of the boilers, and the experiments to illustrate the practical evaporative power of the coals. After Mr. Wilson had for some time proceeded with the investigation, he was joined by Mr. Kingsbury, who volunteered his services to this department. The latter gentleman was formerly a distinguished student at the College for Civil Engineers, Putney, and from his engineering skill has rendered an especial service to this inquiry.

On the translation of Mr. Wilson to Cirencester, the practical superintendence of the investigation was intrusted to Mr. J. Arthur Phillips, a pupil of the Ecole des Mines of Paris. The information obtained had pointed out improvements and corrections in the processes used, to which Mr. Phillips applied himself with much skill and success.

The corrections and the results of his experiments will be found in his appended Report. The excellent scientific education of Mr. Phillips, and his practical resources, rendered his services of great value.

The analyses of coals were intrusted to Mr. Wrightson (a pupil of Liebig,) who had fitted himself by special study for an undertaking requiring so much delicacy of manipulation. Mr. Galloway, an assistant at the Museum of Practical Geology, gave his occasional services in analyzing gases and ashes from the furnaces, but he was not wholly retained for this purpose.

Mr. How, a very careful experimentalist, and assistant at the laboratory of the College for Civil Engineers, was appointed analyst after the retirement of Messrs. Wrightson and Galloway.

It is proper to mention, in terms of approbation, the services of the intelligent working engineer, William Hutchinson, whose assiduity soon enabled him to be of more important service than was to have been expected from his position.

The results obtained by the assistants, with accounts of the modes pursued, are appended, in order that the methods may be examined, and that special attention may be devoted to any particular department of the inquiry.

In the first section of the Appendix, a full description is given of the processes adopted in conducting the practical part of the experiments, as also plans and sections of the boiler, furnace, and apparatus employed.

The second section contains details of the observations and experiments made to ascertain the evaporative power of the different varieties of coals.

The third section describes the formulæ used for calculating the experiments, and for correcting and reducing them to one standard.

The fourth section contains the chemical experiments, including the ultimate and proximate analyses of the coals, and the determination of their calorific values.

It is unnecessary to repeat here the mode in which the experiments were instituted, as these are detailed in the first section of the Appendix, so that it will suffice to draw attention to the points observed in reducing and calculating the results. It will be obvious that there are several circumstances which must receive attention before the true evaporative value of a fuel can be obtained. Thus, the water in the tanks has a varying temperature during the day, dependent on atmospheric changes, and is always different from that in the boiler. The temperature of water in the boiler also varies with the external temperature, and the circumstances under which the experiments are made. The shape of a Cornish boiler favors an inequality in the temperature of the water in its various parts, the colder and denser water sinking to the bottom, and having a tendency to remain there, so that the temperature of water at the surface is far from being the mean temperature of water in the boiler, the difference between the surface and bottom water being, on an average, 70°. Other circumstances naturally affect the evaporative powers of the coal, as for example the fact that all the water exposed to the action of the fire in the boiler is not converted into steam, and that wood is used to light the fire. Another circumstance of considerable importance, is the expansion or contraction of the boiler from an increase or diminution of the temperature. In the early stage of the experiments, those conducted by Messrs. Wilson and Kingsbury, it was thought unnecessary to make a correction for this variation in conditions; but on ascertaining experimentally that the difference was as much as 69.625 lbs. of water in the contents of the boiler, between the temperature 150° and 212°, it became desirable to make an allowance for it, even when the difference between the initial and final temperature was not greater than 10°. Other circumstances of less importance, but influencing the results, have been neglected, because the application of such corrections would have only complicated the results, and would have had little practical value when the errors of observation in such approximative experiments remain so large. Among these may be mentioned the quantity of gases evolved during combustion, the elevation in temperature of the air entering the fire place, the barometrical and hygrometric conditions of the atmosphere, the radiation from the boiler (very small in amount, owing to its brick covering,) the hygrometric state of the fuel, or the heat necessary for obtaining mechanical draught in the chimney. In most of these cases the necessary observations have been made, to enable the corrections to be applied, should it afterwards appear desirable.

In making the calculation for the evaporative value of a fuel, the quantity consumed was divided into two portions, the first being that necessary to raise the whole mass of water, exposed to the fire, from the *mean temperature* to 212°, the second portion being that required to evaporate the water taken from the tanks from a temperature of 212°. To enable this to be done, the mean temperature of the whole mass of the water is ascertained, that is, the temperature of the water in the boiler at its initial temperature after being mixed with the tank water at its average temperature. The average of the latter was the mean of several observations taken during the day, and is designated by t'.

Let w be weight of water drawn from tanks at temperature t'
W „ in boiler „ t''
this being obtained from surface temperature corrected by experiment;

t, temperature after mixture.

$$\text{Then } t = \frac{W\,t'' + w\,t'}{W + w}.$$

The correction for the wood was made from data procured experimentally by Messrs. Wilson and Kingsbury, but it can only be employed for the particular wood used, as in subsequent experiments the evaporative value was found very different from another quality obtained. The co-efficient of the evaporative power of the wood may be deduced from experiment, in which a certain weight of water was raised from a known temperature to the boiling point, and then a certain portion of it evaporated. The following formulæ have been used by Mr. Kingsbury for the calculation.

N is the total weight of wood used in raising $(W + w)$ (the weight of water in the boiler, and of that let down from the tanks during the experiment) from the mean temperature t to 212°; then it is necessary to find the weight N' necessary to evaporate w from 212°.

$$\text{Then } \frac{w}{N'} = c, \text{ the evaporating power.}$$

Let m be the weight of wood required to raise $W + w$ from t to 212°, the number 1000 being assumed as the latent heat of steam.

n to evaporate $W + w$ from 212°
N' „ w „

$$\text{Then } m + N' = n$$

$$\text{Now } \frac{l}{212 - t} = \frac{n}{m}$$

$$\text{But } \frac{n}{N'} = \frac{W + w}{w}$$

$$\therefore N' = n \frac{w}{W + w}$$

$$l\,(N - N') = (212 - t)\, n$$

$$= (212 - t)\, N' \left(\frac{W + w}{w}\right)$$

$$N\, l = N' \left\{ \frac{W + w}{w} (212 - t) + l \right\}$$

$$= \frac{N'}{w} \left\{ (212 - t)\ (W + w) + l\ w \right\}$$

$$\therefore \frac{w}{N'} = \frac{(212 - t)\ (W + w) + l\, w}{N\, l}$$

$$= e$$

or, introducing the value of t as given by the first formula,

$$\frac{(l + 212 - t)\ w + (212 - t'')\ W}{N\, l} = e.$$

If q be the quantity of wood used in lighting the fire, $e\ q$ will be the weight of water evaporated from 212° by the wood, and must be deducted from the weight of water evaporated in calculating the work done by the coal.

The co-efficient of the evaporating power of the coals, or the number of lbs. of water which one lb. of coal will evaporate from 212°, may be calculated as follows:

Let P be the total quantity of coal consumed, then the work done by P will be to raise $W + w$ of water from t to 212°, and to evaporate $w - e\ q$ from 212°.

Let m be weight of coal required to raise $W + w$ to 212° from t
p " " evaporate $w - e\,q$ from 212°
n " " " $W + w$ from 212°

$$\text{Then } \frac{w - e\ q}{p} = \text{E, the evaporating power.}$$

$$\text{Now P} = m + p$$

$$\frac{212 - t}{l} = \frac{m}{n}$$

$$\text{But } \frac{p}{n} = \frac{w - e\ q}{W + w}$$

$$\therefore l \left(\frac{w - e\ q}{W + w}\right) = p\, \frac{212 - t}{P - p}$$

$$\frac{(W + w)\ (212 - t) + (w - e\ q)\ l}{P\, l} = \frac{w - e\ q}{p}$$

$$= E$$

Introducing the values from which the mean temperature t was obtained (first formula,) we have eventually

$$\frac{(l + 212 - t')\,w + (212 - t'')\,W - l\,e\,q}{P\,l} = E$$

in which W is the weight of water in the boiler;

w " drawn from the tanks during the experiment;

t' the mean temperature of water in tanks;

t'' the corrected initial temperature of water in boiler.*

In the preceding formulæ, the latent heat of steam has been taken at 1000°, the number generally used in this country; but after all the calculations had been made on this subject from the experiments by Messrs. Wilson and Kingsbury, and the results sent in to the Admiralty, Regnault's excellent memoir on the latent heat of steam was published. It became necessary, therefore, to use these new results in the future experiments. These, so far as they apply to the present inquiry, are reduced in the following table:

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*A small correction must be also made for the combustible matter in the *residua* of combustion, such as the soot and carbonaceous matter in the ashes; to do this with great accuracy, a series of observations and analyses would have been required, the labor and expense of which would not have been warranted by the amount of correction necessary. It was, therefore, considered sufficient to proceed as follows—although the result is nothing more than a very rough approximation to the truth. For such an approximation it will be admitted that the evaporative value of the coal depends on the ratio of the combustible to the incombustible matter, and that this ratio confers a similar evaporative value on the quantity of ashes, cinders, and soot produced by the combustion; in other words, that if the combustible matter of the latter had been usefully applied in the production of steam, a similar effect would have been produced as if a corresponding quantity of coal had been burned. If then Q be the weight of coal containing the same quantity of combustible matter as the *residua* after its combustion in the furnace.

$$\frac{(l + 212 - t')\,w + (212 - t'')\,W - l\,e\,q}{(P - Q)\,l} = E' \left\{ \text{the corrected co-efficient of evaporating power.} \right.$$

Let then w_1 = weight of ashes after the experiment

w_2 = " cinders " "

w_3 = " soot " "

The weight of the cinders is taken after the clinkers are separated.

Let r_1, r_2, r_3 be the per centage of combustible matter in the ashes, cinders, and soot respectively;

Q the weight of coal containing the same weight of combustible matter;

r the per centage of combustible matter as found in the coal by analysis;

$$\text{Then } r\,Q = r_1\,W_1 + r_2\,W_2 + r_3\,w_3$$

$$\therefore Q = \frac{r_1\,W_1 + r_2\,W_2 + r_3\,w_3}{r}.$$

TABLE No. 1.—*Showing the Specific and Latent Heat of Water and Steam.*

Air Thermometer Centigrade.	Mercurial Centigrade	Number of Unities of Heat abandoned by 1 kilo. of water in descending from T to 0°.	Air Thermometer Fahrenheit.	Mercurial Fahrenheit.	Number of Unities of Heat contained in 1 pound of water at T°.	Mean Specific Heat of Water betw'n 0° and T cent. or between 32° and T Fahrenheit.	Specific Heat of Water from T to T + d T.	Latent Heat of Steam saturated to the temperature T.	
								Centigrade.	Fahrenheit.
°	°		°	°					
0		0.000	32		32.000		1.0000	606.5	1091.7
10		10.002	50		50.003	1.0002	1.0005	599.5	1079.1
20		20.010	68		68.018	1.0005	1.0012	592.6	1066.7
30		30.026	86		86.046	1.0009	1.0020	585.7	1054.2
40		40.051	104		104.091	1.9013	1.0030	578.7	1041.6
50	50.2	50.087	122	122.36	122.156	1.0017	1.0042	571.6	1028.9
60		60.137	140		140.246	1.0023	1.0056	564.7	1016.4
70		70.210	158		158.381	1.0030	1.0072	557.6	1003.7
80		80.282	176		176.507	1.0035	1.0089	550.6	991.1
90		90.381	194		194.685	1.0042	1.0109	543.5	978.3
100	100.0	100.500	212	212.0	212.900	1.0050	1.0130	536.5	965.7
110		110.641	230		231.153	1.0058	1.0153	529.4	952.9
120		12[illegible].806	248		249.450	1.0067	1.0177	522.3	940.1
130		130.997	266		267.794	1.0076	1.0204	515.1	927.2
140		141.215	284		286.187	1.0087	1.0232	508.0	914.4
150	150.0	151.462	302	302.0	304.632	1.0097	1.0262	500.7	901.2
160		161.741	320		323.133	1.0109	1.0294	493.6	888.5
170		172.052	338		341.693	1.0121	1.0328	486.2	875.1
180		182.398	356		360.316	1.0133	1.0364	479.0	862.2
190		192.779	374		379.002	1.0146	1.0401	471.6	848.9
200	200.0	203.200	392	392.0	397.760	1.0160	1.0440	464.3	835.7
210		213.660	410		416.588	1.0174	1.0481	456.8	822.2
220		224.162	428		435.480	1.0189	1.0524	449.4	808.9
230		234.708	446		454.474	1.0204	1.0568	441.9	795.4

It also became desirable to introduce new corrections, which the progress of the inquiry showed to be needful. Thus, Mr. Phillips's careful experiments determined the alteration in the capacity of the boiler at different temperatures, and correction was in future made for this difference. The alteration in the capacity of the measuring tanks was also estimated, whenever the temperature differed 2° from that at which they were guaged. Another cause of error, for which allowance should be made, is any difference which may exist between the initial and final temperature at the beginning and close of the experiment. This difference being known by observation, the correction may be applied from the Table of Expansion of the Water in the Boiler, given in the Appendix. Introducing these new corrections into the experiments for ascertaining the co-efficient of the heating power of the wood, the following are the formulæ used by Mr. Phillips:—

$$\frac{(W + w - w')(l + t) + wt' + (w' - w)t''}{P\,l} = E.$$

In which W is the water let down from the tanks during the experiment.

w = The weight of water (as found by the Table of Expansion) found in the boilers at commencement of experiment.

w' = The weight of water in boiler at close of experiment.

l = Co-efficient of the latent heat of steam.

t = Quantity of heat necessary to raise the water in tanks from its mean temperature to that at which it is evaporated.

t' = Quantity of heat necessary to raise the water in the boiler from the initial to the final temperature.

t'' = Quantity of heat necessary to raise the water at the temperature of tanks to the final temperature of water in the boiler.

P = Weight of combustibles consumed during experiment.

E = The co-efficient of the heating powers of wood.

But when the initial is lower than the final temperature, the formula becomes—

$$\frac{(W + w - w')\,l + Wt + wt' + (w' - w)t'''}{P\,l} = E.$$

All the terms retaining their original value except the last, in which t'' is replaced by t''' (or the heat necessary to raise the final temperature to that at which the water was expanded,) and must be regarded as having a negative value, while t' becomes positive. If now q is the weight of wood used in lighting the fire, the formulæ for estimating the evaporative power of the coal will be

$$\frac{(W - Eq + w - w')\,l + (W + w - w')\,t + wt' + (w' - w)\,t''}{P\,l} = E'$$

And

$$\frac{(W - Eq + w - w')\,l + Wt + wt' + (w' - w)\,t'''}{P\,l} = E'.$$

As the experiments are strictly comparative, and under like conditions, the want of the other corrections, to which we have alluded above, will not be felt in examining the results; while their execution would have introduced a refinement into the experiments which never could be obtained in practice, and which, in fact, would be useless and unwarrantable, while, as previously remarked, the errors of observation in all such approximate experiments remain so large.

The only omitted correction which in appearance might be supposed necessary for practical purposes, is that for the hygroscopic condition of the fuel. Had wood been employed, this must have been done; but the hygroscopic nature of coal is very much less than that of wood. The latter contains ⅕ of its own weight of hygroscopic water; and the heat necessary for the evaporation of this quantity might be shown by a simple calculation to be nearly equal to 22 per cent. of the total heat obtained by the combustion of the wood. The hygroscopic water in coal is, however, very small, as will be seen by the following determinations of some of the Welsh specimens experimented upon:—

	Hygroscopic water.
Graigola Coal - - - -	1.06 per cent.
Anthracite - - - - -	2.44 "
Old Castle - - - - -	0.74 "
Ward's Fiery Vein - - -	1.27 "
Myndd Newydd - - -	0.67 "
Pentrepoth - - - - -	0.78 "
Pentrefelin - - - - -	0.70 "

Had we introduced corrections for these small quantities, practice would have been misled; because the coals will rarely reach a vessel in the dry state that they did in the present case, when they were packed in hogsheads and kept under cover.

It was found unnecessary to correct for any inflammable gases flying up the chimney, because repeated analysis of the chimney gases proved them not to contain any combustible

TABLE II.—*Showing the*

	Names of Coals employed in the Experiments.	Economic evaporating power, or number of pounds of Water evaporated from 212° by 1 lb. of Coal.	Weight of 1 cubic foot of the Coal as used for fuel. Pounds.	Weight of 1 cubic foot as calculated from the density. Pounds.
		A.	B.	C.
Welsh Coals.	Graigola	9.35	60.166	81.107
	Anthracite, Jones & Co.	9.46	58.25	85.786
	Old Castle Fiery Vein	8.94	50.916	80.42
	Ward's Fiery Vein	9.40	57.433	83.85
	Binea	9.94	57.08	81.357
	Llangennech	8.86	56.93	81.85
	Pentrepoth	8.72	57.72	81.73
	Pentrefelin	6.36	66.166	84.726
	Duffryn	10.14	53.22	82.72
	Mynydd Newydd	9.52	56.33	81.73
	Three-quarter Rock Vein	8.84	56.388	83.60
	Cwm Frood Rock Vein	8.70	55.277	78.299
	Cwm Nanty-gros	8.42	56.0	79.859
	Resolven	9.53	58.66	82.354
	Pontypool	7.47	55.7	82.35
	Bedwas	9.79	50.5	82.6
	Ebbw Vale	10.21	53.3	78.81
	Porth-mawr	7.53	53.3	86.722
	Coleshill	8.0	53.0	80.483
Scotch Coals.	Dalkeith Jewel Seam	7.08	49.8	79.672
	" Coronation Seam	7.71	51.66	78.611
	Wallsend Elgin	8.46	54.6	78.611
	Fordel Splint	7.56	55.0	78.611
	Grangemouth	7.40	54.25	80.48
English Coals.	Broomhill	7.3	52.5	77.988
	Lydney (Forest of Dean)	8.52	54.444	80.046
	Slievardagh Irish Anthracite	9.85	62.8	99.57
Patent Coals.	Wylam's Patent Fuel	8.92	65.08	68.629
	Bells "	8.53	65.3	71.124
	Warlich's "	10 36	69.05	72.248

constituent; the only products ever found being carbonic acid, sulphurous acid, oxygen, and nitrogen. The quantity of free oxygen in the chimney varied from $\frac{1}{4}$ to $\frac{1}{2}$ of the oxygen, which combined with the fuel; in other words, nearly twice the quantity of air passes through the fire than that which is strictly necessary by theory.

Economic Values of the Coals.

Ratio of B to C., or of the economical to the theoretical weight.	Difference per cent. between theoretical and economical weights.	Space occupied by 1 ton in cubic feet (economic weight.)	Results of experiments on cohesive power of Coals per centage of large Coals.	Evaporating power of the Coal after deducting for the combustible matter in the residue.	Weight of Water evaporated from 212° by 1 cubic foot of Coal.	Rate of evaporation, or number of lbs. of water evaporated per hour. Mean.
D.	E.	F.	G.	H.	I.	
.742	34.8	37.23	49.3	9.66	581.20	441.48
.679	47.26	38.45	68.5	9.7	565.02	409.37
.633	57.946	43.99	57.7	....	455.18	464.30
.685	46.	39.	46.5	10.6	608.78	529.90
.702	42.53	39.24	51.2	10.3	587.92	486.95
.695	43.76	39.34	53.5	9.2	523.75	373.22
.705	40.17	38.80	46.5	8.98	518.32	381.50
.781	28.051	33.85	52.7	7.4	489.62	247.24
.643	55.43	42.09	56.2	11.80	540.12	409.32
.689	45.09	39.76	53.7	10.59	536.26	470.69
.674	48.26	39.72	52.7	....	498.46	486.86
.706	41.648	40.52	72.5	9.35	480.90	379.80
.701	42.60	40.00	55.7	8.82	471.52	404.16
.712	40 39	38.19	35.0	10.44	559.02	390.25
.676	47.845	40.216	57.5	8.04	416.07	250.40
.611	63.565	44.32	54.0	9.99	494.39	476.96
.676	45.98	42.26	45.0	10.64	544.19	460.22
.614	62.7	42.02	62.0	7.75	401.34	347.44
.658	51.85	42.26	62.	8.34	424.0	406 41
.625	59.984	4[illegible].98	85.7	7 10	352.58	355.18
.657	52.17	45.36	88.2	7.86	398.29	370.08
.694	43.78	41.02	64.	8.67	460.82	435.77
.699	42.92	40.72	63.	7.69	415.80	464.98
.674	48.35	40.13	69.7	7.91	401.45	380.40
.673	48.55	42.67	65.7	7.66	383.25	397.78
.68	47.02	41.14	55.0	8.98	463.86	487.19
.630	58.55	35.66	74.	10.49	618.58	473.18
.948	5.45	34.41	....	9.74	580.51	418.89
.918	8.91	34.30	....	8.65	557.0	549.11
.955	4.49	32.44	....	10 60	715.35	457.84

With regard to the selection of the coals for trial, we have to refer to Mr. Wilson's letter inserted in the Appendix. This letter gives the information obtained in a tour made by Professor Wilson for the purpose of ascertaining the best coals fitted for trial in the South Wales coal district, and the ports from which they can conveniently be shipped. This district was selected because the varying character of the coals, from the bituminous to the anthracitic, offered those which were most likely to combine the qualities desired for naval purposes. It was intended, as being most convenient for the inquiry, to have adhered strictly to districts. In the experiments this has hitherto been done, except in special cases, at the request of the Admiralty.

The preceding Table (Table II., pages 70–71) contains an abstract of the results, so far as regards the evaporative value of the fuel; the special characters of each of the coals being described in the experiments detailed in the Appendix.

This Table relates only to the economical value of the coals examined, and to the steam generated by a unit of the respective coals, without however implying a unit of time. The details with reference to time, which forms a most important element in the value of the respective fuels, will be found in Section II.

The economical results obtained by evaporation in the best applied practice are ascertained to be only a small part of the theoretical result following from the actual quantity of heat capable of being generated. Still, as a comparative statement, it is necessary to contrast the economical heat given out by a coal with the theoretical quantity. The cause of the difference between the applied and theoretical quantities is, at least in a great degree, obvious, and does not by the apparent difference prove the fallacy of calculation. Before the comparison can be made, it is necessary to have a knowledge of the composition of the respective coals, of this we subjoin a Table reduced from Section IV. (See pages 72–73.)

Chemists differ as to the mode of calculating the theoretical heating values of coals, but, as an approximative rule, without insisting on its absolute accuracy, their calorific values are found to stand in relation to the quantity of oxygen required for their complete combustion. This may be estimated experimentally by heating the coal with an excess of litharge, or it may be determined by calculation from the known equivalents of the combustible ingredients of the coal. From the quantity of lead reduced by the coal, the oxygen employed in its combustion may be estimated, and the calorific values stand in direct relation to this quantity. The amount of oxygen necessary to consume the combustible constituents may more accurately be determined by elementary analysis; and thus calculated, the results are generally found to be about ¼ greater than those indicated by experiment with the litharge. The calculation from the elementary analysis depends upon the circumstance, that 6 parts, or one equivalent, of carbon requires 16 parts, or two equivalents, of oxygen for combustion, while 1 part of hydrogen requires 8 parts of oxygen; it is only necessary, therefore, to subtract from the hydrogen a quantity corresponding to the oxygen contained in the coal to enable the calculation to be made on these principles.

As the calorific values are only relative, it is useful to refer them to the heating power of pure carbon, 1 part of which requires 2.666 parts of oxgen for combustion, and is capable, according to Despretz, of heating 78.15 parts of water from its freezing to its boiling point. The calculation may be simplified by multiplying each part of lead obtained by 2.265, which gives at once the weight of water capable of being heated between these temperatures by a unit of the coal used in reducing the litharge. On these principles the following Table is constructed.—(*See* Table IV., pages 76–77.)

With regard to the practical application of fuel, such a Table could not supersede experiment, as the economical values of the coal depend also on adventitious circumstances connected with their physical as well as their chemical condition. This Table, while on the whole it agrees with and confirms the practical results of experiments, still differs in a marked degree in one or two instances: this difference arising as much from the chemical as from the physical differences of the coals. Thus, if by destructive distillation, which occurs in furnaces before combustion, a large quantity of the constituents of the coal are rendered gaseous, so much heat is expended in this act that the heat developed by their after combustion is frequently not greater than that abstracted during their formation, in which case a thermo-neutrality occurs. To ascertain the proportion of fixed and volatile products in the various coals, the very difficult and elaborate process described in Section IV., page 55, was adopted; but the tediousness and chances of failure in this kind of analysis have only induced us to include a limited number of coals (those given in Table V.,) especially as for steam purposes it was sufficient to determine the per centage of coke, as stated in Table II.

It has been for some time asserted, that the evaporative value of a bituminous coal is expressed by the evaporative value of its coke, the heat of combustion of its volatile products proving in practice little more than that necessary to volatilise them. If this supposition were even near the truth, the most useful practical results might follow from it. By a larger and better applied system of gas manufacture, the volatile products of distillation might be made useful not only for

TABLE III.—*Showing the Mean Compo*

	Locality or name of Coal.	Specific Gravity of Coals.	Carbon.
Welsh Coals.	Graigola	1.30	84.87
	Anthracite	1.375	91.44
	Oldcastle Fiery Vein	1.289	87.68
	Ward's Fiery Vein	1.344	87.87
	Binea Coal	1.304	88.66
	Llangenneck	1.312	85.46
	Pentrepoth	1.31	88.72
	Pemtrefelin	1.358	85.52
	Duffryn	1.326	88 26
	Mynydd Newydd	1.31	84.71
	Three-quarter Rock Vein	1.34	75.15
	Cwm Frood Rock Vein	1.255	82.25
	Cwm Nanty-gros	1.28	78.36
	Resolven	1.32	79.33
	Ponty Pool	1.32	80.70
	Bedwas	1.32	80.61
	Ebbw Vale	1.275	89.78
	Porthmawr Rock Vein	1.39	74.70
	Coleshill	1.29	73.84
Scotch Coals.	Dalkeith Jewel Seam	1 277	74.55
	Dalkeith Coronation Seam	1.316	76.94
	Walsend Elgin	1.20	76.09
	Fordel Splint	1.25	79.58
	Grangemouth	1.29	79.85
English Coals.	Broomhill	1.25	81.70
	Park End, Lydney	1.283	73.52
	Slievardagh (Irish)	1.59	80.03
Foreign Coals.	Formosa Island	1.24	78.26
	Borneo (Labuan kind)	1.28	64.52
	" 3 feet seam	1.37	54.31
	" 11 feet seam	1.21	70.33
Patent Fuel.	Wylam's Patent Fuel	1.10	79.91
	Bell's " "	1.14	87.88
	Warlich " "	1.15	90.02

the purposes of illumination, but also for domestic heat, and the residual coke might be used with an equal economy in our manufactures*; thus preventing the emission of that smoke,

*In this case it would be necessary not to carry on the process of distillation so far as at present, as the residual coke would be more combustible and the gases purer.

sition of average samples of the Coals.

Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Per centage of Coke left by each Coal.
3.84	0.41	0.45	7.19	3.24	85.5
3.46	0.21	0.79	2.58	1.52	92.9
4.89	1.31	0.09	3.39	2.64	79.8
3.93	2.02	0.83	Included in ash.	7.04	....
4.63	1.43	0.33	1.03	3.96	88.10
4.20	1.07	0.29	2.43	6.54	83.69
4.50	0.18	....	3.24	3.36	82.5
3.72	Trace.	0.12	4.55	6 09	85.0
4.66	1.45	1.77	0.60	3.26	84.3
5.76	1.56	1.21	3.52	3.24	74.8
4.93	1.07	2.85	5.04	10.96	62.5
5.84	1.11	1.22	3.58	6.00	68.8
5.59	1.86	3.01	3.58	5.60	65.6
4.75	1.38	5.07	Included in ash.	9.41	83.9
5.66	1.35	2.39	4.38	5.52	64.8
6.01	1.44	3.50	1.50	6.94	71.7
5.15	2.16	1.02	0.39	1.50	77.5
4.79	1.28	0.91	3.60	14.72	63.1
5.14	1.47	2.34	8.29	8.92	56.0
5.14	0.10	0.33	15.51	4 37	49.8
5.20	Trace.	0.38	14.37	3.10	53.5
5.22	1.41	1.53	5.05	10.70	58.45
5.50	1.13	1.46	8.33	4.00	52.03
5.28	1.35	1.42	8.58	3.52	56.6
6.17	1.84	2.85	4.37	3.07	59.2
5.69	2.04	2.27	6.48	10.00	57.8
2.30	0.23	6.76	Included in ash.	10.80	90.1
5.70	0.64	0.49	10.95	3.96	....
4.74	0.80	1.45	20.75	7.74	....
5.03	0.98	1.14	24.22	14.32	....
5.41	0.67	1.17	19.19	3.23	....
5.69	1.68	1.25	6.63	4.84	65.8
5.22	0 81	0.71	0.42	4.96	71.8
5 56	Trace.	1.62	Included in ash.	2.91	85.1

which, at present, is so destructive to the comfort of our large cities. It is easy from analysis to examine whether the duty performed by the coal is to be attributed to its fixed ingredients or coke, by estimating the work which the latter is capa-

TABLE IV.—*Showing the*

	Name of Coal.	Quantity of lead reduced by one part of Coal.	Oxygen removed from Litharge by one part Coal.
		A.	B.
Welsh Coals.	Graigola	32.08	2.49
	Anthracite (Jones and Aubrey)	33.48	2.60
	Oldcastle Fiery Vein	31.42	2.44
	Ward's Fiery Vein	31.46	2.44
	Binea Coal	31.64	2.46
	Llangenneck	32.66	2.53
	Pentrepoth	31.16	2.39
	Pentrefelin	30.52	2.37
	Powel's Duffryn	30.00	2.33
	Mynydd Newydd	30.34	2.35
	Three-quarter Rock Vein	26.62	2.06
	Cwm Frood Rock Vein	28.30	2.19
	Cwm Nanty-Gros	29.64	2.28
	Resolven	32.16	2.50
	Pontypool	27.46	2.13
	Bedwas	28.20	2.19
	Ebbw Vale	32.00	2.48
	Porthmawr Rock Vein	24.78	1.92
	Coleshill	26.14	2.03
Scotch Coals.	Dalkeith Jewel Seam	26.42	2.05
	" Coronation Seam	24.56	1.96
	Elgin Wallsend	29.06	2.25
	Fordel Splint	29.00	2.25
	Grangemouth	28.48	2.20
	Broomhill (English)	25.32	1.96
	Slievardagh (Irish)	30.10	2.33
Patent Fuels.	Wylam's Patent Fuel	28.82	2.23
	Bell's "	28.52	2.21
	Warlich's "	31.50	2.44

ble of performing. This may be done by subtracting the amount of ashes in the coal from its amount of coke (Table III.) and estimating the remainder as carbon. This carbon multiplied by its heating power, 13268, and divided by 965.7 or the latent heat of steam, indicates the number of pounds of water which the coke by itself could evaporate, without the aid of the combustible volatile ingredients of the coal. These results are placed in column B. of Table VI., in juxtaposition with the actual work done by the coal, and it will be

Calorific Values of the Coals.

Quantity of Oxygen theoretically required by Carbon and Hydrogen.	Quantity of Oxygen required by Carbon alone.	Relative calorific Values, Carbon taken as 100, calculated from A. and B.	Number of lbs. of water which 1 lb. of Coal can raise from 32° Fahr. to 212° Fahr. calculated from A.
C.	D.	E.	F.
2.49	2.26	93.4	72.66
2.69	2.43	97.5	75.73
2.71	2.34	91.5	71.16
2.65	2.34	91.5	71.25
2.72	2.36	92.2	71.66
2.59	2.28	94.9	73.97
2.69	2.36	89.6	70.57
2.53	2.28	89.2	69.13
2.71	2.35	87.7	67.95
2.67	2.2	88.5	68.72
2.34	2.00	77.2	60.29
2.62	2.19	82.5	64.10
2.47	2.08	85.5	67.13
2.49	2.11	93.7	72.84
2.55	2.15	80.2	62.19
2.60	2.15	82.1	63.87
2.80	2.39	93.0	72.48
2.33	1.99	72.0	56.12
2.28	1.96	76.1	59.21
2.24	1.98	76.8	59.84
2.32	2.05	73.5	55.63
2.38	2.02	84.7	65.82
2.47	2.12	84.7	65.68
2.46	2.13	82.8	64.51
2.63	2.18	73.5	57.35
2.31	2.13	87.7	70.44
2.52	2.13	84.0	65.27
2.75	2.34	83.2	64.59
2.84	2.40	91.5	71.35

seen, that notwithstanding several striking exceptions, which might have been expected, they on the whole show that the work capable of being performed by the coke alone, is actually greater than that obtained by experiments with the original coal.

The whole system of manufacturing coke is at present very imperfect. Besides losing the volatile combustible substances, which under new adjustments might be made of much value, an immense quantity of ammonia is lost by being

TABLE V.—*Showing the Amount of Various Substances*

Name.		Coke.	Tar.
Welsh Coals.	Graigola	85.5	1.2
	Anthracite, from Jones, Aubrey & Co.	92.9	None.
	Old Castle Fiery Vein	79.8	5.86
	Ward's Fiery Vein	....	1.80
	Binea	88.10	2 08
	Llangenneck	83.69	1.22

thrown into the atmosphere. Ammonia and its salts are daily becoming more valuable to agriculture, and it is their comparative high price alone, which prevents their universal use to all kinds of cereal cultivation. By a construction of the most simple kind, the coke ovens now in use might be made to economise much of the nitrogen which invariably escapes in the form of ammonia. As an inducement to this economy, we have appended to Table VI. two columns (H. and I.) showing the quantity of ammonia ($N H_3$,) and its corresponding quantity of commercial sulphate ($N H_4 O, S O_3$,) which each 100 lbs. of the respective coals may be made to produce. When it is remembered, that the price of sulphate of ammonia is about £13 per ton, or that 100 tons in coking is capable of producing, on an average, about 6 tons of this salt, its neglect is highly reprehensible.

By the preceding data, the actual value of the coals will be contrasted with that which is theoretically possible, supposing their combustion proceeded under circumstances which prevented any loss of heat. The actual duty obtained by a pound of coal from the boiler employed may be easily expressed by the number of pounds raised to the height of one foot. This result may readily be obtained by the simple formula—

$$W\, n \times 965.7 \times 782 = x,$$

W representing water, of which n pounds are evaporated by a pound of coal. This formula is deduced from the fact that n pounds of water multiplied by 965.7,* or the co-efficient for

*The co-efficient for the latent heat of steam at 212° is generally taken at 1000°, but the above number is from the recent experiments of Regnault on this subject, as given in Table ¹.

produc d by the destructive Distillation of certain Coals.

Water.	Ammonia.	Carbonic acid.	Sulph. Hydrogen.	Olefiant Gas and Hydro-Carbon.	Other Gases inflammable.
3.1	0.17	2.79	Traces.	0.23	7.01
2.87	0.20	0.06	0 04	?	3.93
3.39	0.35	0.44	0.12	0.27	9.77
3.61	0.24	1.80	0.21	0.21	....
3.58	0.08	1.68	0.09	0.31	4.08
4.07	0.08	3.21	0.02	0.43	7.28

the latent heat of steam at 212°, indicates the number of pounds of water which would be raised 1° Fah.; and the number 782 arises from experiment on the mechanical force denoted by the elevation of a pound of water 1° Fah.; that force being equal to 782 lbs., raised to the height of one foot, according to the careful experiments of Mr. Joule, on the friction of oil, water, and mercury.

The theoretical value of the coals, with reference to the number of pounds of water which one pound of fuel will convert into steam, is obtained by the formula—

$$\left(\frac{C \times 13268}{965.7}\right) + \left(\frac{H - h \times 62470}{965.7}\right) = x$$

in which C is the quantity of carbon, H the quantity of hydrogen in a unit of fuel, and h the quantity of hydrogen corresponding to the oxygen contained in the coal. These multiplied by their heating powers, according to the results of Dulong, and divided by the latent heat of steam, indicate the number of pounds of water that can be converted into the latter by a pound of coal. The numbers thus obtained can be changed into the expression of mechanical force, by the previous formulæ.

The results of these calculations are thrown into Table VI.—(*See* pages 80–81.)

The best Cornish engines are stated to raise 1,000,000 lbs. to the height of one foot, by every pound of coal consumed; so that only about $\frac{1}{8}$ of the *actual* force generated becomes available, or only $\frac{1}{11}$ or $\frac{1}{12}$ of the force theoretically possible, is applied in practice. The various experiments made on boilers, with regard to the evaporative power of coal, have not given very uniform results. Smeaton, in 1772, with one

TABLE VI.—*Showing the Actual Duty, and that*

Name or Locality of coal.	Actual number of lbs. of Water converted into Steam by 1 lb of Coal.	Number of lbs. of Water convertible into Steam by the coke left by the Coal.	Number of lbs. of Water convertible into Steam by the Carbon of the Coal.	Number of lbs. of Water convertible into Steam by the Hydrogen of the Coal.
	Practical.	Theoretical.	Theoretical.	Theoretical.
	A.	B.	C.	D.
Graigola	9.35	11.301	11.660	1.903
Anthracite, (Jones, Aubrey, & Co.)	9.46	12.554	12 563	2.030
Oldcastle Fiery Vein	8.94	10.601	12.046	2.890
Ward's Fiery Vein	9.40	....	12.072	2.542
Binea	9.94	11.560	12.181	2.912
Llangenneck	8.86	10 599	11.741	2.519
Pentrepoth	8.72	10.873	12.189	2.649
Pentrefelin	6.36	10.841	11.749	2.038
Powell's Duffryn	10.149	11.134	12.126	2.966
Mynydd Newydd	9.52	9.831	11.463	3.441
Three-quarter Rock Vein	8.84	7.081	10.325	2.781
Cwm Frood Rock Vein	8.70	8.628	11.300	3.488
Cwm Nanty Gros	8.42	8.243	10.767	3.165
Resolven	9.53	10.234	10.899	3.072
Pontypool	7.47	8.144	11.088	3.207
Bedwas	9.79	8.897	11.075	3.766
Ebbw Vale	10.21	10.441	12.335	3.300
Porthmawr Rock Vein	7.53	6 647	10.263	2 548
Coleshill	8.0	6.468	10.145	2.654
Dalkeith Jewel Seam	7.08	6.239	10.242	2.071
Dalkeith Coronation	7.71	6.924	10.570	2.202
Wallsend Elgin	8 46	6.560	10.454	2.968
Fordel Splint	7.56	6.560	10.933	2 884
Grangemouth	7.40	7.292	10.970	2.722
Broomhill	7.30	7.711	11.225	3.638
Park End, Lydney	8.52	6.567	10.101	3.156
Slievardagh (Irish)	9.85	10.895	10.995	1.487
Formosa Island	....	....	10.752	2.801
Borneo (Labuan kind)	....	....	8.864	1.388
" 3 feet seam	....	....	7.461	1.295
" 11 "	....	....	9.652	1.918
Wylam's Patent Fuel	8.92	8.378	11.186	3.145
Warlich's "	10.36	11.292	12.368	3.596
Bell's "	8.53	9.168	12.074	3.343

pound of Newcastle coal, evaporated 7.88 lbs. of water from 212°; Watt, in 1788, came to the conclusion that 1.62 lbs. of water might be evaporated by the same quantity of coal; and later (in 1840,) Wicksteed found that 1 lb. of Merthyr coal *which is theoretically possible, of the Coals examined.*

Total number of lbs. of Water convertible into Steam by 1 lb. of Coal.	Actual force generated, or the number of lbs. which 1 lb. of the Coal could raise to the height of 1 foot.	Force capable of being generated, or number of lbs. which could be raised to the height of 1 foot by 1 lb. of Coal.	Amount of Ammonia corresponding to the Nitrogen contained in Coal.	Amount of Sulphate of Ammonia corresponding to the Nitrogen contained in Coal.
Theoretical.	Calculated from heat obtained.	Theoretical.		
E.	F.	G.	H.	I.
13.563	7.060.908	10.242.471	0.497	7.032
14.593	7.143.978	11.020.303	0.225	6.990
14.936	6.751.285	11.279.329	1.590	6.175
14.614	7.098.667	11.036.162	1.238	4.808
15.093	7.506.463	11.397.892	1.586	6.741
14.260	6.690 871	10.768.829	1.299	5.044
14.838	6.585.146	11.205.322	0.218	0.848
13.787	4.802.928	10.411.630	Trace.	....
15.092	7.664.295.	11.397.137	1.76	6.835
14.904	7.189.288	11.255.163	1.808	7.340
13.106	6.675.768	9.897.355	1.299	5.044
14.788	6.570.043	11.167.563	1.347	5.232
13.932	6.358.593	10.521.131	1.919	7.448
13.971	7.196 840	10.550.583	1.675	6.505
14.295	5.641.175	10.795.260	1.639	6.364
14.841	7.393.186	11.207.587	1.748	6.788
15.635	7.710.361	11.025.198	2.622	10.182
12.811	5.686.485	9.674.577	1.554	6.033
12.799	6.041.419	9.665.515	1.785	6.930
12.313	5.346.655	9.298.499	1.214	0.471
12.772	5.822.417	9.645.125	Trace.	....
13.422	6.388.800	10.135.991	1.712	6.647
13.817	5.709.141	10.434.286	1.372	5.327
13.692	5.588.312	10.339.888	1.639	6.364
14.863	5.512.795	11.224.201	2.234	8.674
13.257	6.434.111	10.011.386	1.477	9.617
12.482	7.438.497	9.426.124	0.279	1.084
13.553	....	10.234.919	0.777	3.017
10.252	....	7.742.078	0.977	3.771
8.756	....	6.612.333	1.132	4.620
11.600	....	8.760.957	0.813	3.158
14.331	6.736.182	10.822.447	2.040	7.920
15.964	7.823.637	12.055.652	Trace.	....
15.417	6.441.663	11.642.569	0.983	3.818

could be made to evaporate 9.493 lbs. of water from 80°, which is equal to 10.746 lbs. from 212°. In some experiments made on the boiler of the Loam's engine, at the United Mines, in Cornwall, each pound of coal was found, by a trial of six months, to evaporate 10.29 lbs. of water from 212°, this being the reduction of the result given, viz., that 234,210 cubic feet of water at 102° were evaporated by 700 tons of coal. Statements have indeed been made that 14 lbs. of water have been evaporated by 1 lb. of coal burned in Cornish boilers; but as this is the utmost quantity theoretically possible, it is difficult to conceive that it has been realized in practice, even in the best-constructed steam-engines.

To ascertain how far our boiler was inferior to Cornish boilers, as principally from its small size and less efficient coating it was likely to prove, we requested Mr. Phillips to make some experiments on one of the best engines in Cornwall, the results of which are given in the Appendix, Section II. It was found by these experiments, that 11.42 lbs. of water were evaporated by every pound of Welsh coal corresponding in composition to that of Mynydd Newydd; or, in other words, that improved Cornish boilers on a large scale may be assumed to have a superiority of nearly 20 per cent. over that used in these experiments. As the results stated in this Report are only relative, the comparison is not affected by this difference.

We have anxiously looked to the application of these experiments to the different varieties of patent fuel, but we have not been able to carry out our observations in this direction to the extent we could have desired, from our inability to procure patent fuels in sufficient number, although our applications to the patentees have been numerous. Three varieties have been already examined, viz., those manufactured under the patents of Messrs. Wylam, Warlich, and Bell, and the results are given in the Tables. The varieties of patent fuel are generally made up in the shape of bricks, and are therefore well adapted for stowage; so that, though the specific gravity of patent fuels is lower than that of ordinary coals, from their shape and mechanical structure, there are very few coals which could be stowed in a smaller space per ton. While we look to the different varieties of patent fuel as of the highest importance, and, from their facility of stowage, as being peculiarly adapted for naval purposes, and perhaps even destined to supersede ordinary coal, at the same time, the greater part do not appear to be manufactured with a proper regard to the conditions required for war steamers. It is usual to mix bituminous or tarry matter with bituminous coal, and from this compound to make the fuel. An assimilation to the best steam coals would indicate, however, the very reverse process, and point to the mixture of a more anthracitic coal with the bituminous cement. As the greater part is at present made, it is almost impossible to prevent the emission of dense opaque smoke, a circumstance extremely inconvenient to ships of war, as betraying their position at a distance at times when it is desirable to conceal it. Besides this and other inconveniencies, the very bituminous varieties are not well suited to hot climates, and are as liable to spontaneous combustion as certain kinds of coal. To avoid these inconveniences, some kinds of patent fuels have been subjected to a sort of coking, and thus, in a great measure, obtain the desired conditions. There is little doubt, however, that notwithstanding the large number of patents in operation for the manufacture of fuel, its value for the purposes of war steamers might be much enhanced by its preparation being specially directed to this object. It will be seen, by reference to Table II., that the three patent fuels examined rank among the highest results obtained. Should it be desirable to continue this inquiry, we conceive that it would be advantageous to pay especial attention to this subject, by experimenting upon proper mixtures of different coals. Even anthracite may be introduced into such mixtures with advantage.

It is of much importance in an economical inquiry on coals, to obtain exact information as to the effects likely to be produced upon them by stowage, and continued exposure to high temperature, not only as regards their deterioration, but also as to the emission of dangerous gases by their progressive changes.

The retention of coal in iron bunkers, if these are likely to be influenced by moisture, and especially when by any accident wetted with sea water, will cause a speedy corrosion of the iron, with a rapidity proportionate to its more or less efficient protection from corroding influences. This corrosion seems due to the action of carbon or coal forming with the iron a voltaic couple, and thus promoting oxidation. The action is similar to that of the tubercular concretions which appear on the inside of iron water-pipes, when a piece of carbon, not chemically combined with the metal, and in contact with saline waters, produces a speedy corrosion. Where the "make" of iron shows it to be liable to be thus corroded, a mechanical protection is generally found sufficient. This is sometimes given by Roman cement, by a lining of wood, or by a drying oil driven into the pores of the iron under great pressure.

Recent researches on the gases evolved from coal, prove that carbonic acid and nitrogen are constantly mixed with the inflammable portion, showing that the coal must still be uniting with the oxygen of the atmosphere, and entering into further decay.

Decay is merely a combustion proceeding without flame, and is always attended with the production of heat. The gas evolved during the progress of decay, in free air, consists principally of carbonic acid, a gas very injurious to animal life. It is well known that this change in coal proceeds more rapidly at an elevated temperature, and therefore is liable to take place in hot climates. Dryness is unfavorable to the change, while moisture causes it to proceed with rapidity.

When sulphur or iron pyrites (a compound of sulphur and iron) is present in considerable quantity in a coal still changing under the action of the atmosphere, a second powerful heating cause is introduced, and both acting together, may produce what is termed *spontaneous combustion.* The latter cause is itself sufficient, if there be an unusual proportion of sulphur or iron pyrites present.

The best method of prevention, in all such cases, is to ensure perfect dryness in the coals when they are stowed away, and to select a variety of fuel not liable to the progressive decomposition to which allusion has been made. This is, however, a subject of so much importance to the steam navy, that it continues to receive our careful attention; and, beyond these general recommendations, it would be premature to offer any decided course for adoption, from the present limited series of observations.

Several varieties of coal were transmitted from Formosa and from Borneo, for analysis, the results of which are contained in the accompanying table. The quantity of each kind was so small, that no experiments could be made on their evaporative value. We extract from the preceding table the following results:—

Name.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ashes.	Specific Gravity.
Formosa Island.............	78.26	5.70	0.64	0.49	10.95	3.96	1.24
Borneo, Labuan kind......	64.52	4.74	0.80	1.45	20.75	7.74	1.28
" 3 feet seam.........	54.31	5.03	0.98	1.14	24.22	14.32	1 37
" 11 feet seam.......	70.33	5.41	0.67	1.17	19.19	3.23	1.21

It may be desirable to sum up, in a few words, some of the principal points alluded to in the previous parts of this Report.

It has been shown that the true practical value of coals for steam purposes depends upon a combination of qualities which could only be elicited by carefully and properly continued experiments. Their qualities, so far as regards steam-ships of war, may be stated as follows:

1. The fuel should burn so that steam may be raised in a short period, if this be desired; in other words, it should be able to produce a quick action.
2. It should possess high evaporative power, that is, be capable of converting much water into steam, with a small consumption of coal.
3. It should not be bituminous, lest so much smoke be generated as to betray the position of ships of war when it is desirable that this should be concealed.
4. It should possess considerable cohesion of its particles, so that it may not be broken into too small fragments by the constant attrition which it may experience in the vessel.
5. It should combine a considerable density with such mechanical structure that it may easily be stowed away in small space; a condition which, in coals of equal evaporative values, often involves a difference of more than 20 per cent.
6. It should be free from any considerable quantity of sulphur, and should not progressively decay, both of which circumstances render it liable to spontaneous combustion.

It never happens that all these conditions are united in one coal. To take an instance, anthracite has very high evaporative power, but not being easily ignited, is not suited for quick action; it has great cohesion in its particles, and is not easily broken up by attrition, but it is not a caking coal, and therefore would not cohere in the furnace when the ship rolled in a gale of wind; it emits no smoke, but from the intensity of its combustion causes the iron of the bars and boilers to oxidate or waste away rapidly. Thus, then, with some preeminent advantages, it has disadvantages which, under ordinary circumstances, preclude its use. The conditions above alluded to may, however, often be united in fuels artificially prepared from coals possessing these various qualities, somewhat in the manner of what are usually termed "patent fuels," and we have recommended that experiments should be made with this object, especially directed to the wants of the steam navy. Whilst we look with this view to artificial fuel as being of special importance, it was quite necessary to obtain a knowledge of coals in different districts, and, for this purpose, Wales was first selected for examination, as producing coals of all kinds, varying from bituminous to anthracite.

While the experiments devised to obtain information on the various points alluded to have been conducted with all proper precaution, in order that constant *comparative* results might be procured, they have not been overburdened with scientific corrections, which might have been necessary to obtain absolute truth, but would have introduced an affectation of accuracy where practical results only were required; to the latter, therefore, this Report has been principally confined. The Report has been so divided as to bring the results together without complicating them with the details of the properties peculiar to each coal, information on which is of the highest value. Hence, in Table II., the practical results of the experiments are brought together, while the equally practical information regarding each coal, its local position, the port from whence it is shipped, its price, its peculiar characteristics in burning, the greater or less quantity of smoke and of ashes which it produces, the description of the coal, its geological position, and other similar points of importance in practice, are detailed for each coal in Section II. of the Appendix.

The composition and specific gravities of the coals, and the quantity of coke which they produce, are given in Table III., not only as a means for their future identification, but also as a standard of quality, with relation to which particular kinds may be purchased. The amount of sulphur, as given in this table, is of considerable importance in determining the value of the coal for naval purposes, as a means of avoiding the risk of spontaneous combustion.

The heating values of the coal are given in Table IV., as a simpler and more ready method of identification, enabling the purchaser to insure the sample of the coal of a certain heating value.

Table V. shows how the inquiry might easily be extended to other branches of national industry, especially to gas manufactures, but is only adduced as an example of its applicability for such purposes.

Table VI. is principally for the purpose of showing that the actual duty obtained by the combustion of coal in the best applied practice is only a small part of that which the fuel is capable of producing, and is brought forward as an inducement to improvement in the construction of the furnaces and boilers employed for the production of steam. Attention is also drawn in this table to the great loss which agriculture suffers by the waste of ammonia always produced in the coking of coal, and which might to a great extent be economised by very simple adjustments to the ovens used in coking. The economy and consequent reduction of price in the ammoniacal salts, by preventing this great loss in a material so well fitted to aid increased production in land, would be a great boon to agriculture. Suggestions have also been thrown out as to the more economical application of fuel for domestic and for manufacturing purposes.

In concluding this First Report, we cannot refrain from drawing attention to the kind manner in which we have been assisted by various public and private institutions and companies, without whose aid the expenses of the inquiry would have been materially increased.

The College for Civil Engineers, at Putney, afforded us, gratuitously, ground upon which to erect the boilers, and a house and yard for the stowage of the coals. The laboratory and workshops of the college were also placed at the disposal of the investigation, and have constantly been used. The Principal of the College, the Rev. Mr. Cowie, on all occasions, afforded his valuable aid in the prosecution of the experiments.

The owners of the collieries, from which the coals were obtained, furnished them free of expense; and the Great Western Railway Company, with an enlightened liberality, carried those sent to Bristol on their railway to London without charge. To Mr. George Rennie, the eminent engineer, the inquiry is especially indebted. This gentleman not only lent a tubular boiler, gratuitously, to enable the experiments to be repeated on this kind of boiler, but he also offered his premises for the prosecution of the experiments, which offer was accepted, until the larger space at the College for Civil Engineers was placed at the disposal of the investigation.

Such ready and liberal co-operation of the public shows their appreciation of the important practical results which may be expected from these experiments. Seeing the present effective state of the boilers and other apparatus erected at Putney, consequently, that the expenditure on this account has been incurred, and that any further charges for continuing these investigations would chiefly consist of payments of salaries to the persons employed as assistants, we would suggest for consideration, that these experiments may be extended to the coals of other districts than those the coals from which have been examined, and that the needful expenditure may be sanctioned for one or two years more. Should this be deemed advisable, we should anticipate that a most important body of information would be accumulated, alike important to the naval service and the public at large.

We have the honor to be, &c.,

H. T. De La Beche,
Lyon Playfair.

REMARKS ON THE FOREGOING REPORT.

By means of the above report on British coals, and his own trials on American coals, the writer has been enabled to institute a series of comparisons, not only between the several classes, but in some cases directly between individual samples having a similar constitution and apparently the same physical characters. The extent and other circumstances of the researches may also be compared. The number of samples of fuel tested at Washington in 1843, was *forty-five;* and the time devoted to the whole investigation, one year and eight months; the number tried at London was *thirty-one*, and the time employed two years and six months. Of the American, *eight* were anthracites, *ten* were free burning, semi-bituminous coals of Pennsylvania and Maryland; *ten* highly bituminous coals of eastern Virginia; *six* similar bituminous coals of England, Scotland, and Nova Scotia; *two* western bituminous coals; *one*, "natural coke" of Virginia; *two*, artificial cokes; *two*, mixtures of anthracite and bituminous coal, and *one*, pine wood.

Of the British series, *two* were anthracites, *ten** were free burning coals of Wales, *eight* highly bituminous coals of Wales, (resembling those of eastern Virginia,) *two*, English, and *five*, Scotch coals of high bituminousness; *three* were patent fuels, and *one* was wood, species not stated.

MANNER OF OBTAINING THE SAMPLES FOR TRIAL.

The coals for the British experiments were generally *selected* by one of the assistants visiting the several mining districts, and determining which coals should be allowed to enter into the competition. The American Samples were mostly sent by the proprietors of mines under a general invitation from the Navy Department.

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* The Welsh free burning coals are the Graigola, Old Castle fiery vein, Ward's fiery vein, Binea, Llangenneck, Duffryn, Mynydd-Newydd, Resolven, Bedwas, and Ebbw-Vale.

EVAPORATING APPARATUS.

The evaporating vessels used in the American and in the British researches were different in construction. In the former case, the vessel was a cylindrical boiler thirty feet in length, (the furnace being beneath the boiler,) three and a-half feet in diameter, having two interior return flues, each one foot in diameter, and side flues exterior to the boiler, by means of which the gases went completely round the boiler, after returning through the interior flues, making the entire length of circuit for the products of combustion from the centre of the grate under the boiler to their entrance into the chimney, 121 feet. The grate surface was $16\frac{1}{4}$ square feet, and the area of heat-absorbing surface, $377\frac{1}{2}$ square feet, so that the ratio of grate-surface to absorbing surface was as 1 to $23\frac{1}{4}$. The chimney was 63 feet high, with a cross section of 324 square inches.

The British Commissioners used a boiler of the Cornish form, twelve feet long and four feet in external diameter, having an interior flue two feet in diameter, within which the fire was built. The products of combustion, having traversed this flue, returned in a divided current through side flues exterior to the boiler, and finally in a united current passed under the boiler to the chimney, making a circuit of 36 feet in length. The heat-absorbing surface was 197.6 square feet; the area of grate, 5 square feet, and the ratio of grate surface to absorbing surface, 1 to $39\frac{1}{2}$. The chimney was $35\frac{1}{2}$ feet high, and had a cross section of $182\frac{1}{4}$ square inches. The amount of coal burned during the whole series of 144 trials at Washington was $62\frac{1}{2}$ tons; that consumed in the 82 trials at London, was $14\frac{1}{3}$ tons; the average weight of coal burnt at one trial, in the former case being 978 pounds, and in the latter $391\frac{1}{2}$ pounds.

The boiler of the London experiments was liable to one serious inconvenience as an experimental apparatus: it contained constantly water of very different temperatures; that lying beneath the level of the interior flue being by several degrees lower than that above it, and at its sides. The average difference between the bottom and surface temperature was no less than 70 degrees. The bottom water remains at rest, and realizes, in part, the old familiar class-experiment of boiling water in the upper part of a glass tube by applying a lamp near the top, while a lump of ice is kept confined at the bottom. This character of their boiler complicated the calculations, and at length led to the application of an apparatus

for pumping from the bottom a quantity of water, and sending it in spray, through several tubes, into the upper part of the boiler, and also of filling up the boiler through these multiple jets passing into its upper part.

ECONOMIC WEIGHT OF COALS.

In both the American and the British trials the economic weight of all the samples tested was determined by measuring, not in bushels, but in cubic feet; and the relation of the economic weight to the specific gravity of the coal, as found in the mine, was ascertained for each sample. This determination enabled the experimenters to calculate the cubic space required for the stowage of a gross ton of each kind of coal. In the American experiments this was ascertained for the coals as received, and in the ordinary marketable condition as to the size of the lumps. The British Commissioners on the contrary produced an artificial economic value by breaking every kind of coal up, before weighing, into fragments so small that no piece weighed more than one pound. This treatment caused nearly every sample to exhibit a higher economic weight than it would have done had it been weighed in the marketable state—that state in which it is usually put on board of steam vessels.

In the American report (p. 183) it is stated with respect to New York and Maryland Mining Company's coal, that "the variation in the weight of two cubic feet was, according to size of lumps, from 95.75 to 118.25 pounds. It will commonly be observed that the greater weights are given when a considerable portion of fine coal is mixed with the lumps. Such will, in general, be found to be the effect of giving the average sizes to coal, instead of measuring and weighing it entirely in lumps." Numerous remarks to the same general effect occur in the tables of daily observations. A single large lump in the charge-box, covered on every side by fine coal, was usually found to give the greatest weight to a charge.

Having determined the weight of a cubic foot of coal by direct experiment, and also the weight of water which a pound of each coal would convert into steam at 212°, the writer had computed and given in the report to the Navy Department, (Senate document, 386, 28th Congress, 1st session,) the weight of water which one cubic foot of each coal would convert into steam from 212°, and had made this the basis of his fifth table of ranks. (Report, p. 594.)

By breaking up their coals to the degree of fineness above-mentioned, and thereby giving them an artificial economic weight, the British Commissioners have obtained in nearly every case, greater quantities of steam per cubic foot of coal, than were given by analagous coals in the American trials. Thus the free burning coals of Wales, which are analagous to those of Maryland and Pennsylvania, have an average specific gravity of 1.31, while their American congeners have 1.357, or the latter are $3\frac{1}{2}$ per cent. heavier, in the mine, than the former; yet the twelve American free-burning coals, weighed in the marketable state, exhibited 52.84 pounds per cubic foot, and the ten Welsh free-burning coals, treated as above, 54.45 pounds. Adding to this latter weight $3\frac{1}{2}$ per cent. for the greater specific gravity of the American coals, we have 56.35 pounds as the weight of one cubic foot of them, if prepared by breaking up in the way above described. The above weight of 54.45 pounds of British coals, give an average of 543 pounds of steam, and the 52.84 pounds of American coal gave 510.35 pounds of steam. At this rate 56.35 pounds of the same coal gave 544.2 pounds of steam, showing the economic values, bulk for bulk, of the two coals in that state to be in fact identical.

By comparing about twenty different samples of American with the same number of British coals having *corresponding specific gravities*, it is rendered apparent that by the treatment to which the coals were subjected by the British Commissioners, (that is, by breaking them up so small that no piece should weigh more than a pound,) any given space is made to receive, on an average, $10\frac{3}{10}$ per cent. more weight, than when the same coals are measured in their marketable state and without this artificial preparation.

The following tabular view is derived from data furnished in part by the report on American coals, page 591, and in part by that on British coals, page 12—those numbers only representing *weight per cubic foot*, being selected from the table of each report, which belonged to coals, to the specific gravities of which corresponding specific gravities could be found in the other table. They embrace, however, nearly the whole range of the specific gravities of coal:

Corresponding specific gravities of British and American samples.	American Coals.		British Coals.	
	Number of samples compared to give the average weight per cubic foot.	Average weig't, per cubic foot, in the *marketable state.*	Number of samples compared to give the average weight per cubic foot.	Average weig't, per cubic foot, when broken so small that *no lump weighed over one pound.*
1.25	2	48.81	3	54.56
1.27	1	47.65	2	51.55
1.28	4	47.32	1	56.00
1.30	1	53 47	2	55.62
1.31	3	50.99	4	55.66
1.32	4	49.21	4	52.03
1.34	1	45.10	2	56.92
1.39	2	51.51	1	53.30
1.59	1	55.32	1	62.60
General averages	....	49.93	....	55.38

These general averages are in the ratio of 100 to 110.9, as above mentioned.

If, therefore, the weight of steam which was produced by a cubic foot of each American coal, be increased by $10\frac{9}{10}$ per cent., the weight thus increased will correspond to what would have been the weight of steam per cubic foot of the coal had it received this factitious economic weight.

Unless the practice of steamships could be made to conform to the experimental operations of the British Commissioners, (which however they do not recommend or even propose,) it is difficult to perceive the practical utility of reducing the coals in their experiments to the sizes indicated above. The results given, would, in fact, mislead practice and deceive the shipper as to the evaporative power of the coal which his bunkers would contain, unless he should in every instance take the precaution to contract for the delivery of his coal in the state of subdivision prescribed to themselves by Messrs. De la Beche and Playfair.

MOISTURE IN COALS.

It may be remarked that, though the British Commissioners determined the quantity of moisture in the coals upon which they experimented, they made no account of their results in any of their computations of heating power. This we regard as objectionable, where the moisture amounts to so great a quantity as that given in some of the analyses. Thus, of the two Dalkeith Scotch coals, that which came from the "Jewel seam," contained 9.36 per cent. of moisture, and evaporated only 7.08 pounds of water from the boiler per pound of coal; while the coal from the "Coronation seam," gave but 5.88 per cent. of moisture and evaporated 7.71 pounds of water from the boiler. In both cases this hygrometric water replaced so much coal when weighed out to the fireman, and for *that* reason was to be deducted from the weight, in order to get the actual weight of coal burned. Besides this, as so much water was thrown upon the grate to be evaporated, instead of being put into the boiler for that purpose, for *this* reason also, it must be regarded as having been deducted from the useful effect of the fuel. Consequently, the weight of coal must, in each case, be reduced by the per centage of its moisture, and the weight of water delivered to the boiler, must be increased by a like per centage of the weight of coal burned, to get the relative values of the two fuels in like states of dryness. If we deduct the weight of ash in each of these two coals from 100, we get the *combustible matter, including moisture*, 95.63 and 96.90; and computing the steam for one pound of this combustible matter, we get 7.40 and 7.95, of which the difference is 0.55 pound or 7.4 per cent. of the smaller number. If, again, we deduct the per centage of moisture in each coal, from that of the *combustible*, we obtain 86.27 and 91.02 as the true relative quantities of dry combustible, in each variety, and adding to the weight of water evaporated from the boiler by each pound of the moist combustible, the weight of water which it evaporated from the body of the coal itself, we obtain 7.17 and 7.76 as the respective amounts evaporated per pound of moist coal; and as these quantities were evaporated by .86 and .91 of a pound of *dry combustible matter*, we obtain as the evaporative efficiency of one pound of such combustible 8.37 and 8.53, or the difference is reduced to sixteen 100ths of a pound of water to each pound of combustible, which is two per cent. only, of the smaller number. This difference may probably be accounted for by the difference in the composition of the dry combustible matter of the two varieties of coal. In the Jewel seam the fixed carbon was to the volatile combustible as 1.11 to 1; while in the Coronation seam it was as 1.24 to 1. This greater evaporative efficiency among bituminious coals, in proportion as the ratio of their fixed to their volatile combustible material, is higher, is a general truth, established as well by the British as by the American experiments. It was fully brought out in the report of the latter. (See next page.)

TABLE—*showing the relation of evaporative power to the ratio*

AMERICAN EXPERIMENTS.

Names of Coal from Report on American Coals.	Ratio of fixed to volatile combustible.	Steam to 1 of Coal from 212°.
Scotch	1.257	6.940
Liverpool	1.513	7.842
Midlothian, (screened)	1.567	8.944
Tippecanoe	1.599	7.748
Newcastle	1.601	8.656
Midlothian, (new shaft,)	1.684	8.750
Cannelton	1.719	7 341
Midlothian, (average)	1.780	8.295
Clover Hill	1.793	7.675
Chesterfield Company	1.917	8 998
Pittsburg	2.014	8.204
Creek Company	2.032	8.417
Pictou, (New York)	2.105	8.412
Midlothian, (900 feet shaft)	2.239	8 584
Crouch & Snead	2.499	8.345
Pictou, (Cunard's)	2.593	8.485
Sidney	2.838	7.987
Barr's Deep Run, (Va.)	3.435	9.018
Cambria County, (Pa.)	3.656	9.240
Quin's Run	4.046	10.272
Karthaus	4.110	9.091
Easby & Smith's	4.786	9.965
Atkinson & Templeman's	4.937	10.699
Blossburg	4.946	9.724
Easby's "Coal-in-Store,"	5.089	10 018
Lycoming Creek	5.181	8.911
Dauphin and Susquehanna	5.374	9.343
Neff's	5.880	9.442
New York and Maryland Mining Company's	5.971	9.777
Natural coke of Virginia	6.269	8.473
Lyken's Valley	12.337	9.463
Lehigh	16 869	8.932
Lackawanna	23.132	9.789
Beaver Meadow, slope No. 5	25.363	9.879
Forest Improvement	29 754	10.058
Peach Mountain	30.095	10.112
Beaver Meadow, slope No. 3	37.308	9.207

between fixed and volatile combustible ingredients in Coals.

BRITISH EXPERIMENTS.

Names of Coal from Report of the British Commissioners.	Ratio of fixed to volatile combustible.	Steam to 1 of Coal from 212°.
Dalkeith Coronation	1.14	7.71
Coleshill	1.20	8.00
Fordel Splint	1.21	7.56
Lydney, (Forest of Dean)	1.21	8.52
Dalkeith Jewel Seam	1.24	7.08
Porthmawr Rock Vein	1.37	7.53
Three-quarter Rock Vein	1.41	8.84
Grangemouth	1.43	7.40
Wallsend Elgin	1.48	8.46
Pontypool	1.73	7.47
Broomhill	1.78	8.75
Cwm Nanty Gros	1.79	8.42
Wylam's Patent Fuel	1.85	8.92
Cwm Frood Rock Vein	2.08	8.70
Bedwas	2.39	9.79
Bell's Patent Fuel	2.43	8.53
Mynydd Newydd	2.91	9.52
Ebbw Vale	3.59	10.21
Pentrepoth	4.73	8.72
Resolven	5.12	9.53
Pentrefelin	5.52	*6.36
Duffryn	5.56	10.14
Warlich's Patent Fuel	5.89	10.36
Oldcastle Fiery Vein	6.02	8.94
Graigola	6.12	9.35
Llangennech	6.30	8.86
Binea	7.65	9.94
Slievardagh	15.95	9.85
Welsh Anthracite	19.60	9.46

* In respect to the sample called Pentrefelin coal, the report states, that "owing to the extreme smallness of the coal, there was great difficulty both in lighting the fire and in getting the steam up: the same cause no doubt affected the trials throughout, as the work done was very small in comparison with that of other coals. As the fire burnt up, a distinct hissing noise was heard, and on opening the fire door, large quantities of ignited particles, presenting a bright scintillating appearance, were carried over the fire bridge, and passed into the flues. On stoking the fire, a considerable quantity of unburnt coal slipped through the bars, which on being again thrown up, increased the difficulty of getting a good fire—the quantity of cinders and ashes left was consequently very large."

The total waste matter, owing to the cause above stated, was 27.4 per cent. Analysis proved that nearly one half of it was still combustible, but it appears to have been so enveloped in the earthy constituents as to be incapable of any profitable combustion under the steam boiler. Deducting the *waste* and *moisture* from the weight of coal consumed, and allowing for the effect of the matter really burnt, a pound of Pentrefellin *combustible* produced 8.84 pounds of steam. This

The two series of experiments, American and British, are represented in the two preceding pages, side by side, showing in one column the ratio of the fixed to the volatile combustible matter in each coal, and in the other the quantity of steam which 1 part of coal produced. It will not fail to be remarked, that a decided general increase of evaporative power takes place with the increasing ratio of fixed combustible up to about 5 or 6 to 1. After passing this limit, and approaching the anthracite class, the quantity of carbon which is volatilized in coking, as compared with the whole quantity of volatile matter, is diminished, as shown by the British series of per centages of carbon compared with the amount of fixed carbon in each coal.

The following results, selected from the foregoing table, exhibit the ratios of fixed to volatile combustible matter in four samples varying considerably from each other, and the evaporating power of the *combustible matter* of each kind of coal, excluding the *moisture and ashes.* The first is from the American, and the second from the British report:

AMERICAN EXPERIMENTS.

	Coals.	Ratio of fixed to volatile matter.	Evaporative power of the *combustible matter.*
1.	Scotch coal	1.25	7.72
2.	New Castle coal,	1.60	9.18
3.	Virginia Midlothian, new shaft	1.68	9.75
4.	Cumberland, Atkinson & Templeman	4.94	11.62
	BRITISH EXPERIMENTS.		
1.	Scotch, Dalkeith Jewel seam	1.11	7.42
2.	Broomhill, not far from Newcastle	1.78	8.96
3.	Cwm Frood, rock vein	2.08	9.07
4.	Ebbw Vale, (Welch,)	3.59	10.53

COHESIVE POWER OF COALS.

The British Commissioners have given an interesting series of experiments (column G, table II., p. 73) on the relative cohesive powers of the several coals, or their power to bear handling, transportation, and rolling upon each other. Having broken them up as already mentioned to such a size that no lump weighed over one pound, they sifted them upon a seive of one inch meshes, took one hundred pounds of what was left on

brings it much nearer to a conformity with others of its class. The defect of falling into small fragments and passing through the grate was observed in certain American coals. (See report on American coals, p. 367.)

the seive, placed them in a barrel, much like an old fashioned barrel churn, with flanges projecting from its periphery inwards towards the centre, and giving this cylinder fifty turns, took out its contents and again sifted and weighed what was left on the seive. The per centage by weight retained, was taken as representing the cohesive power of the coals.

NITROGEN AND AMMONIA IN COALS.

Having, after the manner of Will & Varentrap, ascertained the quantity of nitrogen in the coals, the British Commissioners employed the results in computing the quantity of ammonia and of sulphate of ammonia which might be obtained during the destructive distillation of each kind of coal.

The highest proportion of sulphate of ammonia which was obtained from the coals tried, was 10.18 pounds, from 100 pounds of coal.

This subject commends itself to gas manufacturers and agriculturists, rather than to engineers and furnace men.

The large amount of ammoniacal liquors obtained in the manufacture of illuminating gas, is, in this country, allowed to run chiefly to waste; whereas, by adopting the sulphuric acid purifier, very large quantities of the sulphate of ammonia, a salt in high request among enlightened farmers, would be obtained. (See Knapp's Chem. Technology, American edition, vol. 1, p. 476.)

EXPANSION OF WATER AT HIGH TEMPERATURES.

The temperature compared with the observed bulk and weight of water in a boiler, has been re-examined by Messrs. De la Beche and Playfair; and, as far as they go, their results confirm essentially those in the American report. These analagous results are found at page 13 of the American report, and page 53 of the British report. The British Commissioners extended their experiments from 70° to 212°, while the American reached from 66° to 230°. The American boiler held, when filled to its normal level with water at 66° temperature, 12,795 pounds; and when heated to 230°, without losing any steam, 493 pounds had to be withdrawn to bring the level once more down to the normal point.

"The observations made on the gradual rise of temperature, and the corresponding weights of water which it had taken to fill the boiler, as much as the expansion by heat now did, gave the following table:

From

66°	to 114½,	viz:	48°.5,	increase	equiv't to bulk of	69 lbs.	at 58°,	or	1.42 lbs.	to	1°
114½	to 149	"	34 .5,	"	"	81	"	"	2.35	"	1
149	to 180	"	31	"	"	97	"	"	3.13	"	1
180	to 207	"	27	"	"	86	"	"	3.18	"	1
207	to 223	"	16	"	"	89	"	"	5.56	"	1
223	to 230	"	7	"	"	71	"	"	10.14	"	1

"This great increase in the rate of expansion of water above the boiling point, being nearly 7¼ times as great in the range of the last 7° as in the first stage of 40°, may probably possess some interest beyond that which attaches to it as a means of correcting certain observations taken during this research." It will be remarked, that this rapid augmentation of the rate of dilation of water in iron, is not prevented by the conversion, at the same time, of a considerable quantity of water into steam of a high density.

The British Commissioners operating with a smaller boiler obtained of course smaller numbers of pounds of water to represent the expansion of the water. The following is their table, to which we have added a fifth column showing the average rate of expansion for one degree, between the successive temperatures marked in the first column.

Table showing the expansion of water in the boiler at different temperatures.

Temperature of water Fahrenheit.	Ratio of apparent to real weight.	Actual weight of water in boiler when filled to normal point	Difference between actual and apparent weight.	Difference for 1 degree Fahrenheit.
70°	1.0000	4730.000	0.000	.000
80	0.9996	4728.108	1.892	.189
90	0.9992	4726.216	3.784	.189
100	0.9987	4723.950	6.050	.226
110	0.9983	4721.960	8.040	.199
120	0.9979	4719.097	10.903	.286
130	0.9974	4717.795	12.205	.130
140	0.9971	4715.283	14.717	.251
150	0.9967	4714.012	15.988	.127
160	0.9954	4708.242	21.758	.577
170	0.9940	4701.620	28.380	.662
180	0.9923	4693.579	36.421	.704
190	0.9901	4683.173	46.827	1.040
200	0.9879	4672.767	57.233	1.040
202	0.9869	4668.037	61.963	2.365
204	0.9859	4663.307	66.693	2.365
206	0.9849	4658.577	71.423	2.365
208	0.9839	4653.847	76.153	2.365
210	0.9829	4649.117	80.883	2.365
212	0.9819	4644.387	85.613	2.365

The second column, as well as the one which we have added, renders it evident that all the numbers in the third column were not obtained by actual observation. The second and third, and the last six or seven numbers, are evidently the results of interpolation. The law of expansion undergoes no such change *per saltum* as would be implied in the supposition, that from 180° to 200° it should be constantly 1.040, and, all at once, more than doubling itself, should from 200° to 212°, continue to be exactly 2.365 lbs. to one degree of increase in temperature. As the American boiler had about three times the capacity of the British, and as the water in the former was heated uniformly throughout by building the fire underneath, while the latter, in consequence of building the fire in the interior, had a part of its water constantly cooler than the rest, so we ought to expect that the amount of expansion for one degree should be different in the two boilers. The British experiments confirm, as far as they go, those previously made here, in proving the rapid increase in the rate of expansion of water in iron. It was more important to the British than to the American experimenters to know accurately the contents of their boiler at every temperature, inasmuch as the former employed a part of their coal along with a small quantity of wood for heating up their boiler and its contents. This expansion of water in iron it is highly important, also, for the steam engineer to be acquainted with.

From the following table a comparison may be made between the amount of expansion of water in iron, as determined by the British Commissioners, and that ascertained at Washington as given on the preceding page. It appears that the rate of expansion, expressed in pounds, to 1° of temperature, was six times as great at $193\frac{1}{2}$° as at $90\frac{1}{4}$°, being 1.2 at the former, and but .2 at the latter temperature.

Temperatures observed.	Contents of the boiler in pounds for different temperatures.		Differ'e in weight at the successive temperatures.	Difference in weight for 1° Fahrenheit.
At 66°	4730.756			
		diff. 48½°	9.885	.203
114½	4720.871			
		" 34½°	16.632	.482
149	4714.139			
		" 31°	20.560	.663
180	4693.579			
		" 27°	32.637	1.208
207	4660.942			

ESTIMATION OF THE WATER SUPPLIED TO THE BOILER, ACCORDING TO ITS TEMPERATURE.

The expansion of water in the supply tank was examined in our experiments, between 58 and 90 degrees; by the British Commissioners, between 40 and 80 degrees.

Table of co-efficients, from the American Report, for correcting the weight of water delivered from the tank to the boiler at different temperatures.

Temperature.	Ratio of actual to apparent weight of water.
58°	1.0000
65	0.9985
70	0.9977
75	0.9969
80	0.9963
85	0.9957
90	0.9953

"Small as is the correction required by the cause now under consideration, it has not been deemed expedient to omit the estimation of its efficiency in modifying the results."

The American water tank was made of wood, the British of plate iron, and, of course, a different co-efficient of expansion would be found applicable.

The following are the results of the British experiments to determine the expansion and contraction of water in the iron tanks, taking 70° as the normal temperature.

Temperature Fahrenheit.	Actual weight of an unity of water.	Temperature Fahrenheit.	Actual weight of an unity of water.
40°	1.001464	62°	1.000712
42	1.001451	64	1.000534
44	1.001439	66	1.000356
46	1.001426	68	1.000178
48	1.001414	70	1.000000
50	1.001401	72	.999763
52	1.001294	74	.999527
54	1.001196	76	.999290
56	1.001094	78	.999054
58	1.000992	80	.998818
60	1.000890		

HEATING POWER OF COALS, ACCORDING TO THEIR CLASSES.

The average heating powers computed from their experiments by the British Commissioners, agree very closely indeed with the averages for corresponding classes of coals given at Washington. Thus, by the

AMERICAN EXPERIMENTS,

Ten anthracites gave steam to one of coal	9.56
Eleven Pennsylvania and Maryland free-burning coals	9.68
One Newcastle coal	8.65
Ten Virginia bituminous coals	8.48
Four Liverpool and Nova Scotia	8.18
Three Scotch and Western	7.49
And the mean of six averages	8.66

BRITISH EXPERIMENTS,

Two anthracites gave steam to one of coal	9.65
Ten Welch free-burning coals	9.58
One Broomhill	8.75
Eight Welch bituminous	8.00
One Forest of Dean	8.52
Five Scotch	7.64
Mean of six averages	8.69

The pine wood used at Washington gave 4.69; the wood of inferior quality used at London, gave 3.10, as its evaporative power.

PATENT FUEL FOR STEAM SHIPS.

Highly interesting to steam navigation are the trials which the British Commissioners made of several patent fuels, proving that some of those fuels contain a much greater evaporative power *under a given bulk* than any of the coals, in their ordinary merchantable state. This may be illustrated by a comparison between Warlick's patent fuel—of which

	Lbs. of steam per 1 lb. of fuel.	
One cubic foot gave	715.35	
Ward's fiery vein coal, which gave	608.78 (a maximum	among coals.
Dalkeith jewel seam	352.58 (a minimum	among coals.

Thus it appears Warlick's patent fuel is 17.4 per cent. superior in evaporative power, per cubic foot, to the best, and 103 per cent. superior to the least efficient of the coals, in their natural state. (See column I, p. 73.)

LATENT HEAT AND HEAT OF CAPACITY OF WATER.

The calorific co-efficients of M. Regnault were adopted by the British Commissioners for computing the latent heat of the vapor of water, and the tendency of these co-efficients is to bring out a higher calculated calorific efficiency than that which would be given by the higher co-efficient directly determined by our own researches. This latter co-efficient gave 1030° for the latent heat of the vapor of water.

To illustrate the effect of adopting the co-efficient of M. Regnault, for computing the calorific efficiency of the coals, we may present an example afforded by the above average evaporative power of American coals, viz:—8.66 lbs. of steam from water at 212°. If the water be supposed to have been delivered to the boiler at 60°, then the weight of water at that temperature would be 7.54 lbs. to 1 pound of coal.

Taking the latent heat of the vapour of water, when generated at 212°, to be 1030°, the sensible heat imparted to the water before it is evaporated, is 212°—60°=152°; and the whole quantity of heat, taken up in heating and evaporating, is 152+1030=1182°. Hence, the evaporative power from water, at 212° is,

$$7.54 \times \frac{1182}{1030} = 8.66.$$

By using Regnault's co-efficient, these numbers vary as follows:

$$7.54 \times \frac{1117.7}{965.7} = 8.72$$

hence the difference by the two methods, is, .06 lbs.=0.69 per cent., or say *seven-tenths of one per cent.*, of the smaller number. This difference will be slightly enhanced by using also Regnault's numbers for the quantity of heat in water at different temperatures. These numbers show, that in heating water from 60° to 212°, there is expended a quantity of heat equal to 152°.89, and the calculation would give

$7.54 \times \frac{1118.59}{965.7} = 8.73$ lbs. of steam from 212°, or about eight-tenths of one per cent. above what is given by the American calculations. This difference practice will seldom or never appreciate.

USE MADE OF THE HEATING POWER OF COALS.

The British Commissioners employed a part of the coal burned in giving temperature to the boiler, its contents, and the brick work of its setting, and a part in generating steam, instead of heating up the boiler and furnace with wood, (as in the American experiments,) and then using the whole heating power of the coal solely to generate steam. They thus complicated considerably the calculations.* In considering the effect of that part of the fuel which is used in heating up the water in the boiler, they have not included that expended on the boiler itself, which, from its considerable weight and high specific heat, might reasonably require a computation. As the experiments on American coals were commenced with the furnace, boiler, and contents, all at normal temperature, such an allowance was not required.

COMPOSITION AND HEAT-ABSORBING POWER OF THE GASES OF THE CHIMNEY.

Though the British Commissioners have made experiments on the gases of the chimney, they have not used them to ascertain how much of the whole heating power was expended on those gases. They came to a conclusion in regard to the oxygen remaining unconsumed in the gases, identical with that previously reached by the American researches, viz: that in ordinary steam-boiler furnaces of good construction, the oxygen which has not been consumed, is from one-fourth to one-half of the whole quantity originally in the air.†

From the columns under "ratio to total bulk of dry gases, of carbonic acid and oxygen, in table 194," it is found that the average per centage of those two materials and their sum, for the several classes of coals, was as follows, viz:

* See their formula, pages 66–68.

† See American report, page 582.

(1.) Of the anthracite class, by 22 analyses, the carbonic acid was 9.443, oxygen 12.094—sum 21.537.

(2.) Maryland free-burning, by 10 analyses, the carbonic acid was 10.819, oxygen 10.284—sum 21.103.

(3.) Pennsylvania free-burning, by 9 analyses, the carbonic acid was 9.951, oxygen 10.572—sum 20.523.

(4.) Virginia bituminous, by 16 analyses, the carbonic acid was 9.564, oxygen 11.598—sum 20.862.

(5.) Foreign bituminous, by 11 analyses, the carbonic acid was 10.927, oxygen 9.886—sum 20.813.

(6.) Cannelton bituminous, by 2 analyses, the carbonic acid was 13.207, oxygen 5.510—sum 18.717.

(7.) Pine wood, by 2 analyses, the carbonic acid was 9.214, oxygen 10.210—sum 19.427.

In several of these cases, the sum of the oxygen and carbonic acid is almost identical with the proportion in which oxygen is found in the atmosphere. Thus—Nos. 2, 3, 4, and 5, give a mean of 10.315 of carbonic acid, 10.510 of oxygen. An excess may probably be referred, in some instances, to the existence of carbonic acid in the coal, in the state of carbonates; and a deficiency to the production of much water of combustion, as in cases of the highly bituminous coals and of pine wood.

FIXED CARBON AS A MEASURE OF HEATING POWER.

Reference is made in the report on American coals to an opinion which had gained some currency, to the effect, that the heating power of coals is always proportionate to the quantity of fixed carbon which they severally contain; that is, to the amount of coke obtained by destructive distillation, diminished by the amount of ashes left after complete incineration. This point is also referred to by the British commissioners at page 13 of their report.

The commissioners then proceeded to examine the question by calculating the heating power of the carbon of the coke, theoretically, and comparing the results with the evaporative effects. Instead of this, we prefer to arrange the coals according the per centage of fixed carbon, and set opposite to each, the weight of steam generated by one pound of the coal, as in the subjoired table:

Table exhibiting the classification of the British coals in the order of their per centage of fixed carbon determined by coking and incineration, and a comparison of this with their evaporative powers, derived from the data furnished in the tables at pages 11 and 12 of the British report.

Name of Coal.	Per ct. of fixed Carbon.	Average Carbon.	Evaporative power.	Average steam power.	Calculated steam power.
1. Dalkeith Jewel Seam......	45.43		7.08		
2. Coleshill	47.08		8.00		
3. Wallsend Elgin..........	47.75		8.46		
4. Parkend, Lydney.........	47.80		8.52		
		47.01		8.01	5.44
5. Fordel Splint	48.03		7.56		
6. Porthmaur Rock Vein......	48.38		7.53		
7. Dalkeith Coronation.......	50.40		7.71		
8. Three-quarter Rock Vein...	51.54		8.84		
		49.58		7.91	5.73
9. Grangemouth	53.08		7.40		
10. Broomhill	56.13		8.75		
11. Pontypool...............	59.28		7.47		
12. Cwm Nanty Gros.........	60.00		8.42		
		57.12		8.01	6.60
13. Wylam's Patent Fuel......	60.96		8.92		
14. Cwm Frood Rock Vein....	62.80		8.70		
15. Bedwas..................	64.76		9.79		
16. Bell's Patent Fuel	66.74		8.53		
		63.81		8.98	7.38
17. Mynydd Newydd.........	71.56		9.52		
18. Resolven...............	71.69		9.53		
19. Ebbw Vale..............	76.00		10.21		
20. Old Castle Fiery Vein.....	76.16		8.94		
		74.60		9.55	8.62
21. Llangenneck.............	77.15		8.86		
22. Pentrepoth	79.14		8.72		
23. Slieverdach, (anthracite,)	79.30		9.85		
24. Duffryn.................	81.04		10.14		
		79.15		9.39	8.95
25. Warlich's Patent Fuel.....	82.19		10.60		
26. Graigola	82.26		9.35		
27. Binea	84.14		9.94		
28. Welsh Anthracite.........	91.38		9.46		
		84.99		9.84	9.84

An inspection of the above table will render it abundantly evident, that though the amount of fixed carbon in coal may serve as a general index, it can by no means be regarded as the *measure* of the heating power of coals.

In the first place, the right-hand column shows that the steam-generating power of coals having 57 per cent. of fixed carbon, is no greater than that of coals possessing only 47 per cent.

It also shows that the four coals which had $74\frac{6}{18}$ per cent. of carbon had a higher heating power than the four which contained $79\frac{1}{10}$ per cent. In the next place, the proportion of the fixed carbon varies in the several sets of four samples, from 47.01 to 84.99, or the latter is 80 per cent. more than the former proportion of fixed carbon; while the steam produced by them respectively, varied only from 8.01 to 9.84, the latter being but 22.8 per cent. more than the former. This want of all true proportion between the *fixed carbon* and the *heating power* will of necessity preclude the use of the one as a *measure* of the other.

In the progress of the researches on American coals, it was repeatedly proved that the quantity of carbon which remains fixed, after the coal has been subjected to a red heat, varies for the same specimen of coal according to the greater or less rapidity with which the heat is applied.

COMPARISON OF CARBON AND HYDROGEN WITH THE PRACTICAL HEATING POWER.

The following table shows that while of the seven sets of calculated efficiencies, the averages (column 3) increase from 12.591 to 15.550, or by $23\frac{1}{2}$ per cent. of the former number, the experimental averages first diminish from 8.66 to 8.18, and then increase to 9.88 the difference between the first and the last of these numbers being 14 per cent. of the first. It will also be observed that this principle of classification brings together at the very head of the list, the Scotch coal of the Dalkeith Jewel Seam and the Slieverdach (Irish) anthracite—two species of fuel which are, in all their characters, as well as in their evaporative powers, the very antipodes of each other. A principle of computation which classes together materials so utterly unlike, can have no foundation in nature, and should have no place in science. The very highest of the theoretical efficiencies (15.964) is 29.6 per cent. greater than the lowest, (12 313); and the very highest practical efficiency by experiment (10.60) is 49.7 per cent. greater than the lowest, 7.08. It is therefore evident that the practical heating powers of these coals did not correspond even to the *order* of the calculated results, when classed by fours or fives together, and that consequently no direct *relation* can be found between the powers of the practical series and those of the theoretical one, founded on the combination of the calculated carbon, with that of the hydrogen, efficiency.

Arrangement according to the order of numbers obtained by multiplying the weight of carbon in each coal, by 13268, and the weight of hydrogen by 62470, and dividing the sum of the products by 965.7, (the latent heat of steam by Regnault,) the numbers being derived from column E, and compared with those in column A, (pages 72 and 73.)

The experimental efficiencies.	Numbers from column E, theoretical efficiency from carbon and hydrogen.	Average calculated efficiency.	Actual efficiency by experiments from column A.	Average experimental efficiency.	Hydrogen in excess beyond the equivalent of the oxygen.	Average of hydrogen in excess.
Dalkeith Jewel Seam.....	12.313		7.08		3.20	
Slieverdach Anthracite..	12.482		9.85		2.30	
Dalkeith Coronation......	12.772		7.71		3.41	
Coleshill..........	12.799	12.591	8.00	8.66	4.11	3.25
Porthmawr Rock Vein...	12.811		7.53		4.34	
Three-quarter Rock Vein	13.106		8.84		4.30	
Park End, Lydney........	13.257		8.52		4.88	
Wallsend Elgin............	13.422	13.149	8.46	8.34	4.59	4.53
Graigola......................	13.563		9.35		2.94	
Grangemouth................	13.692		7.40		4.21	
Fordel Splint...............	13.817		7.56		4.46	
Cwm Nanty Gros.........	13.932	13.751	8.42	8.18	4.90	4.13
Resolven	13.971		9.53		4.75	
Llangenneck....	14.260		8.86		3.90	
Pontypool....................	14.295		7.47		5.11	
Wylam's Patent Fuel.....	14.331	14.214	8.92	8.69	4.86	4.65
Welsh Anthracite.........	14.593		9.46		3.14	
Ward's Fiery Vein..	14.614		9.40		3.93	
Cwm Frood Rock Vein..	14.788		8.70		5.39	
Pentrepoth..................	14.838	14.708	8.72	9.09	4.10	4.14
Bedwas.......................	14.841		9.71		5.82	
Broomhill....................	14.863		8.75		5.79	
Mynydd Newydd..........	14.904		9.52		5.36	
Oldcastle Fiery Vein......	14.936	14.886	8.94	9.23	4.47	5.36
Powel's Duffryn............	15.092		10.14		4.59	
Binea..........................	15.093		9.94		4.51	
Bell's Patent Fuel.........	15.417		8.53		5.17	
Ebbw Vale...................	15.635		10.21		5.10	
Warlich's Patent Fuel	15.964	15.550	10.60	9.88	5.56	4.97

HEATING POWER MEASURED BY THE REDUCTION OF LITHARGE.

The method of Berthier, applied to determine heating powers, on the supposition that the latter are proportionate to the quantity of oxygen required for the consumption of the coal, was employed both in the American and British researches. The results of the former are found in the general synoptical table of American coals hereafter given. The following are the numbers obtained by the British Commissioners.

Names of coals in the order of reductive powers.	Lead reduced by 1 part of coal.	Average reductive powers.	Evaporative power in lbs. of steam from 212 deg. to 1 of coal.	Average evaporative power of each set.
1. Dalkeith Coronation Seam	24.56		7.71	
2. Porthmawr Rock Vein	24.78		7.53	
3. Broomhill	25.32		8.75	
4. Coleshill	26.14	25.20	8.00	7.99
5. Dalkeith Jewel Seam	26.42		7.08	
6. Three-quarter Rock Vein	26.62		8.84	
7. Pontypool	27.46		7.47	
8. Bedwas	28.20	27.17	9.79	8.29
9. Cwm Frood Rock Vein	28.30		8.70	
10. Grangemouth	28.48		7.40	
11. Bell's Patent Fuel	28.52		8.53	
12. Wylam's Patent Fuel	28.82	28.53	8.92	8.38
13. Fordel Splint	29.00		7.56	
14. Wallsend Elgin	29.06		8.46	
15. Cwm Nanty Gros	29.64		8.35	
16. Duffryn	30.00	29.42	10.14	8.63
17. Slieverdach Anthracite	30.10		9.85	
18. Mynydd Newydd	30.34		9.52	
19. Pentrepoth	31.16		8.72	
20. Old Castle Fiery Vein	31.42	30.75	8.94	9.26
21. Ward's Fiery Vein	31.46		9.40	
22. Warlich's Patent Fuel	31.50		10.60	
23. Binea Coal	31.64		9.94	
24. Ebbw Vale	32.00	31.76	10.21	10.04
25. Graigola	32.08		9.35	
26. Resolven	32.16		9.53	
27. Llangenreck	32.66		8.86	
28. Slieverdach Anthracite	33.48	32.59	9.85	9.39

The last of the above average proportions of lead is 29 per cent. greater than the first, while the corresponding averages of steam generated, show a difference of 17½ per cent.; or excluding the last set of four samples, 31.76 is 26 per cent. more than 25.20, and 10.04 is 25.3 per cent. more than 7.99; so that the method of Berthier up to this point proves to be a much nearer approximation to a true measure of economical value than either of the preceding methods.

On pages 584–585 of the report on American coals will be found a similar comparison between the evaporative and the reductive powers of American coals.

PER CENTAGE OF CARBON, AS A MEASURE OF HEATING POWER.

At page 517 of the Report on American coals, after a discussion of ultimate analyses of New Castle Coal, and showing the intimate relation which those analyses had with the question of heating power, the following remark was added:

"The discussion of the measure of heating power, contained in the present description, may serve to show the bearing upon each other of the several modes of testing coals. It is to be regretted that an opportunity has not yet occurred of subjecting all the samples of coal to the same species of analyses on the organic method, and with mixtures from fragments of many specimens, in order that the average ultimate, as well as proximate constituents of each may become known. The earnest desire repeatedly expressed by the Department to be in possession of the results of these experiments, and the want of further appropriations to prosecute this important research to its proper termination, has hitherto precluded the possibility of accomplishing this purpose in the manner originally designed."

On the 11th of February, 1845, the writer made to the Academy of Natural Sciences of Philadelphia a communication relative to the different methods of testing the heating power of fuel, the following account of which will be found in the proceedings of that institution, Vol. II, page 202. It will be hereafter seen how completely the British experiments confirm the deduction made from the six trials then compared:

"Some of the methods which have been hitherto employed by chemists and others, to ascertain the relative heating powers of fuel, are—

"1. *The heating of water,* without converting it into vapour, as practised first by Rumford, and more recently by other experimenters, particularly by Despretz and Dulong. The French chemists assume as the *unit of calorific power,* 1 gram of water heated 1° centigrade, (1°.8 Fahr.) The number of such units produced by burning 1 gram of combustible is termed its *colorific efficiency.*

"2. *The melting of ice,* as in the calorimeter of Lavoisier and Laplace, also employed by Hassenfratz. The heat of fluidity, (135° Fahr,) is here the measure of effect.

"3. *The heating of air,* or maintaining a certain difference between an interior room in which combustion is conducted, and an exterior one, kept cool by the open air. The *length of time* such difference is maintained by a given weight of each fuel, is the measure of its efficiency. This is the method of Mr. Marcus Bull.

"4. *Combustion in contact with metallic oxides,*—measuring the heating power by the weight of metal, reduced on the supposition that the latter is proportionate to the weight of oxygen withdrawn. This is illustrated by M. Berthier's process by litharge.

"5. *The reduction of the nitrate or the chlorate of potash to the state of a carbonate,* by fusing these salts, and then gradually adding the combustible, till complete saturation has taken place.

"6. *The practice of the Cornish engineers,* of measuring the efficiency by the weight of water which a given bulk of it (as 1 bushel) will raise one foot high, when burned under a boiler driving a pumping engine.

"7. *The distillation of coals to ascertain the weight of fixed carbon which they contain,* suggested by the experiments of Mr. Fyfe, of Edinburgh; the weight of that constituent being supposed to measure the heating power.

"8. *Ultimate analysis;* which assumes that the quantity of heat developed by an organic combustible, depends on the heating power of the carbon which it contains, added to that of its excess of hydrogen, above what is required to combine with its oxygen in forming water. This method has been applied by Messrs. Peterson and Schoedler to wood, and by Richardson, Regnault, and others, to coals.

"9. *The direct or practical trial by evaporation,* as practised by Messrs. Parkes, Wicksteed, Fyfe, Schaufhautl, and Manby, in Great Britain; by Messrs. S. L. Dana, A. A. Hayes, J. A. Francis, and more recently by the writer in this country. (The results of the trials last referred to are contained in the

Report to the Navy Department on American coals recently published by Congress.)

"10. *The melting of iron* either in a reverberatory or a cupola furnace, the weight of metal fused by one part of combustible being the standard of comparison.

"11. *The performance of smith's work of a uniform character*, such as the manufacturing of chains by means of the several varieties of fuel. The number of links of chain formed by a given weight of each coal, is here the measure of useful effect.

"The object of the present communication is mainly to exhibit the relation between the results obtained by the *eighth*, and those by the *ninth* method of trial above mentioned.

"The existence, in bituminous coals, of variable proportions of nearly pure charcoal, is referred to as furnishing evidence of a want of homogeneousness in this class of bodies. A diversity of results may consequently be expected when ultimate analysis is resorted to for the purpose of establishing a theory of transmutations, or of demonstrating what changes have occurred in bringing vegetable substances into the state of bituminous coal. Those who assume *woody fibre* as the sole basis from which it has been derived, do not pretend to prove that the other proximate constituents of vegetables, the resinous matter, for example, and the oily components of seeds, have been wholly removed. Hence analyses of coal applied to this purpose may not always lead to unobjectionable inferences. But as means of determining the calorific power of combustible bodies, they may, especially when performed on average samples, or multiple specimens, afford information both interesting to science and valuable to the arts.

"The relation between the calorific power *calculated* from analysis, and the practical heating power decided by evaporating water, is determined for six different varieties of bituminous coals, varying considerably in their composition.

"In applying calculations to the ultimate analysis of coals as well as to the products of combustion, the atomic weight of carbon is assumed to be six, of oxygen eight, and of nitrogen fourteen times that of hydrogen, in accordance with the recent determinations of Dumas. In calculating evaporative powers, the latent heat of steam is taken at 1030°.

"In ascertaining the relative efficiencies and values of combustible bodies, with a view to economical applications, it is necessary to take them either as found in nature, or as supplied to commerce, including, of course, whatever impurities they may chance to contain. But in order to deduce general relations between bodies differently constituted, in regard particularly to their combustible constituents, the comparison must be made after deducting the waste and incombustible matter found in the crude state of the fuel. This principle is applied both to the ultimate analyses and to the evaporative experiments; and hence in the following table both *the calculated evaporative power of the carbon constituent*, (column 15,) and the *total evaporative efficiency by experiment*, (column 18,) are referred to, and calculated for, one part by weight of *combustible matter*.

"The relation between the *fixed* and the *volatile* combustible matters of coals, is liable to considerable variation, according to the rate of distillation to which they are subjected. The more slowly this process is conducted, the higher (within certain limits) will be the proportion of fixed carbon.* The estimation of heating powers, therefore, from the quantity of fixed carbon which coals contain, if not wholly erroneous in principle, must be liable to considerable uncertainty in practice.

"Many highly bituminous coals contain more than 5 per cent. of materials converted into ammoniacal liquor by simple distillation without contact of air. This is proved on the largest scale in the manufacture of illuminating gas. That proportion, therefore, is not only unavailable for heating purposes, but it also abstracts from the really combustible materials of the fuel, all the heat, sensible and latent, which the vaporized ammoniacal products receive during combustion.

"The proper *water of combustion*, namely, that derived from the *hydrogen in excess*, and oxygen of the atmosphere, must in every instance where heat is applied to evaporate water above the boiling point, as in all ordinary steam boilers, be likewise incapable of giving up its latent, as well as much of its sensible heat.

"The average specific gravity of the six varieties of bituminous coals assayed is 1.31—that of water at 60° being unity. Admitting the hydrogen in its solid state to have a density of only 1.25, it must, in passing into the state, first of gaseous hydrogen, and then into that of watery vapour, (still having the same bulk as the hydrogen,) undergo an enlargement to 2117 times its original bulk. This volume is further increased according to the usual law of gaseous expansion, by whatever heat above boiling point is left in the vapour, when it passes away from the surface to be heated. In a well constructed

*See Proceedings of the Acad. of Nat. Sciences, Vol. 2, pages 9–10.

evaporative apparatus producing steam of 6 pounds pre. sure, in which the circuit traversed by the gases after passing the grate, and before reaching the chimney, was 121 feet, the temperature of the gases was generally about 100° above the boiling point; and the watery vapour, being of course surcharged with heat, possessed 2431 times the bulk which it had in the solid state and at 60 degrees of temperature.

"By the experiments of Dulong, (Comptes Rendus, tom. 7,*) one grain of pure carbon developes, in burning, heat enough to raise the temperature of 7170 grains of water, 1° centigrade, or 12906 grains 1° Fahrenheit. This latter number is, therefore, used as a co-efficient, by which to multiply the numbers in the 12th column of the following table to obtain those of the 15th. By the same authority, 1 gram of *gaseous* hydrogen gives heat sufficient to raise 62,535 grams of water 1° Fah.

"The average *excess of hydrogen* for the six varieties of coal by evaporation, as deduced from columns 13 and 14 of the table, is 4,636 per cent. which, calculated after the manner of the European chemists, ought to possess an evaporative power of 2.814. This would raise the average of the 15th column from 10.700 to 13.514, as the calculated evaporative power of the unit of combustible matter, showing the calculated to be 26.3 per cent. higher than the experimental effect."

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*See also Peclet, Traité de la Chaleur, Tom. I, p. 50.

Table exhibiting the analyses of several varieties of Bituminous with the calculated and the experimental

Designation of the coals.	Specific Gravity.	Proximate Analysis. Composition of the raw coal in 100 parts.					Ratio of fixed to 1 of volatile combustible matter.	Ultimate analysis. Grains of		
		Moisture Expelled below 250° F.	Sulphur.	Volatile combustible matter.	Fixed Carbon.	Earthy matter.		Dried coal assayed.	Carbonic acid collected.	Water collected.
Summit Portage railroad, Cambria Co., Pa.	1.3647	0.700	1.500	18.195	64.245	15.360	3.535	7.26	20.62	3.23
Midlothian "new shaft," Virginia.	1.3006	0.914	2.282	29.274	62.050	5.480	1.966	4.57	14.82	2.23
New Castle, Engl'd.	1.2567	1.461		28.312	68.377	1.850	2.415	6.46	19.56	3.21
Clover Hill, Virginia.	1.2887	1.277	0.514	28.409	65.425	4.375	2.268	6.05	17.0[illegible]	2.5[illegible]
Scotch.	1,2759	1.365		35.586	60.342	2.707	1.696	7.64	22.6[illegible]	[illegible]
Caseyville, Kentucky, and Cannelton, Indiana.	1.3920	1.150		30.669	44.493	23.687	1.450	4.21	8.96	1.92
Averages.	......	......	......	......	......	......	......	......	......	.....
Osage River, Mo.	1.2000	1.670	0.482	41.348	51.160	5.340	1.237	6.94	19.95	3.69
Pure bitumen.	1.1558	.000		72.438	24.799	2.761	0.342	8.16	22.60	5.73

Remarks.—The evaporative trials were performed by burning about two tons of each kind of coal, under a boiler capable of evaporating 15 cubic feet of water per hour.

It appears that, on an average, these coals expended in evaporating water from the boiler 85.35, and on the products of their combustion 14.65 per cent. of their

Coal, both into their proximate and their ultimate constituents, determination of their evaporative powers.

By calculation 100 parts of the *combustible matter* are found to be constituted of			Calculated evaporative power of the carbon alone in one of combustible matter, by Dulong's co-efficient, from water at 212°.	Practical evaporative power.			Difference between the calculated and the experimental efficiency of the combustible matter.
				Pounds of water from 212° to one of combustible matter.			
Carbon.	Hydrogen.	Oxygen and Nitrogen.		Evaporated from the boiler.	Vaporisable by the heat expended on the gaseous products of combustion.	Total of evaporative efficiency of one part of combustible matter, by experiment on a practical scale.	
91.955	5.876	2.178	11.522	10.238	1.312	11.550	—.028
93.620	5.739	0.641	11.731	10.191	1.269	11.460	+.271
84.157	5 626	10.218	10.545	9.178	1.720	10.898	—.353
83 393	4.958	11.649	10.445	8.588	1.949	10.537	—.082
82.952	5.607	11.441	10.393	8.868	1.338	10.206	+.187
76.335	6.663	17.002	9.565	7.734	1.823	9.557	+.008
....	....	....	10.700	9.133	1.5685	10.701	....
81.855	6.168	11.977	10.256	....	.. ..	....	....
77.679	8.023	14.298	9.464				

whole heating power. Both the *sum* and the *number* of differences between the practical and calculated evaporative powers, affected by the positive sign, are seen in the last column to be the same as those affected by the negative sign.

No evaporative trials of Osage coal, or of bitumen, have been made.

"The data furnished by the preceding table afford the means of ascertaining the proportion of its carbon volatilized in the distillation of the *combustible matter* in each kind of coal.

"The calculations prove that of its whole carbon constituent, the per centage volatilized, was as follows:

Cambria county coal - - - - -	16,767
Midlothian, new shaft - - - -	29.195
New Castle - - - - - - -	15.967
Clover Hill - - - - - - -	16.847
Scotch Cannel - - - - - -	24.169
Caseyville, Ky., Cannel - - - -	22.452
And that the average was - - -	20.883

"The *identity* of results obtained in the averages of the 15th and 18th columns should seem to demonstrate that the heating power of bituminous coals is proportionate to the *carbon* which they severally contain."

The British experimenters continued their analyses of the coals till every sample had been submitted to both proximate and ultimate determination. In the American experiments time was not allowed before the report was demanded, for extending the ultimate analyses to more than one-eighth part of the samples. From such trials as were made, the deduction which appeared to be authorized by a careful comparison between the constituents of the coals and their *evaporative efficiency, was, that the latter depended upon the total amount of* CARBON *in the coal.* If the hydrogen had been, as most European chemists had contended, the more efficient element, weight for weight, then all highly bituminous coals ought to have presented a greater heating power than those of lower bituminousness. Both the British and American experiments concur in proving the reverse of this to be the fact. Indeed, the observed deficiency in heating power of the highly bituminous class where, for example, the ratio of fixed to volatile combustible is nearly one of equality, or, as 1 to 1; and the increasing evaporative power as we approach the free burning bituminous and the anthracite class, might naturally conduct us to this conclusion.*

*To verify completely this principle, a full series of ultimate analyses was required, and through the tardiness of the American, we have now to thank the British Government for supplying the data necessary for at least a partial verification of this important principle. The writer can take to himself no share of the blame for thus allowing foreigners to anticipate us in an important investigation.—He has, since the Report on American coals was rendered, repeatedly brought to

To show the value of the researches by the method of ultimate analysis, and the important bearing which the results now obtained on the other side of the water have upon the practical computation of heating powers, as founded on the proportions of carbon, the following table is presented:

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the attention of the Navy Department, the necessity, both for practical and general usefulness, of a continuance of those researches. In that Report itself, the very points which the British experimenters have evidently labored with the greatest care, were signalized as the parts which for want of time and of appropriations, were, among the American researches, left in an unfinished condition; and it was expressly stated that they were so left on account of the pressing urgency of the Department to be in possession of the practical results of the investigation. To aggravate the disappointment, and seemingly in disregard of the desire which had been expressed in many quarters for the continuation of the American experiments, the authorities having control of the Washington Navy Yard, allowed the valuable apparatus, constructed with so much care and expense, to be dismantled and virtually destroyed, the boiler cut up and applied to other purposes, the appendages scattered and rendered useless, and even the collections of numerous specimens of coal, preserved from all the samples for future analysis, distribution and comparison, to be turned into the common stock of fuel, and burned up by the workmen!

It is within the knowledge of the writer that numbers of applications have been made to the Government from different parts of the country, desiring that his experiments on coal should be continued. Before this can be done, it will be necessary to reconstruct the apparatus thus allowed to be destroyed. Some part of the means which would have been necessary for the prosecution of the researches must now be employed in reproducing the apparatus. By an estimate of the Engineer of the Navy Yard, this will cost about $3,000. But no pecuniary appropriations can ever restore the valuable collection of specimens thus allowed to be hopelessly destroyed.

Table exhibiting the coals arranged in the order of the per by the analysis of average specimens, and the evaporative the data being found in the respective tables at page **11** *and*

Name of Coal.	Per centage of Carbon by analysis.	Average per cent. of Carbon.	Steam to 1 of Coal by experiment.
1. Park End, Lydney (forest of Dean)	73.52		8.52
2. Coleshill	73.84		8.00
3. Dalkeith Jewel Seam	74.55		7.08
4. Porthmawr Rock Vein	74.70	74.15	7.53
5. Three-quarter Rock Vein	75.15		8.84
6. Wallsend Elgin	76.09		8.46
7. Dalkeith Coronation Serm	76.94		7.71
9. Cwm Nanty-gros	78.36	76.63	8.42
9. Resolven	79.33		9.53
10. Fordel Splint	79.58		7.56
11. Grangemouth	79.85		7.40
12. Wylam's Patent Fuel	79.91	79.67	8.92
13. Slieverdach Anthracite	80.03		9.85
14. Bedwas	80.61		9.71
15. Pontypool	80.70		7.47
16. Broomhill	81.70		8.75
17. Cwm Frood Rock Vein	82.25	81.06	8.70
18. Mynydd Newydd	84.71		9.52
19. Graigola	84.87		9.35
20. Llangenneck	85.46		8.86
21. Old Castle Fiery Vein	87.68	85.68	8.94
22. Ward's Fiery Vein	87.87		9.40
23. Bell's Patent Fuel	87.88		8.53
24. Duffryn	88.26		10.14
25. Binea	88.66	88.12	9.94
26. Pentrepoth	88.72		8.72
27. Ebbw Vale	89.78		10.21
28. Warlich's Patent Fuel	90.02		10.60
29. Anthracite, (Welsh)	91.44	89.99	9.46

centage of carbon which they severally contain, as determined power given by the same coal when tested under the steam boiler, 12, of the Report of the British Commissioners.

Average steam power.	Hydrogen in excess in each coal.	Average excess of Hydrogen.	Steam to 1 of of coal after deducting cinder.	Average after deducting cinder.	Steam by calculation.
7.78	4.88 4.11 3.20 4.34	4.13	8.98 8.34 7.10 7.75	8.04	8.24
8.35	4.30 4.59 3.41 4.90	4.30	8.67 7.86 8.82	8.45	8.51
8.65	4.75 4.46 4.21 4.86	4.57	10.44 7.69 7.91 9.74	8.94	8.85
8.89	2.30 5.82 5.11 5.79 5.39	4.88	10.49 9.99 8.04 9.18 9.35	9.41	9.01
9.17	5.36 2.94 3.90 4.47	4.17	10.59 9.66 9.20	9.81	9.52
9.50	3.93 5.17 4.59 4.51	4.55	10.60 8.65 10.72 10.30	10.06	9.80
9.75	4.10 5.10 5.56 3.14	4.47	8.98 10.64 10.60 9.70	9.98	10.00

From the above table we may, without deducting for the residual cinder, derive the relation of the steam-generating power of the coals to the amount of their carbon constituent. Thus the—

			Carbon.		Steam, by experiment.		Steam by calculation		Difference of exp't & calcu'n.
1st class	*four*	coals	74.15	per cent.,	7.78	pounds,	8.03	pounds,	—.25
2d "	*four*	"	76.63	"	8.35	"	8.37	"	+.08
3d "	*four*	"	79.67	"	8.65	"	8.60	"	+.05
4th "	*five*	"	81.06	"	8.89	"	8.75	"	+.14
5th "	*four*	"	85.68	"	9.17	"	9.25	"	—.08
6th "	*four*	"	88.42	"	9.50	"	9.51	"	—.01
7th "	*four*	"	89.99	"	9.75	"	9.75	"	+.00

The 4 positive differences amount to...+.27
The 3 negative " " ....—.34

Total average difference...—.07

The accordance between these results is remarkable, when we consider that no account is taken in the calculations of the British experimenters of the moisture in the coal; and when it is recollected that two coals of the series are true anthracites, the burning of which always involves the expenditure of more of its heating power on the products of combustion than is demanded by either the freeburning or the highly bituminous coals.

Though the table presents some deviations among the individual coals from the law, that an increase of the carbon constituent of coal is attended by a proportional increase in its evaporative efficiency, yet by grouping a few together, the deviations essentially neutralize each others effects, and the law which the writer had demonstrated with respect to a few coals of high bituminousness, can now be extended to all classes of bituminous coals and to anthracites.

One consideration may serve, in part, to explain any discrepancies among the individual samples of coal which may present themselves in comparing the members of the series now under review. Besides carbon, considered as a solid fuel, the sulphur in coal, by combining with oxygen to form sulphurous acid, gives out a notable quantity of heat, sufficient in some cases to cause spontaneous combustion. The proportion of sulphur to oxygen in that compound is 16 to 16, (SO_2,) and the vapor of sulphurous acid being very heavy, (only $\frac{1}{8}$ of the volume of hydrogen,) this material does not, like hydrogen, (see Report on American coals, page 500,) consume, in assuming the gaseous form, all the heat given out in burning into sulphurous acid.

It may further be remarked, that the discrepancies observable among the averages are quite within the errors of observation; and though it might be expected, that in associating them into groups, the effect would be to neutralize these errors, yet it is possible, that in regard to a whole group, the errors *may* all be in one direction.

This developement finally sets aside the old calculations about the relative heating powers of the carbon and of the hydrogen in coals. By the principle of that calculation, any coal having a high degree of bituminousness, ought, in consequence of the large proportion of hydrogen in its bitumen, to possess a much higher heating power than any coal of lower bituminousness. An inspection of the table will show the reverse of this to be true. The higher the bituminousness, or in other words, the greater the proportion of volatile matter a coal contains, the less is its available heating power. The fact has been pointed out in former publications of the writer, that when solid hydrogen (that being its state in coal) is converted by the effect of heat into gaseous hydrogen, it requires for this change a large amount of heat, as experimentally proved in the manufacture of illuminating gas. The hydrogen thus brought to the gaseous state, assumes the same bulk at a given temperature, say 212°, as it will retain at the same temperature when converted into the vapor of water under atmospheric pressure; and, consequently, unless we can suppose the capacity for heat of gaseous hydrogen, bulk for bulk, to be greater than that of the vapor of water, we can conceive no reason why it should give out more heat in combining with oxygen, than it had taken up in being converted into gas. The British Commissioners refer to this view of the subject,* but do not clearly express an opinion of its validity.

Fortunately, their silence is of the less importance, as their own experiments furnish abundant proofs of the correctness of the principle. In order more clearly to exhibit the independence of *hydrogen efficiency* in computing heating powers from analysis, we have placed in the above table the per centage of hydrogen found in each sample of coals From this column the averages are deduced, and a glance will show that so far as any law or relation is perceptible, the coals of

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* At page 12 of the British Report, the principle that gaseous developement is a cause of cooling, and that the heat expended on converting a material into gas, may be just equal to what it will afterwards give out in burning, is recognized in the following terms:

"If, by destructive distillation, which occurs in furnaces before combustion, a large quantity of the constituents of the coal are rendered gaseous, so much heat is expended in this act that the heat developed by their after combustion is frequently not greater than that abstracted during their formation, in which case a thermoneutrality occurs."

This should have rendered the commissioners cautious in admitting the hydrogen constituent into so large, or, indeed, into any participation in the heating power. They say, that "for steam purposes, it was sufficient to determine the per centage of coke, as stated in table II." See above p. 75.

highest heating powers are those which have the lowest per-centage of hydrogen. Thus the four coals which have a heating power of 7.78, have excess of hydrogen, 4.13; the four having a heating power of 9.17, have of hydrogen in excess, 4.17. It will also be noted that an intermediate class of coals having a heating power of 8.65 has a higher per centage of hydrogen than either of the above, viz, 4.57. This is as we might expect to find it, if the hydrogen be truly without efficiency in the practical use of coal. Indeed, the hydrogen appears from the practical tests thus far adduced, no more to merit consideration as an element of evaporative efficiency in a coal, than an equal weight of silica, alumina, oxide of iron, or other inert substance found in its earthy residium or ash.

EARTHY RESIDUES OF THE COALS.

In computing the quantity of combustible matter in the coal burned, it is safer to adopt the result of analysis by the furnace than of that by the crucible. In several instances, both in the American and British researches, it appears that wide discrepancies existed between the per centages of absolutely incombustible matter, as proved by these two methods of analysis. Thus the British Commissioners found by their laboratory analyses, and by the weighing and analyzing of the residues from the furnace, the following proportions of waste or absolutely incombustible matter.

Name of Coal.	Earthy matter by analysis in laboratory.	Earthy matter from residues of the furnace.	Name of Coal.	Earthy matter by analysis in laboratory.	Earthy matter from residues of the furnace.
Graigola	3.24	5.78	Grangemouth	3.52	3.37
Duffiyn	3.26	2.28	Broomhill	3.07	1.69
Oldcastle Fiery Vein	2.64	2.96	Resolven	9.41	1.80
Ward's Fiery Vein	7.04	6.25	Porty Pool	5.52	6.91
Binea	3.96	4.77	Bedwas	6.94	3.22
Llangenneck	6.54	7.26	Porth Mawr	14.72	6.75
Mynydd Newydd	3.24	6.43	Warlich's Patent Fuel	2.91	4.17
Three-quarter Rock Vein	10.96	4.46	Ebbw Vale	1.50	2.51
Pentrefelin	6.09	14.22	Fordel Splint	4.00	1.06
Park End	10.00	3.20	Coleshill	8.92	4.88
Pentrepoth	3.36	7.44	Slievardagh Anthracite	10.80	1.74
Cwm Frood Rock Vein	6.00	5.82	Wallsend Elgin	10.70	2.31
Welch Anthracite	1.52	6.10	Dalkeith Coronation	3.10	3.99
Cwm Namy-gros	5.60	4.25	Dalkeith Jewel Seam	4.37	3.10
Wylam's Patent Fuel	4.84	5.42	Bell's Patent Fuel	4.96	4.73

From this table it appears that the average quantity of earthy matter found in these coals by the analysis of the laboratory was 5.76 per cent., and that the average afforded by the residues of the furnace was 4.62 per cent., or one-fifth less than by the operations of the laboratory. A small quantity of dust no doubt escapes at the top of the chimney; but it is not credible that so large a part as this should be lost in that way, especially as the length of horizontal flue was so great. It will be observed, that the quantity of ash given by analyses in the Three-quarter Rock Vein, Bedwas, Porthmawr, and Coleshill, was more than twice as great as that given by the furnace; in Park End, Lydney, it was three times; in Fordel Splint, it was nearly four times; in Walsend Elgin, four-and-a-half times; in Resolven, five times; and in Slievardagh Anthracite, six times as great. But it will not fail also to be noted, that in one or two cases the reverse variation took place, the furnace yielding a much larger residue than the crucible; and that of the whole series of coals thirteen gave higher residues when burned on the large scale of practice, and seventeen when incinerated over a lamp. The danger of leaving some part of the carbon unconsumed in this latter case, and the necessity, even in the muffle, of peculiar precautions against such a result, are known to all who are familiar with the analysis of coals.

In the American experiments twenty-six samples gave higher per centage of earthy matter by the operations of the furnace than by those of the crucible, and only nine samples gave a contrary preponderance.

The average by the furnace is 17.27 per cent. greater than that found in the laboratory. The American coals appear to be either naturally more highly charged with earthy matter, or to have been so mined as to contain larger proportions of slaty matter than the British. In the American Report will be found several cases in which the coal supplied to commerce proved much more impure than that obtained from the same mines, when sent by the proprietors expressly for the purpose of being tested.

As nearly all the samples of British coals were mined expressly for the purpose of the "Admiralty coals investigation," it is fair to presume that at least the full share of attention was given to free them from slate and other impurities.

The following table exhibits the results of the American experiments on the quantity of earthy matter:

Name of Coal.	Earthy matter by analysis in laboratory.	Earthy matter from residues of the furnace.	Name of Coal.	Earthy matter by analysis in laboratory.	Earthy matter from residues of the furnace.
Beaver Meadow, slope 3..	9.865	7.112	Barr's Deep Run.........	10.000	10.475
Beaver Meadow, slope 5..	2.460	5.149	Crouch & Snead.........	8.720	14.280
Forest Improvement.......	3.050	4.444	Midlothian, 900 ft. shaft	13.660	10.467
Peach Mountain............	6.553	6.125	Creek Company's.........	5.329	8.572
Lackawanna................	4.655	6.411	Clover Hill.................	5.324	10.432
Lyken's Valley..............	5.530	9.252	Chesterfield Mining Co..	5.425	8.634
Natural Coke................	6.862	11.826	Midlothian, average......	4.587	14.737
New York and Maryland			Tippecanoe	8.862	9.374
Mining Companies	18.624	12.408	Midlothian, new shaft...	7.544	9.440
Neff's Cumberland coal...	9.976	10.343	Midlothian screened.....	5.285	9.655
Easby's "coal in store"...	5.288	8.083	Pictou, (N. Y. sample.)	2.515	13.389
Atkinson & Templeman's	5.446	7.334	Sidney, C. B..............	12.480	5.495
Easby & Smith's..........	8.253	9.254	Pictou, (Cunard's s'ple.)	10.747	12.508
Dauphin & Susquehanna.	19.010	11.494	Liverpool..................	2.030	4.622
Blossburg....................	9.323	10.773	Newcastle.................	2.800	5.399
Lycoming Creek...........	10.330	13.961	Scotch......................	13.597	9.388
Karthaus	5.883	7.000	Pittsburg..................	3.715	7.074
Cambria County...........	12.200	9.150	Cannelton.................	5.831	4.974
Average..				7.763	9.104

The general average per centage of earthy matter in thirty-five American and thirty British samples as deduced from operations in the two modes, may be stated as follows:

35 American in laboratory,	7.76,	in steam boiler furnace	9.10
30 British "	5.76,	" "	4.62
Differences	2.00		4.38

This establishes the fact that the British samples were freeer from earthy matter than the American. In both the British and American reports several analyses of ashes are given, and will be found at p. 66 of the former, and 599 of the latter document.

USE OF WOOD IN HEATING UP THE BOILER AND FURNACE.

In the American experiments, wood was employed to kindle the fire and to raise the temperature of the brick work of the setting of the boiler and its contents to that temperature at which the operations were to be carried on. After attaining this temperature the wood was withdrawn and its place supplied with coal, so much charcoal only being left on the grate as was barely sufficient to ignite the mineral coal.

In the British experiments wood was employed only to kindle the fire, and then it became necessary to divide the coal burned into two portions, one of which was considered as employed solely in raising temperature, and the other in both evaporating and raising temperature. This mode of experimenting complicates, to some degree, the calculation of evaporative efficiency, as already noted. One element in every day's calculation will be the heating up of the furnace, and the material of the boiler; and since the weight of iron in a boiler is very considerable, and as every nine pounds of iron require as much heat to raise their temperature as one pound of water, the total calculated efficiency of the fuel cannot fail to be in some degree affected by the omission to take account of the weight and specific heat of the boiler, especially when much difference of temperature existed between its initial and its final temperature.

We may in this connexion again refer to the per centages of moisture in many of the samples of British coal, as determined by analysis. In the American experiments, this element was ascertained, not only by analysis, but also by heating to 212° for several days, in a drying apparatus heated by steam, twenty-eight or thirty pounds of the coal as it was found on the days of trial in the furnace. The loss of weight by this treatment was the element principally relied upon in the calculations of the efficiency of the *combustible matter.*

Including the two Dalkeith coals, which yielded as above stated, 9.36 and 5.88 per cent. of moisture, we have the following pretty high per centages of moisture to offset against the small number on page 10, (British Report,) given by the commissioners, and on which they base the remark that the hygroscopic moisture in coal is very small.

Old Castle Fiery Vein	7.40	Dalkeith Coronation	5.88
Ward's Fiery Vein	3.08	Wallsend Elgin	2.49
Llangenneck	4.07	Fordel Splint	8.40
Resolven	1.55	Grangemouth	6.42
Porthmawr Rock Vein	1.70	Broomhill	9.31
Coleshill	4.96	Lydney	2.78
Dalkeith Jewel	9.31	Slieverdach Anthracite	4.93

In the above coals, it would be exceedingly interesting to have a computation of the effect of the combustible matter when freed from moisture. There is water thrown upon the grate more than sufficient to mask the effect of the small quantity of wood used in kindling, and also some of the differences between the initial and final temperature of water in the boiler.

SPECIAL COMPARISON OF RESULTS OF AMERICAN AND BRITISH EXPERIMENTS ON COALS OF SIMILAR CONSTITUTION.

The following table gives a synoptical view of the composition, evaporating power, behavior in the furnace, and reductive efficiency of twelve samples of coal, arranged in six pairs,

Table of results of American and British

Number of Comparison.	Name of Coal.	Specific gravity.	Calculated weight in pounds per cubic foot.	Weight in pounds per cubic foot by experiment.	Ratio of experimental to calculated weight.	Space required to stow one gross ton in cubic feet.	Difference between theoretical and practical weight per cent.	Moisture.	Volatile matter other than moisture.	Sulphur.	Fixed Carbon.
1	Scotch...............	1.519	94.95	51.09	.538	43.84	85.65	3.01	38.84	0.36	48.81
	Dalkeith Jewel....	1.277	79.67	49.80	.625	44 98	59.98	9.36	40.84	0.38	45.43
2	Newcastle, Eng...	1 267	78.54	50.79	.647	44.08	54.63	2.01	35 60	0.23	56.99
	Broomhill, "	1.25	77.99	52.50	.673	42.67	48.55	9.31	31.49	2.85	56.13
3	Midlothian new shaft..............	1 325	82 81	47.90	.581	46 76	72.88	0.67	33 49	2.28	56.40
	Cwm Frood Rock	1.255	78 29	55.28	.706	40.52	41.64	1.12	30.08	1.22	62 80
4	Atkinson & Templeman, Md....	1.313	82.09	52 92	.614	52 33	55 12	0.45	15 53	......	76.69
	Ebbw Vale........	1.275	78.81	53.30	.676	42.20	45.98	1.34	21.16	1.02	76.00
5	Lyken's Valley, Pa	1 385	86 82	48.56	.559	46.13	78.79	0.11	6.79	0.91	83 84
	Llangenneck	1.375	85.78	58.25	.679	38.45	47.90	2.87	4.23	0.79	91 38
6	Beaver Meadow, slope 5, Pa.......	1 551	96.93	56.19	.579	39 86	72.5	0.89	3.60	0.06	90 35
	Slievardagh, Irish.	1.590	99.57	62.80	.630	35.66	58.55	4.93	5.47	6.76	79.30

ERRATA.

The writer mentions the following errors in the British Report, not by any means in a captious spirit, or with any view to cast discredit on this highly valuable document, but merely to enable those into whose hands the original may come, to read it, after applying the corrections. He does not permit the first sample in each pair being taken from the American, and the second from the British series. As the Scotch and Newcastle samples of the American series were purchased in New York, nothing is of course certainly known of the particular mine or seam from which they were severally taken.

trials of Coals of comparable qualities.

Coke.	Ash given by analysis per cent.	Ratio of fixed to volatile combustible.	Pounds burnt on 1 square foot of grate per hour.	Steam to 1 of coal from 212.°	Pounds of Steam to 1 cubic foot of coal.	Steam to 1 of *combustible* matter.	Per centage of clinker and ashes.	Per centage of clinker alone.	Ratio of clinker to total waste.	Pounds of cinder or unburnt coke.	Lead reduced by one of combustible.	Pounds of water evaporated per hour during steady action.
58.15	9.34	1.257	10.77	6.94	353.8	7.72	10.19	5.63	.558	5.75	27.03	895.42
49.80	4.37	1.112	10.30	7.08	352.58	7.42	4.65	2.65	.571	5.0	26.42	355.18
62.39	5.40	1.60	8.03	8.66	439.59	9.13	5.68	3.14	.553	10.69	27.55	859.72
59.20	3.07	1.78	9.11	8.75	459.37	8.96	2.40	0.33	.137	8.65	25.32	327.58
65.84	9.44	1.68	7.60	8.75	418.61	9.75	10.26	4.21	.421	17.08	26.79	844.38
68.60	6.00	2.08	8.72	8.70	480.90	9.07	4.11	1.78	.433	18.33	28.30	327.60
84.02	7.33	4.94	7.33	10.70	56	11.62	7.96	2.12	.268	5.12	30.06	981.24
77.50	1.50	3.59	9.07	10.21	544.19	10.53	3.00	0.40	.133	9.20	31.98	393.33
93.09	9.25	12.34	6.92	9.46	459.56	10.79	12.24	4.40	.375	18.00	31.15	805.81
92.90	1.52	21.60	8.65	9.46	565.02	9.83	3.77	0.00	.000	19.66	33.48	359.00
95.50	5.15	25.36	6.27	9.88	556.11	10.59	6.74	0.59	.092	61.25	31.85	691.40
90.00	10.80	14.68	9.22	9.85	618.58	11.69	2.60	0.90	.322	59.00	30.10	173.18

himself to doubt that his own report may, with all the care which was bestowed upon it, be found to contain some errors:

Of Ward's fiery vein, it is said (p. 59, British Report,) that "5.2 grammes lost of moisture, 0.763=1.38 per cent." Now if we are not greatly in error in our calculations

$$\frac{763}{5200}=0.138=13.8 \text{ per cent.}$$

Also, of Old Castle fiery vein, it is said (page 58) that 2.4314 lost at 212° 0.18; and at page 10, this coal is put down as having lost 0.74 per cent. Now $\frac{1800}{24314}$=0.074, or 7.4 p. ct.

At page 10, the formula

$$\frac{(W - Eq + w - w')\,t + Wt + wt' + (w' - w)\,t''}{Pl} = E',$$ should

read, $$\frac{(W - E\,q + w - w')\,l + Wt + wt' + (w' - w)\,t''}{Pt} = E'$$

One pound of Broomhill coal is, in tables on pages 11 and 15, represented to have evaporated 7.3 lbs. of water from 212°, and the same number is found in the summary, page 39—while on page 38, in the detailed statement of the results of trials of that coal, the weights of water evaporated per pound of coal from 212°, on the respective days, are 8.55, 9.02 and 8.7, making the true average 8.75. In table, page 11, the effect of the error just noted, is extended to the 10th and 11th columns, where the evaporation, after allowing for the unconsumed fuel in the residue, is made 7.66 instead of 9.18.

This error was first detected by observing a want of conformity between the composition of the coal and its evaporative power.

Old Castle Fiery Vein is, in the tables, represented as having produced of steam to one of coal, from 212°, 8.94; whereas in the table, page 27, of daily experiments, we have 8.65, 8.92, and 9.72, of which the mean is 9.09.

In the table, page 29, the average *weight of soot* per day in the flues, after burning about 300 lbs. of coal per day, is put down at 75 lbs. This is presumed to be an error of the press for 0.75 lbs.

In the detail of the trial of Ebbw Vale coal, (British Report, p. 43,) the weight of soot put down in the table, is 7 lbs. for each days burning. This is doubtless another error from omission of the decimal point. It should stand 0.7 lb., instead of 7 lbs.

In computing the column I (per centage of residue of the coals) in the summary, on page 39, of their report, the commissioners have divided the sum of the ashes, cinder, and soot, *minus* the weight of clinker, by the weight of coal burned. In the other summary, at page 48, which is, in fact, a part of the same table, they have taken the same *sum*, (but sometimes omitting the soot.) *plus* the weight of the clinker for a dividend. The first of these methods of calculation appears to be in accordance with the foot note, at page 52. But the second will give true results, if we suppose that under the head of cinder in the second part (page 48) they have included only that part of the cinder which is left after deducting the clinker, viz. the *coke*. We are not expressly informed which of these modes of calculation ought to be applied. This and some other discrepances appear to have arisen from the change of assistants during the investigation.

In computing the per centage of residue in the coal of Lydney, Pontypool, and Porthmawr, the weight of soot is omitted from the calculation, while it is included generally in calculating the waste matter of the other coals, and a conjectural quantity of soot appears to have been added, in the case of Bell's patent fuel, and Warlich's patent fuel, where the detailed tables of operations do not give any. Trivial as these differences in calculation might at first seem, they assume a considerable importance in view of the use which must be made of them, when we wish to calculate the heating power of the combustible matter in the coals, divested of their respective useless or prejudicial constituents.

At page 11, under August 2d, 1st day, opposite to weight of coals consumed, we have 43 lbs.—an obvious error, but what the true number of pounds is, we have no means of determining—we *suppose* it to be 430.

In the table, on page 48, British report, column II, opposite Ebbw Vale, has 7.10, which ought to be 10.64; and the same column opposite to Dalkeith Coronation Seam, has 78.6; an evident misprint for 7.86.

At page 17, against weight of clinker in cinder, we have 8 lbs., instead of .8 lbs., which latter is proved to be the true number by the per centages in column I, page 48, against Dalkeith Jewel and Coronation Seams.

SYNOPTICAL TABLE OF AMERICAN COALS.

We will terminate this comparison between American and British experiments, by placing before the reader the general synoptical table of the American results preceded by the classification of the coals according to those general characters which are found to distinguish them.

CLASS I.

ANTHRACITES—NATURAL COKE—ARTIFICIAL COKE—MIXTURES.

SAMPLES.

No. 1. Beaver Meadow, slope No. 3.
2. Beaver Meadow, slope No, 5.
3. Forest improvement.
4. Peach Mountain.
5. Lehigh,
6. Lackawanna.
7. Lyken's valley.
8. Beaver Meadow, (navy yard.)
9. Natural coke, (Virginia.)
10. Coke of Midlothian (Virginia) coal.
11. Coke of Neff's Cumberland coal.
12. Mixture $\frac{1}{5}$ Midlothian and $\frac{4}{5}$ Beaver Meadow.
13. Mixture $\frac{1}{5}$ Cumberland and $\frac{4}{5}$ Beaver Meadow.

General characters.

The anthracites have specific gravities varying from 1.39 to 1.61; retain their form when exposed to a heat of ignition, and undergo no proper intumescence while parting with the small portion of volatile matter which they contain; or, if changed at all, are only disintegrated into angular fragments. Their flame is generally short, of a blue color, and consequently of little illuminating power. They are ignited with difficulty; give an intense concentrated heat; but generally become extinct while yet a considerable quantity remains unburnt on the grate.

CLASS II.

FREE-BURNING BITUMINOUS COALS OF MARYLAND AND PENNSYLVANIA.

SAMPLES.

Maryland Coals.

No. 1. New York and Maryland Mining Company.
2. Neff's.
3. Easby's "coal in store."
4. Atkinson and Templeman's.
5. Easby and Smith's.
2. Cumberland, (navy yard.)

Pennsylvania Coals.

7. Dauphin and Susquehanna.
8. Blossburg.
9. Lycoming creek.
10. Quin's Run.
11. Karthaus.
12. Cambria county.

General characters.

In specific gravity, coals of the free-burning class fall a little below the anthracites, ranging from 1.28 to 1.44. Their mean weight per cubic foot is, however, only two-thirds of a pound less than that of the first class. As they contain but a small portion of matter to be vaporized, they soon come to the temperature of full ignition. The considerable increase of volume which they take in coking, favors the subsequent rapid and effective combustion of their fixed carbon. In some cases, especially when brought very gradually to ignition, their masses of coke scarcely cohere, and the original forms of their lumps are in a measure preserved.

CLASS III.

BITUMINOUS CAKING COALS FROM THE EASTERN COAL FIELD OF VIRGINIA IN THE NEIGHBORHOOD OF RICHMOND.

SAMPLES.

No. 1. Barr's Deep Run.
2. Crouch & Snead's.
3. Midlothian 900 feet shaft, (average.)
4. Creek Company's.
5. Clover Hill.
6. Chesterfield Mining Company's.
7. Midlothian *average.*
8. Tippecanoe.
9. Midlothian "new shaft."
10. Midlothian *screened.*
11. Midlothian, (navy yard, Washington.)

General Characters.

The range of specific gravities in this class is nearly the same as in that of the free-burning coals; but the *average* is rather less. The average weight per cubic foot is also less by about 3.5 pounds. These coals burn with a long flame and much smoke—giving an intumescent, coherent coke, preserving nothing of the original form of the coal.

CLASS IV.

FOREIGN BITUMINOUS COALS, AND THOSE OF SIMILAR CONSTITUTION WEST OF THE ALLEGHANY MOUNTAINS.

SAMPLES.

Foreign Coals.

No. 1. Pictou, (purchased in New York.)
2, Sidney.
3. Pictou, (Cunard's.)
4, Liverpool.
5. Newcastle.
6. Scotch.

Coals from west of the Allghany Mountains.

7. Pittsburg.
8. Cannelton, (Ia.)

General characters.

In many respects, this class of coals bears a strong analogy to the preceding. The ratio of the fixed to the volatile combustible matter, is, however, something less. The exterior presents often a resinous lustre. The surfaces of deposition are easily developed by fracture. Great facility of ignition, and a high degree of activity in the combustion of their volatile constituents, are also general peopertics of this class. Their high proportion of volatile combustible matter renders these coals, when nearly free from sulphur, eminently suitable for the production of illuminating gas; and the tendency of their cokes, with few exceptions, to intumescence strongly, renders them, in common with the preceding class, highly serviceable in forming large hollow fires for smithing purposes.

[*See Table opposite.*]

The following remarks from p. 598, Report on American coals, are still applicable to the subject:

As every sample of coal has been allowed a fair opportunity to exhibit its own distinctive character, it would be useless to attempt to substitute for the results of practical experiments, on such a scale as is here presented, any mere

Designation of coal.	Specific gravity.
Beaver Meadow, slope No. 3.........Pa.	1.
Beaver Meadow, slope No. 5.........Pa.	1.
Forest Improvement....................Pa.	1.
Peach Mountain..........................Pa.	1.
Lehigh.......................................Pa	1.
Lackawanna..............................Pa.	1.
Lyken's Valley...........................Pa.	1.
Beaver Meadow, (navy yard).........Pa.	...
Natural coke of Virginia..............Va.	1.
Coke of Midlothian coal...............Va.	...
Coke of Neff's (Cumberland) coal...Va.	...
Mixture, one-fifth Midlothian and four-fifths Beaver Meadow......	...
Mixture, one-fifth Cumberland and four-fifths Beaver Meadow....................	...
New York and Maryland Mining Company's..............................Md.	1
Neff's Cumberland......................Md.	1
Easby's "Coal-in-Store"..............Md.	1
Atkinson & Templeman's...........Md.	1
Easby & Smith's.........................Md.	1
Cumberland, (navy yard).............Md.	1
Dauphin and Susquehanna...........Pa.	1
Blossburg...................................Pa.	1
Lycoming Creek.........................Pa.	1
Quin's Run.................................Pa.	1
Karthaus.....................................Pa.	
Cambria County..........................Pa.	
Barr's Deep Run.........................Va.	
Crouch & Snead's.......................Va.	
Midlothian, (900 feet shaft.)...........Va.	
Creek Company's coal.................Va.	
Clover Hill.................................Va.	
Chesterfield Mining Company's......Va.	
Midlothian, (average)..................Va	
Tippecanoe.................................Va.	
Midlothian, ("new shaft")..............Va.	
Midlothian, (screened).................Va.	
Midlothian, (navy yard)................Va.	
Pictou, (from New York)..........N. S.	
Sidney....................................N. S.	
Pictou, (Cunard's)....................N. S.	
Liverpool...................................Eng.	
Newcastle..................................Eng.	
Scotch..................................Scotland.	
Pittsburg.....................................Pa.	
Cannelton...................................Ind.	
Dry pine wood..............................	

General synoptical table of the character and efficiency of the American Coals.

esignation of coal.	Specific gravity.	Weight per cubic foot, calculated from specific gravity.	Weight per cubic foot, by experiment.	Ratio of actual to calculated w'ght.	Cubic feet of space required to stow a ton.	Volatile combustible matter, in 100 parts.	Fixed carbon, in 100 parts.	Earthy matter, in 100 parts.	Ratio of fixed to volatile combustible matter.	Total weight of coal consumed.	Pounds burned on a square foot of grate per hour.	Hours required to bring the boiler to steady action	Cubic feet of water evaporated per hour during steady action.	Pounds of steam to 1 lb. of coal from initial temperature.	Pounds of steam to 1 of coal from 212°.	Pounds of steam furnished by 1 cubic foot of coal.	Total waste in the state of ashes and clinker from 100 of coal.	Weight of clinker alone from 100 of coal.	Average weight, in lbs., of unburnt coke left on the grate after each experiment.	Parts of lead reduced from litharge by 1 of combustible matter of the coal.	Steam from 212° from 1 of combustible matter.
adow, slope No. 3.........Pa.	1.610	100.645	54.93	0.546	40.78	2.38	88.94	7.11	37.31	3944.5	6.69	3.87	12.57	8.20	9.21	505.5	11.96	1.01	112.4	32.41	10.462
adow, slope No. 5.........Pa.	1.551	96.93	56.19	0.580	39.86	2.66	91.47	5.15	25.36	4250.5	6.27	2.42	10.66	8.76	9.88	556.1	6.74	0.60	61.2	33.29	10.592
rovement........................Pa.	1.477	92.31	53.66	0.581	41.75	3.07	90.75	4.41	29.75	3810.0	6.52	3.32	12.89	8.92	10.96	440.8	6.97	0.81	40.2	33.39	10.807
ntain...............................Pa.	1.464	91.51	53.79	0.588	41.64	2.96	89.02	6.13	30.09	7371.9	6.69	3.54	14.04	8.96	10.11	545.7	6.97	3.03	26.6	33.49	10.871
...................................Pa	1.590	99.39	55.32	0.557	40.50	5.28	89.15	5.56	16.87	3838.2	6.95	3.27	11.63	7.73	8.93	494.0	7.22	1.08	36.1	28.92	9.626
a................................ Pa.	1.421	88.84	48.89	0.550	45.82	3.91	87.74	6.35	23.13	4112.5	6.45	2.67	11.92	8.56	9.79	477.7	8.93	1.24	57.2	33.53	10.764
lley..............................Pa.	1.389	86.82	48.56	0.559	46.13	6.88	83.84	9.25	12.34	2471.0	6.92	2.63	12.89	8.43	9.46	459.6	12.21	4.40	18.0	32.60	10.788
adow, (navy yard).........Pa.	....	....	55.08	....	40.65	....	....	8.10	....	1897.3	4.63	5.08	9.42	7.86	9.08	500.0	8.10	1.40	107.1	....	9.881
ke of Virginia.............. Va.	1.323	82.70	46.64	0.564	48.03	12.44	75.08	11.83	6.27	4209.0	8.15	1.74	12.56	7.47	8.47	395.3	18.46	5.31	60.9	32.49	10.389
dlothian coal...... ....Va.	....	....	32.70	....	68.50	....	....	16.55	....	1037.0	9.64	2.00	16.50	7.40	8.63	282.6	16.54	10.51	53.2	....	10.343
eff's (Cumberland) coal...Va.	....	....	31.57	....	70.95	....	....	13.34	....	994.2	8.43	1.17	14.91	7.85	9.00	284.0	13.34	3.55	43.7	....	10.381
one-fifth Midlothian and four- aver Meadow...	....	....	54.29	....	41.26	....	....	8.88	....	2050.0	5.83	3.21	10.06	7.69	8.86	481.1	8.88	4.91	9.5	....	9.725
ne-fifth Cumberland and four- aver Meadow..................	....	....	54.51	....	41.09	....	....	8.18	....	2074.0	7.97	2.25	12.81	7.97	9.18	498.5	8.18	3.09	16.0	....	9.997
, and Maryland Mining Com- ....Md.	1.431	89.44	53.70	0.600	41.71	12.31	73.50	12.40	5.97	2127.7	6.28	1.33	12.79	8.65	9.78	524.8	12.71	5.43	10.1	30.33	11.208
nberland.......................Md.	1.337	83.28	54.29	0.652	41.26	12.67	74.53	10.34	5.88	4318.4	7.86	1.68	14.80	8.19	9.44	512.7	10.96	4.53	6.1	30.72	10.604
Coal-in-Store"..............Md.	1.307	81.69	53.47	0.655	41.90	14.98	76.26	8.08	5.09	1158.0	6.04	1.75	12.73	8.88	10.02	535.6	8.38	1.33	18.2	32.69	10.935
& Templeman's.............Md.	1.313	82.09	52.92	0.645	42.33	15.53	76.69	7.33	4.94	2318.2	7.33	0.99	15.70	9.47	10.70	566.2	7.96	2.12	5.1	30.06	11.624
Smith's.............................Md.	1.332	83.26	51.16	0.614	43.78	15.52	74.29	9.30	4.79	4474.5	8.02	1.52	14.97	8.69	9.96	511.1	9.69	3.04	5.3	33.01	11.034
nd, (navy yard)..............Md.	1.414	88.40	53.29	0.603	42.04	14.87	70.85	14.98	5.00	....	....	....	....	....	....	....	14.53	2.29	13.5	27.98	....
nd Susquehanna..............Pa.	1.443	90.19	50.54	0.560	44.32	13.82	74.24	11.49	5.37	2557.0	6.86	0.83	13.35	8.31	9.34	472.8	16.36	3.50	23.7	31.18	11.171
...................................Pa.	1.324	82.73	53.05	0.641	42.22	14.78	73.11	10.77	4.95	4295.0	7.77	0.84	15.67	8.64	9.72	515.9	11.20	3.40	13.7	32.54	10.956
Creek.............................Pa.	1.388	86.74	55.38	0.638	40.45	13.84	71.53	13.96	5.18	3073.2	6.33	1.72	12.13	7.92	8.91	493.3	16.92	3.26	46.2	32.89	10.724
m. ....Pa.	1.331	83.22	50.34	0.605	44.50	17.97	72.79	8.41	4.05	1883.2	7.29	0.75	13.90	9.08	10.27	517.0	8.94	1.31	14.7	30.90	11.275
...................................Pa.	1.284	80.22	52.54	0.655	42.63	19.53	73.77	7.00	4.11	3643.8	6.66	1.87	12.48	7.92	9.09	477.4	7.89	3.66	52.5	33.31	9.887
County............................Pa.	1.407	87.84	53.46	0.608	41.90	20.52	69.37	9.15	3.66	3488.5	6.68	2.00	12.47	8.04	9.24	486.9	9.75	3.48	14.8	31.46	10.239
ep Run ....Va.	1.382	86.41	53.17	0.615	42.13	19.78	67.96	10.47	3.43	5072.7	7.60	1.52	13.42	7.84	9.02	478.7	11.07	4.78	6.4	28.01	10.142
, Snead's.... ....Va.	1.451	90.71	53.59	0.591	41.80	24.38	59.98	14.28	2.50	3834.7	7.13	1.16	11.65	7.30	8.34	445.0	14.34	5.37	6.0	25.77	9.740
n, (900 feet shaft.)...........Va.	1.437	87.50	50.52	0.577	44.34	27.28	61.08	10.47	2.24	3417.5	8.68	1.38	14.51	7.50	8.58	403.7	10.70	6.47	5.9	26.99	9.611
mpany's coal...................Va.	1.319	82.48	46.50	0.564	48.17	32.47	60.30	8.57	2.03	3769.6	8.59	1.17	14.88	7.44	8.42	391.8	8.64	4.41	10.5	30.52	9.211
ill..................................Va.	1.285	80.36	45.49	0.566	49.25	32.21	56.83	10.13	1.79	3775.1	5.84	1.93	8.35	6.71	7.67	347.4	10.60	3.86	11.5	28.53	8.588
eld Mining Company's......Va.	1.289	80.57	45.55	0.565	49.18	32.63	58.79	8.63	1.92	3876.0	8.46	1.17	14.47	7.95	9.00	410.9	9.07	4.19	10.5	27.38	9.896
an, (average)...... ....Va	1.294	80.90	54.04	0.568	41.45	29.86	53.01	14.74	1.78	4506.4	6.68	1.52	10.08	7.30	8.29	448.5	14.83	8.82	6.4	29.03	9.741
oe ....Va.	1.346	84.14	45.10	0.536	49.67	34.54	54.62	9.37	1.60	4904.7	7.37	1.33	10.62	6.74	7.75	350.2	9.72	4.03	11.2	29.17	8.583
an, ("new shaft")............Va.	1.325	82.82	47.90	0.581	46.76	35.77	56.40	9.44	1.68	2918.5	7.60	0.91	13.46	7.66	8.76	418.6	10.26	4.21	17.1	26.80	9.751
an, (screened)................Va.	1.283	80.21	45.72	0.570	48.99	34.70	54.06	9.66	1.57	4132.0	6.24	1.29	10.11	7.84	8.94	408.7	10.27	3.33	14.8	29.74	9.970
an, (navy yard)..............Va.	1.390	86.86	54.47	0.627	41.13	29.12	56.11	14.14	1.95	1463.5	....	....	....	....	....	....	....	4.42	43.2	27.23	....
from New York)...........N. S.	1.318	82.35	53.55	0.650	41.83	27.83	56.98	13.39	2.11	4153.9	7.84	0.94	12.79	7.48	8.41	450.6	13.37	6.13	5.7	28.18	9.710
...................................N. S.	1.338	83.66	47.44	0.567	47.22	23.81	67.57	5.49	2.84	1601.1	8.31	1.18	13.85	7.01	7.99	378.9	6.01	2.24	5.9	29.15	8.497
Cunard's).......................N. S.	1.325	82.83	49.25	0.595	45.48	25.97	60.74	12.51	2.59	1962.5	9.84	0.85	16.47	7.45	8.48	417.9	12.06	6.19	3.7	26.69	9.648
l.....................................Eng.	1.262	78.89	47.88	0.607	46.78	39.96	54.90	4.62	1.51	3786.0	8.59	0.86	13.43	6.95	7.48	375.4	5.04	1.86	11.1	27.88	8.255
le.............................. ...Eng.	1.257	78.54	50.82	0.647	44.08	35.83	57.00	5.40	1.60	4023.0	8.03	0.84	13.75	7.68	8.66	439.6	5.68	3.14	10.7	27.55	9.178
.............................Scotland.	1.519	94.95	51.09	0.538	43.84	39.19	48.81	9.34	1.26	3860.0	10.74	0.96	14.32	6.14	6.95	353.8	10.10	5.63	5.7	27.00	7.719
...................................Pa.	1.252	78.37	46.81	0.598	47.85	36.76	54.93	7.07	2.01	208.4	....	....	10.56	7.03	8.20	384.1	8.25	0.94	9.9	28.89	8.942
..................................Ind.	1.273	79.54	47.65	0.599	47.01	33.99	58.44	4.97	1.72	2465.5	11.09	0.50	15.05	6.31	7.34	348.8	5.12	1.64	6.4	26.53	7.734
on................................ wood................................	....	....	21.01	....	106.62	....	....	0.307	....	2360.5	15.87	......	13.86	4.06	4.69	98.6	0.307	0.00	0.0	....	4.707

opinions or conjectures derived from observations made at random, with no standards of time, weight, or magnitude; or even any *theoretical conclusions* drawn from tests, however skilfully applied, merely to single hand specimens. It has been my aim in all these researches to avoid matters extraneous to the experiments themselves and to their legitimate interpretation. It has not been deemed expedient to swell this report by the introduction of matters not within my own cognizance.*

The numerous certificates and declarations which, either in the form of reports, or other published articles, have from time to time been put forth in regard to certain coals, may in some instances be entitled to consideration, as evidences of their superior worth; in others, of a commendable industry and energy on the part of the proprietors, agents, directors of companies, and others interested in their development and use. If these commendations have not in every instance been entirely justified, it is perhaps to be taken as a new evidence that in this, as in many other important matters, those merits which have not been the most loudly proclaimed may, upon due examination, be found among the most estimable and the most enduring.

It will not fail to be remarked, that the justly celebrated foreign bituminous coals of Newcastle, Liverpool, Scotland, Pictou, and Sidney—coals which constitute the present reliance of the great lines of Atlantic steamers—are fully equalled or rather surpassed in strength, by the analogous coals of eastern Virginia; that they are decidedly surpassed by all the free-burning coals of Maryland and Pennsylvania; and that an equally decided advantage in steam-generating power is enjoyed by the anthracites over the foreign coals tried, whether we consider them under equal weights or equal bulks.

Experiment appears to demonstrate that, for the purposes of *rapid* evaporation, and for the production of illuminating gas, the coal of Indiana, though neither very heavy nor very durable, is inferior to none of the highly bituminous class to which it belongs; since in heating power, and in freedom from impurity, it surpasses the splint and cannel coal of Scotland.

Apprized of the strong desire felt by the Department to be in possession of the results of these inquiries, I have spared no effort to bring them to an early conclusion, though satisfied that in doing so the researches cannot be considered complete.

One of the important points which it would be desirable further to investigate, is the proportion of *sulphur;* which, it will be seen by the several synoptical tables, was only tested on single specimens, for a part of the series. This is a labor of time, which, for reasons already assigned, is unavoidably left incomplete.

Another point of practical importance is the composition of the earthy matter, or ashes, of each coal. On the investigation of this, it was not found practicable even to enter. It is of no inconsiderable interest, in relation to the metallurgic arts to which coal is applicable. In lieu of any researches on this subject upon the samples of coal here reported, I beg leave to add a series of analyses of this nature, which I made some years since. They are chiefly the ashes of anthracites. One happens, however, to have come from the same mines which furnished one of the samples of bituminous coal examined in this report.

I cannot by any means regard the *investigation of American coals* as an exhausted subject.

A glance at any good geological map of the United States, in which the coal fields are laid down, will show how exceedingly limited is the whole amount of space covered by the several detached coal troughs from which the samples here presented were derived, compared with the immense extent of that formation which covers western Pennsylvania and Virginia, eastern Ohio, the eastern part of Kentucky, a part of middle Tennessee, and an undefined portion of Alabama; and much more when compared with the vast tracts of coal country in Illinois, Iowa, Missouri, Arkansas, and a considerable portion of Michigan.

The surprising extension of steam-navigation on the western rivers and the northwestern lakes, as well as on the gulf of Mexico and the adjacent seas, the increase of population, and the consequent clearing of woodlands, all point significantly to a necessity which must be felt, at no distant day, to have recourse to mineral fuel for supplying this rapidly increasing demand.

To understand the relative strength and usefulness of the coals from the several parts of the three great western coal regions, requires that they be examined with no less care than has been applied to the limited spaces from which were derived the materials operated on during these experiments. It may be added, that the products of many coal districts *east* of the Allegany mountains are yet unexamined.

If in any case *knowledge is power*, it is pre-eminently so when it relates to a subject which constitutes the greatest element of power in the physical world, and in the present age of marvellous developments.

MISCELLANEOUS RESEARCHES

ON THE

CONSTITUTION, PROPERTIES AND RELATIVE VALUES

OF

COALS.

In the proceedings of the National Institution, at Washington, (2d Bulletin, p. 165,) for February, 1842, the following paper was published:

"*On the Practical Determination of the Heating Power of Fuel, by Walter R. Johnson.*"—"In the progress of improvements in arts, navigation, and the application of heat to domestic purposes, questions of great interest present themselves for experimental determination.

"The new era in our naval history which is about to commence with the introduction of war steamers, is a very suitable period to inquire into the relative values of those varieties of fuel which may be found available for the purposes of steam navigation.

"In various parts of the United States are found combustibles adapted to this purpose; but as yet their relative values, either as compared with each other or with the foreign mineral fuel so much used at present, have been but partially determined.

"In a work recently published relating to the use of anthracite in the manufacture of iron, I have given several tables of experiments conducted by different individuals, exhibiting the result of trials on a few varieties of anthracite and bituminous coals. The same work also contains a synopsis of what has been done in Europe towards determining this important question of the relative values of coals for the production of steam.

"It is proposed in this communication to present to the National Institution some few general results, to which the details contained in the above mentioned work appear to lead, and also to embrace a comparison with other results obtained with the same kinds of fuel.

"It may not be amiss to state that the method of determining the relative value of combustibles for the purpose of generating steam, consists in ascertaining the weight of water which can be converted into vapor by the combustion of a given weight of each variety of fuel.

"The method which has been often heretofore pursued, consisted in ascertaining the amount of the ultimate constituents of fuel—carbon, hydrogen, and oxygen—and computing the quantity of oxygen required to enter into combination in order to effect their complete combustion. Assuming that the quantity of heat afforded was directly proportionate to the quantity of oxygen consumed, the calculation of relative heating powers was made upon the admission that the heating power of pure carbon had been determined, and that the power of other combustibles would be proportionate to the several quantities of oxygen which they would absorb.

"The experiments of Lavoisier, and more recently those of Despretz, have been relied upon to give the heating power of pure charcoal. The latter fixed the quantity of water evaporated by the combustion of one pound of pure charcoal, obtained by the distillation of sugar, at 12.3 pounds, taking the water at 32°, which is equivalent to 14.45 pounds, at the temperature of 212.°

"The experiments of Richardson and those of Regnault on coals, and the analyses of wood by Peterson and Shoedler, have all had in view the determination, by this theoretical means, of the heating power of the several combustibles.

"Ingenious as this method certainly is, it has failed to give results which could be, generally, reproduced when a practical application was sought to be made of the information thus acquired. The practical commonly fell short of the calculated efficiency of fuel.

"In the practical determination of the value of the fuel, the kind of evaporating vessel, the due regulation of the fire, the nature and condition of the products of combustion, the temperature of water used, and that of the air which supplies the grate, are all circumstances to be attentively considered. The hygrometic state of the fuel itself also deserves notice.

From the tables in the treatise above referred to, are derived the following results deduced from Dr. S. L. Dana's experiments. Each result is generally the average of several days' working.

Kind of Boiler employed.	Kinds of Coal used.	Pounds of Coal burned per h'r.	Steam to 1 of Coal from 212°.
1. Plain Cylindrical, 20 feet in length, 30 inch. in diameter.	Sydney, N. S., coarse bituminous coal	208	7.18
	Philadelphia pea anthracite.........	180	8.60
	Philad. pea, mean of 10 days running.	100	9.48
2. Cyndrical, 20 feet long, 45 inches in diameter.	Sydney, coarse..................	300	6.04
	½ Anthracite dust, ½ Sydney slack...	253	7.40
	¾ Anthracite dust, ¼ Sydney slack...	228⅓	7.51
	Best Peach Mountain anthracite.....	243	8.00
	Peach Mountain anthracite.........	240½	8 43
	Beaver Meadow anthracite..........	196	8.89
	Coarse Lackawanna anthracite......	219	9.17
3. A set of 3 Cylindrical boilers, 36 ft. long, 36 in. diameter.	Coarse anthracite.................	179	10.60
	Coarse anthracite.................	151	11.59
4. Four Cylindrical, set on the plan of Mr. A. A Hayes, each boiler 20 feet long and 24 inches in diameter.	Sydney, screened from dust.........	250	5.83
	Sydney slack alone................	148⅓	8.64
	Philadelphia pea anthracite........	117	9.06
	¾ Anthracite dust, ¼ Sydney slack...	108	9.60
	Lackawanna anthracite, nut size.....	106	9.77*
	¾ Anthracite dust, ¼ Sydney slack...	141.5	10.24*
	Lackawanna anthracite, egg size.....	147.3	10.28
	½ Anthracite dust, ½ Sydney slack...	112.5	12.52
	¾ Anthracite dust, ¼ Sydney slack...	67.1	11.36*
	½ Anthracite dust, ½ Sydney slack...	107	11.37*
	¾ Philad. pea anthr'te, ¼ Sydney slack.	100	10.86*
	Lackawanna anthracite, egg size.....	109	11.55
5. Tubular, 36 ft. long, 33 in. diameter, 12 tubes, 3 in. diamet'r.	Coarse Lackawanna anthracite......	85.8	11.96
6. Cornish, usual construction, 36 feet long, 6 ft. exterior, 3 ft. 10 in. in interior diameter.	Sydney, coarse....................	233⅓	6.32
	Lackawanna anthracite, coarse......	155.4	7.75
7. Improved Cornish, having 3 inter'r boiler, tubes each 19 in. in diameter inserted in the interior flue, end of the lower — cut away to give room for grate.	Coarse anthracite, kind uncertain....	57.3	9 51
	¾ Pea anthracite, ¼ bituminous slack..	136 6	12 08
	Lackawanna anthracite, usual size....	145	12.98
	Beaver Meadow anthracite..........	122	13.41

* Burned with fan blast.

"The following results have been obtained by Mr. Stevens in New Jersey, in a Locomotive boiler of the common form:

Schuylkill anthracite, 9.51, 57.3 pounds burned per hour.
Wood, 4.71, 112.6 pounds burned per hour.

"Mr. Thomas Wicksteed has published a set of results obtained in Cornish boilers, using various sorts of fuel, which are here reduced to the standard of 212°, to render them comparable with the preceding and following sets:

Blythe Maine Northumberland bituminous coal, 7.44.
Derbyshire bituminous coal, 7.64.
Large New-Castle coal, average 8.64.
Derbyshire ½, small New-Castle ½, 8.69.
Welsh ½, New-Castle ½, 8.86.
Gas coke ½, small New-Castle ½, 8.91.
Gas coke alone, 8.92.
Average Welsh, 8.98.
Average small New-Castle, 9.01.
Best small New-Castle, 9.38.
Anthracite, 10.17.
Best Welsh coal, 10.71."

"In the work on Anthracite Iron, above mentioned, will be found at page 149, the following table of the evaporative powers of different kinds of fuel, as given by experience in different forms of boilers.

1. *In a Locomotive Boiler.*

Bituminous coal, by N. Wood's experiments, 5.12.
Coke, by Pambour's trial, 7.12.

2. *In Wagon Boilers.*

Newcastle bituminous coal, by Watt's trials, 9.63.
Bituminous coal, variety uncertain, eight sets of experiments, 8.76.
Bituminous coal, Parke's experiments for six months, 10.28.

3. *In Cornish Boilers.*

Welsh coal, trial by Henwood, 11.62.
Welsh coal, experiments cited by Henwood, 11.78.

4. *In a Marine Boiler on board the Steamer African.*

Heaton bituminous coal, 8.15.

5. *In four Cylindrical Boilers on Hayes's plan.*

Anthracite ¾, bituminous dust ¼, 11.83.

6. *In a plain High Pressure Boiler.*

Scotch bituminous coal, by Fyfe, 7.74.
Anthracite, kind uncertain, 10.10.

7. *In Player's Boiler for using Anthracite.*

Anthracite, by Schaufbautl's trials, 12.40.
Anthracite, by Parke's and Maubey's trials, 13.25.

SPECIFIC GRAVITY, AS AN INDEX OF PURITY IN COALS.

1. The following analyses of anthracites found on the head waters of Beaver Creek, Luzerne county, Pa., are contained in a report published by the writer in the Journal of the Franklin Institute, Vol. 24, p. 289, for November, 1839. :

	Sp. gr.	Vol. mat.	Fixed carbon.	Ashes.
1st.	1.560	6.42	92.30	1.28
2d.	1.594	4.31	91.69	4.00
3d.	1.613	7.51	87.48	5.01
4th	1.630	9.60	85.337	5.063
Mean	1.599	6.96	89.452	3.838

From the above table, it will be perceived that the quantity of ashes increases as the specific gravity increases, and that the quantity of fixed carbon diminishes as the specific gravity increases. This might possibly not be found to hold good in all coal-fields, though I am inclined to think that in the same coal-field the relations of different plies will be found to confirm the same general law.

2. The so called Cumberland coal basin of Maryland is not limited to that State, but extends in a northeastwardly direction into the County of Somerset, in Pennsylvania, and southwestwardly into the State of Virginia. The writer had occasion some time since to examine, professionally, the geological structure, and to analyze the coals of a portion of this coal field near the borders of Pennsylvania.

The coal field appears to be gradually rising from about the vicinity of Frostburg to a point about five miles northeast of that at which the coal trough crosses the State line.

The following table embraces the several coals subjected to analysis, and indicates their physical characters, their be-

Name of Coal.	Specific Gravity.	Moisture expelled below 300°	Volat'e matter other than moisture.	Fixed Carbon.
Hoyman's new opening	1.32	2.0	18.2	74.75
Weller's 4 feet Vein	1.32	1.4	18.5	69.10
Hoyman's Old Opening	1.34	1.2	20.6	69.90
Hoyman's 6 feet Bed	1.36	1.3	18.5	68.53
Hoyman's 8 feet Bed	1.36	1.1	17.2	71.50
Schaeffer's New Opening	1.37	1.3	17.5	70.70
D. Korns' Old Opening	1.38	1.4	18.7	68.46
Uhl's 7 feet Bed	1.39	1.7	16.8	68.44
Meeting-house Vein	1.48	1.2	17.5	68.56
Weller & Hardin's	1.49	1.4	16.2	66.36
George's Creek, Md	1.34	Inclu'd with volat'e mat.	16.03	70.75
Eckert's Mine, Maryland Mining Co.	1.44	Do.	15.62	68.56
Average results	1.374	1.5	17.61	69.71
Average of 6 samples in Amer. Rept.	1.355	1.56	14.19	75.95

The above table affords the means of testing the principle, that within the same coal field a higher specific gravity in one specimen of coal than in another is an index of a greater quantity of earthy matter in the heavier than in the lighter specimen. Grouping together by two's, the first ten numbers in the above table, all of which are from the Pennsylvania end of the coal trough, we have—

haviour under the effect of heat, their proximate constituents, the nature of their ashes, and the ratio of their fixed carbon.

Ashes.	Ratio of fixed to volatile combustible.	Characters of Coal, Coke, and Ashes.
4.05	4.162	Ashes bright, buff, or fawn colored; remarkably light.
11.00	3.735	Color of coal deep black; structure columnar; cross fracture brilliant; horizontal partings dull; ashes blackish gray; coke more than double the amount of the coal.
8.10	3.393	Texture open; color jet black, with iridescent spots; lustre alternately shining and dull; structure rhomboidal; angles 75° and 150°; ashes reddish grey, dense.
11.66	3.705	Structure rhomboidal; surfaces of deposition dead black; edges of plies shining jet black; coke moderately dense, double the bulk of coal; ashes reddish grey, moderately dense.
10.20	4.157	Color nearly jet black, shining; structure rhomboidal, foliated; grain occasionally contorted, main cleats inclined to surfaces of deposition 30° and 150°; ashes light colored, bulky; coke dense.
10.50	4.040	Surface shining; stained with ochre; ashes chocolate brown, dense.
11.44	3.661	Structure cubical; color deep black, swells but little in coking; coke dense, dark grey, without lustre; ashes between fawn and flesh color, dense.
12.06	4.073	Coal discolored with ochre; ashes purplish red, bulky; coke more than double the bulk of coal.
12.79	3.918	Structure columnar; color deep black; plies varying in lustre; coke double the bulk of coal, iron gray, reddish; ashes reddish grey, dense.
16.04	4.096	Structure columnar; color dull black or iridescent; texture friable; coke two-thirds more bulky than coal; ashes flesh red, dense.
13.22	4.413	Coke bulky; ashes reddish grey.
15.82	4.389	Coke like the preceding; ashes lighter color
11.32	3.978	
10.41	5.211	

Mean specific gravity of the two specimens.	Mean per centage of earthly matter in the two specimens.
1.32	7.52
1.35	9.58
1.365	10.35
1.385	11.75
1.485	14.41

And again comparing the last two specimens, (both from Maryland,) we have—

George's Creek,	1.34	13.22
Eckert's Mine,	1.44	18.25

3. Besides the foregoing proofs of the use which may be made of the density of coals to determine, approximately, their relative freedom from earthy matter, the following extract from the Proceedings of the Academy of Natural Science, Vol. II., p. 8, February 13, 1844, may be adduced:

"Prof. Johnson communicated some observations in relation to the properties and habitudes of different varieties of coal.

"1. He gave the results of some recent analyses of coal, which strongly confirm the position which he had previously advanced, viz.: that in coals from the same coal district, and where that part of the mineral substance which is combustible may be considered as similarly constituted, the *density* of different specimens may be regarded as the index to their relative impurity.

"From seven samples of coal from different mining districts were taken, at random, specimens for analysis.

From the first sample,	specimen	a	had a sp. gr.	1 438,	and gave of	ashes,	18.99
	specimen	b	"	1.424	"	"	18.318
" second do.	"	a	"	1.322	"	"	5.653
	"	b	"	1.305	"	"	5.239
" third do.	"	a	"	1.304	"	"	4.081
	"	b	"	1.309	"	"	6.519
" fourth do.	"	a	"	1.339	"	"	9.109
	"	b	"	1.225	"	"	7.398
" fifth do.	"	a	"	1.315	"	"	10.090
	"	b	"	1.335	"	"	11.071
" sixth do.	"	a	"	1.347	"	"	13.768
	"	b	"	1.329	"	"	11.072
" seventh do	"	a	"	1.511	"	"	21.250
	"	b	"	1.289	"	"	6.080

"2. He also called attention to the fact that, from the same hand specimen, may often be obtained widely different results by analysis. A small specimen was shown, in which were displayed most decided differences of structure, lustre, color, character of powder, amount of volatile matter, amount and character of impurities. This was a specimen of coal from the Cumberland coal field of Maryland—in which a portion was columnar and crystalline in form—of a deep jet black color, shining and friable, giving a brown powder, and when coked, yielding a highly intumescent porous mass, and leaving, when completely incinerated, only 1.754 per cent. of reddish yellow or fawn coloured ashes, exceedingly light, and liable to be carried away by the slightest motion of air. The same part yielded 18.28 per cent. of volatile matter, and consequently left 79.966 per cent. of fixed carbon. The other part of the specimen was amorphous in structure, tough in consistence, dull, and almost destitute of lustre, yielding, when completely pulverized, an almost black powder. It gives, when incinerated, 14.736 per cent. of ashes, of a greenish white color, very dense, and cohering slightly when strongly heated. Its volatile matter is 15.976 per cent., and consequently the fixed carbon 69.288. The coke swells more or less, according to the rapidity of the application of heat. The ratios of fixed to volatile combustible are 4.37 and 4.40.

"3. He adverted to the designations red and white ash coals, and exhibited proofs that mere analysis, on a minute scale, is liable to mislead us in regard to the true character of the earthy residua of the coals in question. He exhibited a sample of ashes and of clinker, from Lackawanna anthracite, obtained from the combustion of two tons of that coal; and also a specimen of ashes from the analysis of a hand specimen—the former being dark brownish red, and the latter almost perfectly white.

"4. He presented evidences of the effect of the rate of heating on the amount and character of the coke produced from a given weight of coal of the same kind, showing that when a brisk and intense action of heat suddenly applied is made the means of coking the coal, a considerably greater amount of volatile matter is expelled than when a slow application of heat gradually drives off the matter volatilizable by that principle alone."

SALTS OF AMMONIA IN THE DUST OF ANTHRACITE FURNACES.

(*From the proceedings of the Academy of Natural Sciences, vol. 3, p.* 191, *for March* 16, 1847.)

"Professor Johnson communicated some observations and experiments on the dust of anthracite furnace flues. Having several years since ascertained the presence of large quantities of salts of ammonia, both sulphates and chlorides, in flues and stove pipes where anthracite is consumed, he had recently directed attention to this as a source from which a moderate supply of these salts for the uses of horticulture may readily be obtained. It was therefore deemed worthy of a trial to ascertain in what proportion the salts soluble in water might occur in the dust of a flue, such as ordinary practice in domestic use would afford. For this purpose, one pound of the dry dust was treated with successive portions of distilled water until the liquid ceased to be coloured, or to give a saline residuum on complete evaporation. The liquid was of a dark brown color, and on analysis afforded

Sulphate of lime - - - - -	12.3 grains
Sulphate of Ammonia - - - -	285.5
Chlor-hydrate of Ammonia - - -	160.6
Compound tarry matter - - -	20.4
Total in 1 pound - - - -	478.8 grains, =

6.84 per cent., which, including the losses incident to the several steps of analysis, may be taken at 7 per cent.

MECHANICAL STRUCTURE AND RELATIVE AGES OF COALS.

(From the Proceedings of the Academy of Natural Sciences of Philadelphia, Vol. I., p. 9, April 13; p. 73, August 24; p. 118, November 2.)

The question of the identity and contemporaneousness of the two great divisions of the coal measures of Pennsylvania, has sometimes occupied the attention of geologists. A similar question is occasionally agitated in Europe, in reference to the Anthracite and Bituminous coal fields of that quarter of the world.

Among the arguments in favor of the contemporaneous deposition of the coal in the two regions, those which are derived from the similarity of the accompanying measures or members of the coal series in the two regions, and the resemblance or identity of the fossil organic remains accompanying the coal in both cases, are not the least weighty. The presence of large bodies of carbonate of iron interposed among the coal beds in both coal districts, is an analogous circumstance strongly corroborative of the opinion that both varieties of coal were produced under circumstances at least strongly resembling each other.

Another circumstance favorable to the supposed similarity of circumstances which accompanied the deposition of anthracite and bituminous coal, is the resemblance in mechanical structure of the two kinds. This may, at the first enunciation, seem somewhat startling; especially since the terms heavy, hard, and tough, are generally applied to the one, and light, soft and friable, or tender, to the other. It is nevertheless true, that strong mechanical resemblances exist; and the more minutely we examine the two varieties, the more shall we be impressed with the conviction of the importance of the resemblance.

In the first place, the coal of all coal measures has a series of partings parallel to the floor or bottom of the bed on which it rests, and to the cover or roofing under which it lies. These are as distinct in inclined and vertical beds as in those which still remain horizontal.

In the second place, the connection between the coal and its underlying slate, as well as with its top slate, is so definite and well understood, that it serves to determine the true original position of coal beds, which have been so far disturbed as to be turned nearly upside down; of which examples are not wanting. These characteristics are found in beds of both kinds of coal.

In the third place, there is most commonly a fracture or division of the coal in some direction, (which, for the same bed, is generally continuous,) and nearly at right angles to the planes of deposition.

Fourth, a third series of divisions by vertical planes, called cross partings, inclined to the last mentioned. This system of planes is not always continuous throughout the bed, but varies in the different plies.

The principal vertical divisions are known to miners by the names of "cleats" or "slines," and sometimes by that of "grains." The direction in which these run, seems to determine the manner of working out the coal; for, in attempting to separate large masses from their natural position by means of wedges, it is only in the direction of the cleats that the separation can take place. In inclined beds, from which the coal is to be extracted by a *slope* or railroad laid down on the floor of the bed, it is a great convenience to have the cleat lie in a direction diametrically across that of the slope, or in conformity with the *strike* of the bed; for then in running a drift from the bottom of the slope horizontally along the bed, and afterwards carrying the workings upward, the cleat will always face the miner, and he will be enabled to obtain heavy falls of coal by undermining and wedging down.

In most bituminous coals, and in not a few anthracites, the "cleavage of the laminæ," or what I have chosen to call surfaces of deposition, are sufficiently distinct, and afford ready partings to separate masses into small pieces. In some of the harder anthracites, however, these surfaces are nearly obliterated, being distinguishable only by different shades of black. The actual cleavages of the coal, in such instances, seldom take place along the surface of deposition; but on igniting the specimen, we may generally obtain partings in those Natural seams.

The regular slines also, in anthracite, are sometimes so far obliterated as to be only developed by strong heat or partial combustion. They are then shown by the thin, white shining laminæ of earthy matter, which mark two opposite sides of a lump of half burnt coal.

The absolute direction of the cleat is very various. At the Laurel Hill mines, in Hazle creek valley, it is believed to be about north 80° East.

In some beds of coal which I discovered and examined on the West Branch of the Susquehanna, it is due east and west by compass.

In the Middleton mine coal, in the northerly part of England, it is from N. 20° W. to N. 32° W.

The second, or "short cleat," in opposition to the "long cleat," which extends for great distances, is the cross parting already spoken of, and not unfrequently runs perpendicularly to the directions of both the "cleavage of the laminæ and to the long cleat." This is seen in both bituminous coals and anthracites.

Another circumstance to which I would refer, as indicative of the similarity of origin and correspondence in character, between bituminous coals and anthracites, is the correspondence of the two, in respect to the composition of the ashes of the two kinds. Silica, alumina, oxide of iron, with small amounts of lime, magnesia, and occasionally of oxide of manganese, are the ingredients of the ashes of both kinds of coal. The proportions vary, not only in the different kinds of coal, but also in the several plies of the same bed, both in the bituminous and anthracite districts. In the anthracite, the diversity of composition is marked by the color of the different streaks after partial incineration.

Another resemblance between the two kinds is, that in the anthracite beds, spaces partially vacant are found to contain masses, with a puffy aspect on the exterior, so strongly resembling coke, that it might be difficult at the first glance to distinguish a fragment of it from a piece of artificial coke. Natural coke is also found in connection with beds of bituminous coal, especially where the latter are in close proximity with primitive strata—as in the mines of Virginia.

When coal contains a large proportion of earthy matter, and is deposited in thin laminæ, it will, in the state of anthracite, be found to part with great difficulty in the direction of the surfaces of deposition. It will then be seen to give fractures, developing a multitude of small conchoidal surfaces. This is by the miners termed bony coal; and that it well deserves its name may be evinced by its actually being so hard as sometimes to strike fire with steel.

Coal occasionally assumes the appearance of well defined rhombic prisms and octaedra, occasionally with striated surfaces, in which cases, though the cleavages be difficult and obscure, they are nevertheless practicable.

August 24.—Professor Johnson exhibited several specimens of *crystalloid* anthracite and bituminous coal, and stated some of the circumstances which seem to determine the assumption by this mineral, of certain figures contrary to the assertion of many mineralogists that it has no definite form.

The forms which anthracite occasionally presents are—1. *Ovoid*, which causes it, in breaking, especially when the fracture takes place from long exposure to the atmosphere, to fall into spheroidal masses with salient portions strongly reminding us of truncated angles in ordinary crystals. This figure has often been observed in one of the beds of anthracite found on Beaver creek; and a large specimen furnished by Mr. Jacob Thomas, of Beaver Meadow, was exhibited, showing the truncated borders along the lines of separation in a very remarkable manner, and also displaying beautiful irridescent colors. It was remarked that coal affecting this form is frequently found to leave a considerable portion of oxide of iron among its earthy residue; but that the whole of the latter was not usually a large per centage of the coal.

2. The next definite form mentioned as affected by coal, is a *radiated* structure, well characterized in several specimens from the third bed, from the bottom of the formation at Beargap, Dauphin county, Pa. This structure was likewise illustrated in a sample of Welsh bituminous coal. The radiations generally proceed from two points at no great distance from each other and forming two sections of conical surface, unite at certain distances from their points of departure into a single cylindrical section near the termination of the rays. The exterior of these radii is of a silky lustre, striated, and sometimes interrupted by the interposition of fragments of organic remains, in the state of fossil charcoal. Very large stems are occasionally found with radiated, crystalloid anthracite adhering to the opposite sides—the directions of the striæ being on the two sides very nearly the same.

3. The rhombic hexaedron was exhibited in a well marked specimen of anthracite adhering to its accompanying slate.

Few mineral forms are better defined than this mass of anthracite. The angles can be determined by the goniometer with tolerable precision, liable, however, to the slight uncertainty arising from the presence of organic bodies, tending to oppose the crystalline arrangement.

4. An octahedron with tolerably well defined faces, striated in different directions on the adjoining sides, was exhibited, and the circumstance of possessing a large portion of earthy matter was noticed, as belonging to many samples of coal which exhibit this exterior aspect.

The presence of several well marked crystalloid forms being thus established, he adverted to the argument which such forms had been supposed to furnish against the vegetable origin of coal, and stated that in the very samples under examination were seen the most incontrovertible evidences of the source from which not only bituminous coal, but anthracite also had been derived. In one and the same specimen of the latter, were seen mineral charcoal, natural coke, and true anthracite, indicating as well the vegetable origin of all, as the process of formation, by which the last two had probably been derived from the intermediate state of bituminous coal.

In accounting for the supposed impossibility of crystalline structures being formed out of organic matter, he observed that a distinction is to be drawn between *organic elements* and *organized substances*, and that the *former* may often be so proportioned, when derived by distillation, fermentation, or other chemical reaction from the latter, as to be capable of assuming definite figures. The production of coal from vegetable bodies is supposed, on all hands, to have resulted from a slow chemical decomposition of the latter, and the establishment of new orders of affinity between the original constituent atoms. The carbon as well as the other materials of vegetables was by this process reduced, at least in part, to the condition of ultimate molecules, instead of being merely mechanically divided into small particles. It would therefore be capable of obeying any law of movement which either its own affinities or those of the earthy constituents which had entered into the composition of the vegetables from which it had been derived, might tend to impress. That it is the earthy constituents which determine the forms assumed by coal, seems probable from the fact that the more earthy residuum of a particular kind any coal contains, the more prone does it appear to be to assume a crystalloid structure.

Reference was made, in this connexion, to those cubic, rhombic and columnar structures which often occur in both anthracite and bituminous coal, and which not unfrequently exhibit to the eye, especially after partial incineration, the clearest evidence of a tendency among the earthy ingredients to regulate the arrangement of forms throughout the whole mass. It was also stated that the result of a considerable number of analyses of the ashes of coal, appeared to favor the presumption that the two principal constituents, silica and alumina, are in definite proportion to each other, and may therefore have a power of assuming definite forms. The oxide of iron in the ashes is commonly derived from the decomposition of pyrites, while the lime and magnesia in the coal are probably in the state of carbonates, unless where the production of sulphuric acid by the decomposition of the pyrites has converted the former into gypsum and the latter into espom salt. From this latter play of affinities the carbonate of iron would be produced and subsequently the sequoxide, often seen covering the interstices of outcrop coal, and forming bog ore in the springs which proceed from coal seams, the coal in the meantime retaining the form impressed by the agency of the silicate of alumina, and having a portion of its interstices or those of the underlying slates filled up with crystallized sulphate or carbonate of lime.

Admitting the justness of this view of the causes which produced crystalloid forms in coal, we have no more difficulty in accounting for the number of different forms which it occasionally exhibits than for the analogous variety in regard to other minerals; the carbonate of lime, for example, which, as is well known to mineralogists, takes on a great number of distinct forms."

November 2.—"Professor Johnson made some remarks on the samples of Anthracite from Rhode Island, this evening presented, and stated—

That the formation in which they occur, reposes on a coarse conglomerate, which rests immediately on granite or hornblende rocks of the primitive series. The near proximity of igneous rocks appears to have exercised an important influence, not only on the position, but on the present character of the anthracite of this formation; for while it has thrown the beds into a highly inclined position, it has expelled the last vestiges of volatile matter, decomposed the sulphuret of iron, and changed the color of the coal in some of the beds to a nearly steel blue. The vegetable impressions, are in these cases, to a great extent obliterated, and the traces of them only appear at the surfaces of deposition. In other beds, the impressions are more perfect, and their genera and species are more readily made out.

An idea has been formerly current, that the coal formation of Rhode Island and Massachusetts is of more ancient date than those of Pennsylvania; but the identity of fossil remains, seems to determine the geological period of both to be the same. And in this respect we have analogies sufficiently numerous in our own country, to induce us to believe that all the coal formations are essentially contemporaneous, and that whether they rest on granite, as in Rhode Island, Massachusetts, and Virginia, on the older members of the secondary, as in the anthracite fields of Pennsylvania, or on the mountain or the "cliff" limestone of the Western States, the coal series has every where been the product of a period in the history of our planet which was highly prolific in vegetable life, of which the remains were deposited on whatever member of proceeding formations was exposed in a condition to receive them.

The anthracite of Rhode Island appears to have been subjected not only to a high temperature, but also to intense pressure, and to have been much comminuted by the friction of one member of the formation sliding over another in the uptilting which the strata have evidently undergone. The coal in all such cases being more tender and friable than the sandstones, slates and limestones, becomes the unguent in the joints of the stratification, and the results of its power to facilitate the motions of the strata as they are partially folded up, is, 1st, a pulverulent portion in contact with either the top or the bottom rock of the bed; 2d, a high polish imparted to some of the sliding surfaces of the more durable coal; 3d, an irregularity in the thickness of the coal beds, the indentations of the upper and lower rocks being not unfrequently found opposite to each other, forming thick places in the coal seam, and containing much of the broken material which has been displaced from the parts where the prominences of the rocks come nearly in contact, and almost shut up the seam.

He adverted to the fact that for reasons stated by the geologists of Rhode Island and Massachusetts, viz. the great amount of drift or diluvial matter with which all parts of this coal formation have been covered over, the limits of the coal trough have not hitherto been traced with much precision.

Within the city of Providence, the strike of the beds is a little to the east of south, and the dip to the north of east. The mining operations are in general very troublesome and expensive, on account of being carried on below water level, and through a thick stratum of loose earth and gravel. Very little of the coal hitherto obtained has been of merchantable quality.

ON THE RELATION BETWEEN THE COAL OF SOUTH WALES AND SOME PENNSYLVANIA ANTHRACITES.

(From the Proceedings of the Academy of Natural Sciences, Vol. 1, p. 40.)

Having received some time since a number of samples of the coals used by Mr. Crane at the Yniscedwyn iron works in South Wales, some pains have been taken to trace the relation of that mineral to some of the many varieties of anthracite found in Pennsylvania. It was the first step in this inquiry to mark the relation by external characters. These in the Welsh coal are, 1st. A structure often lamellated, and tending to separate on the surfaces of deposition, owing to the quantity of carbonaceous clod which occupies the dull seams between the bright plies of coal.

2d. The abundance and width of the reeds constituting the charcoal deposits.

3d. The shining and polished surfaces occasionally presenting themselves to view at some of the natural partings.

4th. The purplish tints of metallic oxide often observable on the surfaces of fracture.

5th. The general color is deep black, and either dull or shining according as the ply which is examined belongs to the coal proper, or to the carbonaceous clod partings of the seams.

The next circumstance worthy of attention in tracing the relation of coals, is their specific gravity; and this in the Welsh anthracite is from 1.336 to 1.372—not greater than that of many bituminous coals.

The next point of comparison is the quantity of volatile matter, and this by the mean of two trials is 9.18 per cent.; that on the anthracite containing most clod is 10.7, and that of the more compact variety is 7.66 per cent.

Mr. Mushet makes it from 6.66 to 7.70 in the coals of the same locality. Mr. Frazer analyzed a sample of the same coal, and found 7.60 of volatile matter, 86.6 of carbon, and 5.8 of ashes.

The quantity of earthy matter in the Yniscedwyn anthracite, according to the mean of 3 analyses of Mr. Mushet, is 3.578 per cent. Adopting this for the proportion in the sample which yielded 10.7 per cent. of volatile matter, we have the solid carbon=85.722 per cent. and in the other 88.762.

Among Pennsylvania anthracites that which approaches most nearly to the Yniscedwyn coal, is that of Lyken's Valley, situated in the northwestern fork of the southern anthracite field. This coal has all the exterior characters of the Welsh anthracite; containing in many samples a large portion of carbonaceous clod, with well marked vegetable impressions; and in color, structure, and varieties of surface, the two coals might readily be taken the one for the other. Of nine samples analyzed, the lowest specific gravity was found to be 1.374, the highest 1.416, and the mean 1.390. The average amount of volatile matter was found to be 8.067, the highest being 11.854 per cent.; the mean proportion of earthy matter and metallic oxides is 4.46; and that of the fixed carbon 87.472 per cent.

From these data are derived the following comparisons.

	Sp. Gr.	Vol. mat.	Carbon.	Ashes.
Yniscedwyn, lighter variety,	1.336	10.7	85.922	3.578
Do. heavier,	1.372	7.66	88.762	3.578
Mean of two, . =	1.354	9.18	87.242	3.578
Lyken's Valley, .	1.390	8.067	87.472	4.460

In distilling the Welsh anthracite, the first portion of gas which comes over, burns with a pale blue flame, like that of carbonic oxide, which is succeeded at a certain point of temperature by a sudden outburst of carburetted hydrogen, burning with a bright flame and smoke, a quantity of bituminous matter being at the same time evolved, sufficient in one instance to close up the narrow beak of the retort employed in the distillation. The coke is perfectly anthracitous, and the angles of the fragments entirely sharp and well defined.

The gaseous matter of the Lyken's Valley anthracite also burns with a brilliant flame, but no violent explosive development of it was remarked.

ANALYSES OF AMERICAN AND FOREIGN COALS.

On the 8th of March, 1842, the writer communicated to the Academy of Natural Sciences the results of a series of experiments on American and foreign coals, exhibiting the residue of each on which he had experimented, with a view of ascertaining the relative proportions of volatile matter, earthy matter, and fixed carbon. The experiments were performed on all in a similar manner, viz. by exposing the coal to a red heat, raised as rapidly as possible. As the moisture, however, is in such cases brought in contact with carbon at a high temperature, it may, by decomposition, cause some of the carbon to be carried off, and thus raise the estimate of the volatile matter above what it would be, if more slowly conducted. Incineration was conducted in a muffle, at a high and long continued temperature.

The following are the results of the analysis of some of these coals:

	Vol. matter.	Ashes.	Carbon.	Fixed to vol. combus'e.
Newcastle coal, per cent. -	29.0	0.44	70.56	2.43
Sydney, - - - - -	43.5	1.50	55.00	1.26
Liverpool, - - -	37.9	0.72	61.38	1.62
Staffordshire, - - -	47.5	1.86	50.64	1.06
Welsh, anthracite, - -	4.4	4.10	91.50	20.80
Pictou, - - - - -	30.7	8.00	61.30	1.99
Richmond, - - - - -	15.1	24.74	60.16	3.98
Do. (another sample,)	17.3	17.08	65.62	3.79
Rhode Island, anthracite -	13.1	11.26	7[illegible]	5.77
Fallstown, (Beaver river,) Pa.,	35.8	6.42	57.76	1.61
Beaver Meadow, (spheroid coal,)	9.0	5.60	85.50	9.50
Shamokin, anthracite, -	9.1	5.84	85.06	9.34
Wilkesbarre, do. - -	8.9	11.66	79.74	8.96
Beaver Meadow, (Piatt tract,)	7.9	6.00	86.10	10.9

ANALYSIS OF THE NATURAL COKE OF VIRGINIA.

From the Proceedings of the Academy Natural Society, vol. 1, p. 223.

Prof. Johnson mentioned that he had made trials to determine the volatile and earthy ingredients of the so-called natural coke from Virginia, of which samples were exhibited at a preceding meeting of the Academy. This substance presents in its exterior appearance a strong contrast with all known varieties of either anthracite or bituminous coal. It is wholly wanting in lustre. It has lost, if it ever possessed, all continuous slines or cleats, and even the surfaces of deposition appear to be in a great degree obliterated. Its texture is porous. It is in very many, if not all, specimens, strongly charged with iron pyrites, which, by exposure to the air, efflorescing into sulphate of iron, gives the appearance of friability to the material, and by this means distinguish it clearly from anthracite.

Two samples of this combustible were tried for the purpose of ascertaining the amount of earthy matter, volatile matter, and fixed carbon. The first gave of

	Per cent.
Volatile matter, - - -	11.16
Carbon, - - - - -	77.86
Earthy matter, - - -	10.98
	100.

The second, which appeared to be rather more highly charged with pyrites than the other, gave, by the mean of four separate incinerations, of

	Per cent.
Volatile matter, - - -	14.82
Earthly matter, - - -	2.43
Fixed Carbon, - - -	82.75
	100.

The distillation of this substance by the immediate application of a red heat, produces a gas which burns with a steady clear flame, of a yellowish white color, accompanied by a little smoke, which, however, nearly or quite disappears when the access of air is free and abundant.

The distillation produces no enlargement of volume or adhesion of the particles of carbonaceous matter, as in certain semi-bituminous or "transition" coals, such as that found on Stony Creek, in Dauphin county, Pennsylvania.

In regard to the applicability of the term "natural coke" to this substance, it was remarked, that, understanding this term as indicating a change of texture from that of the bituminous coal of the same district, a partial discharge of the volatile ingredients of the same coal, and as a necessary consequence, a relative augmentation of the earthy material as well as of the fixed carbon, there is no impropriety in its use, but, on the contrary, a peculiar propriety, inasmuch as neither of the other terms in general use to designate mineral fuel is applicable to this variety. He referred to the geological report of the State of Virginia, in which an analysis of this substance is given, exhibiting its composition as follows, viz:

Volatile matter, - - -	9.98
Fixed Carbon, - - -	80.30
Ashes, - - - - -	9.72

COAL FROM THE VALLEY OF HAZEL CREEK, PA.

The following analyses from the Valley of Hazle Creek, were published in the Journal of the Franklin Institute, Vol. 24, page 73, for August, 1839:

No. 1 is compact in structure, giving conchoidal fractures in all directions, apparently indifferent to the surfaces of deposition, which are manifested only by alternating lines or seams of blueish black and jet black, which mark the successive layers. This appearance gives the idea that these surfaces have been in a great measure obliterated, while the whole mass was, from some cause, in a semi-fluid state. The specific gravity of this specimen is 1.591.

When heated to a temperature sufficient to expel the water which it contains, without decomposing it,

		Per cent.
The specimen No. 1 lost - - - - - -		1.915
When the dried coal is ignited to redness for some time in a close vessel, it yields carbonic oxide and carburetted hydrogen, with a small portion of sulphur, - - - - - - - -		5.068
The remaining fixed carbon is - - - - -		88.187
Earthy matter 4.83 per ct. viz.	Silica, - -	2.589
	Alumina, - -	1.772
	Peroxide of iron, -	.270
	Lime, - - -	.138
	Magnesia, - -	.052
	Protoxide of manganese, - -	.009
		100.

From the latter numbers it will be perceived that of the fixed ingredients or ashes of this coal, 100 parts will be composed of

Silica, - -	53.603
Alumina, - -	36.687
Perox. of iron, -	5.590
Lime, - - -	2.857
Magnesia, - -	1.076
Prot. manganese,	0.186

The ashes of this coal are of a yellowish white or very light buff color, and very bulky. Exclusive of moisture, the fixed is to the volatile combustible matter as 17.4 to 1.

Specimen No. 2 has a specific gravity of 1.574. The color and other external characters of this coal are similar to those of No. 1, but it was remarked that the surfaces of deposition are even more completely obliterated than in that specimen; and that in the direction of those surfaces, no even faces could be procured in fracturing the coal; while in planes at right angles to those surfaces, it has a "grain" or "sline" represented by exceedingly thin plates of white earthy matter, along which fractures frequently occur.

		Per cent.
By heating to a temperature of 370° Fahrenheit this coal loses - - - - - - - -		2.196
By heating to whiteness in a close vessel, it gives of carbonic oxide and a little carburetted hydrogen		3.165
The carbon not capable of being volatized by simple heat, is - - - - - - - -		85.909
Its earthy impurities, including oxides, amount to 8.73 per ct. viz:	Silica, - -	3.938
	Alumina, - -	3.230
	Peroxide of iron, -	1.135
	Lime, - - -	.120
	Magnesia, - -	.120
	Loss, - - -	.015
		100.000

The proportions of the several ingredients of the ashes of this coal are somewhat different from those of No. 1.

Thus the Silica is - - -	45.105	per cent.
Alumina, - - - -	37.000	"
Peroxide of iron, - -	13.000	"
Lime, - - - - -	1.380	"
Magnesia, - - - -	2.430	"
Loss, - - - - -	1.085	"
	100.000	

The fixed to volatile combustible, 27.1 to 1.

The ashes are nearly white, or with a very slight tinge only of red, and are distinguished from those of No. 1 by a far greater *density*, being under a given bulk about two and a half times as heavy as the latter. A larger portion of oxide of iron and of manganese will be observed in the second than in the first analysis.

Specimen No. 3 was taken from the same bed as No. 2, and was found to have a specific gravity of 1.55. The color of this coal is a deep and nearly uniform black—shining. Fracture irregular, splintery.

	Per cent.
The water in this coal was found to be - -	2.250
Loss by heating for some time to whiteness, gas burning with bluish white light - - -	4.625
Carbon not volatile at white heat, - - -	90.705
Earthy ingredients 2.242 per ct. composed of	
Silica, - - - - -	1.071
Alumina, - - - -	.965
Peroxide of iron, - - -	.135
Lime, - - - - -	.141
Magnesia, - - - -	.073
Oxide of manganese, trace, -	.
	99.965

Fixed to volatile combustible, as 19.61 to 1.

It appears therefore that this is considerably richer in carbon than either of the other specimens, and that its earthy residuum is but little more than one fourth as great as that of No. 2.

The proportion of the several ingredients of the ashes, it will be observed, is

Silica, - - - -	43 68
Alumina, - - - -	39.34
Peroxide of iron, - -	8.22
Lime, - - - -	5.76
Magnesia, - - -	3.00
	100.00

This specimen has, therefore, both in the amount of its fixed carbon and in the small proportion of its earthy residuum, a considerable advantage over either of the preceding. Its specific gravity is also the lowest of the three. The density of its ashes is intermediate between that of 1 and 2, being exactly three-fourths as great as the latter, so that the density

of the residuum of No. 1 is represented by -	8
That of No. 2 by - - -	15
That of No. 3 by - - -	20

By an average of the three analyses above given, it will be seen that the proportion of water in this coal, is 2.120 per cent.

The other volatile ingredients are - -	4.286	"
The earthy matter, oxides, &c. - - -	5.263	"
Carbon, - - - - - - - -	88.331	"
	100.	

and the mean ratio of fixed to volatile combustible, 20.60 to 1.

Hence the combustible matter, including the gaseous and solid materials amounts to 92.552 per cent.

In conclusion, I may observe, that while these analyses demonstrate the high density and compactness of this coal, fitting it for the purposes of steam navigation, for which these qualities, combined with great heating power, are of primary importance, they also show that, for the various arts, and for domestic consumption, its properties are calculated to sustain the high character of the central coal-field of Pennsylvania, for the concentrated and durable heat which it furnishes, and the absence of those ingredients which might interfere with its useful application.

COALS OF BRADFORD COUNTY, PA.

The coal-field of Carbon Creek, Bradford County, Pa., ten miles from Towanda, was examined by the author of these pages, in 1839, and the following analyses given:

Number.	Locality.	Specific Gravity.	Water at 212° to 300.	Condensible vapour in coking.	Uncondensible gas.	Fixed Carbon.	Earthy matter.	Fixed to volatile matter.
1	Fall Creek..	1.51	1.3	4.5	9.2	62.6	22.4	4.16
2	Fall Creek..	1.45	1.9	6.2	9 3	70.0	12.6	4.02
3	Fall Creek...	1.46	1.2	5.7	12.2	63.9	17.0	3.34
4	Miller's opening, middle ply, old drift...	1.38	2.5	3.0	15.0	68.1	11.5	3.32
5	Miller's opening, upper ply, old drift.....	1.38	1.0	3.5	14.7	65.5	15.3	3.48
6	Do. do. do. do.	1.35	1.3	6.5	11 5	74.9	5.73	3.88
7	Mason's bed, middle ply....................	1.39	0.6	2.8	15.4	69.0	13.1	3.85
8	Mason's bed, lower ply......................	1.40	2.1	.....	16.8	68.5	12.53	3.63

In all the above analyses except the last, the weight of condensible vapours, produced by heating to redness, is determined separately from that hygrometric moisture which is expelled a little above the boiling point.

It may be observed that the ratio of fixed to volatile combustible matter in this coal is on an average 3.71. This, as seen at p. 96, places the Towanda coal in range with those of Cambria County and Queen's Run, (Clinton County,) Pa.; and the evaporative power may therefore be supposed to range between 9.24 and 10.27. In the British series, (p. 97,) it might possibly take rank with Ebbw Vale coal, which would make the evaporative power 10.21. But this could hardly be expected, since the earthy matter of the Towanda coal is 13.77 per cent., while that of Ebbw Vale coal is no more than 1.5 per cent. (vide ante, p. 77.)

RECENT INVESTIGATIONS

RELATIVE TO

AMERICAN AND FOREIGN COALS.

I.—COAL FIELD OF NORTH CAROLINA.

That coal exists in the interior of North Carolina has been known to a limited number of persons for some years. But of the nature, extent, and exact position of this coal, its geological relations, or the rocks with which it is associated, little has hitherto been made known. In October, 1819, the writer being on a tour through the middle and western parts of North Carolina, took occasion to pay a visit to the coal field in question, and, in company with his obliging friend, Prof. E. Mitchel, of the University of North Carolina, spent two or three days in traversing the northern and western out crop of the basin. This basin lies partly in the county of Chatham, and partly in that of Moore, and is traversed longitudinally by the channel of Deep River, a branch of the Cape Fear River. This coal field consequently lies almost exactly in the centre of the State, and its northeastern extremity is about seventy-five miles by the course of the stream above the town of Fayetteville, to which, it is known, steamboat navigation reaches from the city of Wilmington. The Cape Fear and Deep Rivers are about to be rendered navigable by means of slack water pools and locks, for which the surveys have already extended to the upper part of the coal field, and contracts have been entered into for the execution of the work.

The first point at which the coal measures were observed, was near the farm of Mr. Ferrish, situated at the mouth of George's Creek, a tributary of Deep River. This is in the southern part of the county of Chatham, and, according to information, is not far from the northeastern extremity of the basin. A thin seam of coal is said to have been observed on the southern side of the river, about two miles southeastward from Ferrish's house. The rock which appears to constitute one of the lowest, if not the very lowest, member of the coal series, is a reddish brown sandstone, sometimes employed in the country for building purposes, at other times for making grindstones. A similar rock was noticed on the Raleigh road about thirteen miles from Chapel Hill, and at other places, where it is, from point to point, interrupted by dikes of a dark colored trap. At the edge of the coal basin, this red sandstone seems to repose on the upturned edges of the older slates belonging to the gold region, but of this fact I had no opportunity of seeing positive evidence.

The sandstone in the creek at the rear of Ferrish's house, dips southward in a low angle not exceeding 6°. The mere edge of the seam, three feet three inches thick, has been laid bare in three or four places on the plantation; but nowhere is it pursued far enough to determine the actual thickness, when found under a sufficient covering of rock, to justify mining operations. The coal is covered with a stratum of slate, and over that is another bed of red sandstone. The slate is seen in considerable thickness on the margin of the river, a few hundred yards south of Mr. Ferrish's house. It appears to be destitute of vegetable impressions, but filled with minute bivalve shells, and interspersed with many coprolites of fishes or reptilia. In some of the laminæ of the slate are thin plates of carbonate of lime.

The coal found at Ferrish's has the character of out-crop coal, but among the less friable portions are some specimens which may with tolerable correctness represent the general quality of the seam.

The next point examined was at Horton's Mills, four miles higher up the river. The openings on the seam are here made along the course of a small tributary, a few hundred yards from the river, on its northern bank. The dip is towards the S. 13 W. and the inclination of rocks at the mill-race is not more than ten or twelve degrees, but on the underlying rocks in the rear of the coal, it increases to about thirty degrees. The coal is here used by blacksmiths. The thickness of the seam is stated to be from four to five feet.

Four miles still higher up the river, a short distance above Evans' Mills, and barely within the borders of Moore county, the rocks were noticed dipping S. 43 E.

Two and a half miles further southwestward, are the coal openings on Wilcox's land, the dip is to S. 45 E., and the angle thirteen degrees. From being highly bituminous at Ferrish's and semi-bituminous at Horton's, the coal at Wilcox's is wholly anthracitic. The thickness of the beds appears not to have been ascertained, as only the edge has been explored for a few rods along the course of a rivulet about half a mile from the river.

The coal measures continue two or three miles further, to the plantation of Dr. Chalmers, (the Alston place, noted for one of Fanning's attacks during the Revolution,) near which the materials of the coal appear to have passed even beyond the anthracitic state, and to have been converted into plumbago. This material is used by the inhabitants for paint, crayons, pencils, and other purposes for which the same substance has been elsewhere employed.

It is currently reported that coal has been found on one of the branches of Drowning Creek, which is the principal head of the Little Pedee. If so, it must be several miles to the south or southwest of the point last designated, and very near the borders of the gold formation of Moore County. It is a fact worthy of notice, that the older slates containing veins of auriferous quartz, the gneiss rocks which border them, the coal measures which overlie the latter, and the diluvial sands overlapping all, come into immediate contiguity within the limits of Moore County. In the rear of Ferrish's house is a high outlying mound of the quartzose pebbles which, though now reposing on the rocks of the coal formation, appear to have been derived from the older slate veins a short distance to the northwest. We were assured also that particles of gold had been found among the sands in the very stream, and at the spot where Mr. Ferrish had found the seam of coal above referred to. Cases of the superposition of the drift-sand upon the red sandstones, apparently those of the coal series, may be observed in travelling S. S. W. from Carthage, towards the Fayetteville and Yadkin road, where though the general level of the road is on the sandy beds, yet the denudations caused by the streams have in numerous instances revealed the nearly horizontal older sandstone beds of the coal series. The coming in contact of the drift beds and the slates and gneissoid rocks may be noticed on the Fayetteville road, about 5 miles above Chisholm's, towards Troy. The beds of reddish clay, sand, and pebbles, are here seen distinctly interstratified and reposing on the older rocks. From this point westward, the pebbles increase in size, and at length become boulders, the quartz being in some cases cemented into a conglomerate by clay and oxide of iron. In one locality, about 8 miles from Troy, the auriferous slates and quartz are seen on edge, overlaid by the beds which have evidently been derived from the materials of the older series against which they rest. These observations may hereafter be found of some value as indicating the possible extension of the coal measures beneath the sandy plains where no trace of their rocks is now visible, and they at least signify, that but for the extensive denudation caused by the Deep River and its tributaries, we might still be ignorant of the existence of coal in the parts to which we have already referred.

An attentive comparison of the following analyses, will prove that we have here added another to those cases of coal fields which contain in different parts coals of widely differing constitution. We had previously the South Welsh coal field, the Lehigh, Schuylkill, and Susquehanna coal trough, (the most southern of the Pennsylvania anthracite districts,) the Belgium coal field, and the coal field of Eastern Virginia, which yields at the northeastern part the Natural coke, (a species of anthracite,) and Barr's Deep Run semi-bituminous coal, together with the Midlothian and Clover Hill coals of high bituminousness. Besides going through all the gradations of coal, the North Carolina field evidently runs at both extremities into plumbago, associated with, and apparently produced by the igneous rocks which have been injected into the coal series altering and tilting the strata, and in many cases disintegrating the sandstones and other materials. A few miles from Raleigh, towards the Northeastern part of the coal district, is found the extensive bed of graphite which has already attracted considerable attention. This is underlaid by a sandstone very closely resembling that found beneath the coal at Deep River, but giving signs of having been subjected to intense heat for a long period, developing certain metamorphic characters, such as the partial coalescing of the integrant particles, as if by incipient fusion.

In 1824, in a report to the Legislature of North Carolina on the geology of that State, Professor Dennison Olmstead describes the formation containing the plumbago, referring to the 4th volume of Silliman's Journal for a more full account.

Of the coal formation, Prof. O. remarks, "it is fifty years since the coal was first discovered. For some years past the mine has been neglected. The principal excavation is one mile from Deep River. It dips to the southeast in an angle of twenty-five degrees—the thickness of the bed when entirely exposed is about one foot. The coal is highly bituminous, burns readily with a bright flame, and is of much the same quality as the Richmond coal. With regard to extent, I have no certain information. On the road from Salem to Fayetteville by the way of Tyson's mills, on Deep river, the traveller crosses a number of ridges of that shelly kind of black slate which is the accompaniment of the coal, and may be considered a symptom of it wherever it occurs. This, however, passes under a soft red rock called by geologists slaty clay, which extends southwards towards Moore Court-house, and nothing is seen of the slaty rock south of the river."

By comparing this description with the foregoing account of the North Carolina coal field, it will be observed that subsequent examinations have much extended our knowledge of this interesting coal formation. Not only the slate but the coal has now been discovered south of the river, and not only these, but the soft red rock overlying the slate is seen several miles on the road from the river towards Moore Court-house, and even several miles further to the south or southwest. On the old road towards Troy, the red sandstone appears wherever the denuding action of the streams has removed the diluvial white sands which, as already noted, overspread in part the very edges of the coal formation. A notice of this sandstone rendered highly probable the account given at Moore Court-house, of the recent finding of coal on Drowning Creek. The edges of the Richmond coal fields are in a similar manner partly covered by the drift, and all those of Rhode Island and Massachusetts, as noticed on a preceding page.

The shells and coprolites found overlying the coal in North Carolina very forcibly recalled the appearance of similar materials in the slates overlying the principal seam at Sydney, Cape Breton, and at the South Joggin's shore on the Bay of Fundy. As to the contemporaneousness of the bituminous, semi-bituminous, and anthracite beds of North Carolina, there can no longer be a doubt; and that the plumbaginous mass at the northeastern prolongation of the coal formation, as well as the graphitous slate at the southwestern part, has had a similar origin, appears equally certain.

ANALYSES OF DEEP RIVER COALS, NORTH CAROLINA.

1. *Ferrish's highly bituminous coal.*

The mean specific gravity of two specimens from this locality was 1.313.

It contained—Volatile matter,	32.82	per cent.
Fixed carbon,	63.78	"
Earthy matter,	3.40	"
	100.00	

Hence the fixed is to the volatile combustible matter as 1.94 to 1. The ashes are very light and of a yellowish color tinged with red, or approaching a salmon color.

2. *Horton's semi-bituminous coal.*

Specific gravity by the mean of two specimens 1.311.

It contains of Volatile matter,	23.63	per cent.
Fixed carbon,	72.57	"
Earthy matter,	3.80	"
	100.00	

Fixed to volatile combustible matter, as 3.07 to 1. The ashes are heavier and of a darker color than the preceding. It will be observed that this sample shows 28 per cent. less bituminous matter than Ferrish's, and contains 11.17 per cent. more earthy matter.

3. *Wilcox's anthracite.*

The mean specific gravity of two specimens was found to be 1.549.

The Volatile matter,	6.64	per cent.
Fixed carbon,	83.76	"
Earthy matter,	9.60	"
	100.00	

The fixed to the volatile combustible is, consequently, as 12.61 to 1. The ashes are heavier than those of either of the other specimens. The per centage of ash is exactly double of that of Horton's coal. Its color is a reddish gray. It will form a portion of clinker when subjected to intense ignition; but in this respect it is believed to be on a par with the average of Pennsylvania anthracites.

4. *Plumbaginous slate near Dr. Chalmer's, on Deep River, six miles southwest of Horton's.*

On immersing this substance in water, it imbibed the liquid with much rapidity, giving out bubbles of air, and throwing off scales of the slate with great activity. It was consequently impracticable to get the specific gravity by this means. The porousness thus indicated may perhaps be received as an evidence of the expulsion from it by heat of what was once a part of its constituents.

When subjected to a red heat without access of air, it loses - - - - - - - - -	11.18
When incinerated it loses of fixed carbon, - -	10.35
And leaves of reddish grey ash, - - - - -	78.49
	100.00

The ash when finely pulverized gives a beautiful flesh color, which might probably be advantageously employed as a pigment, as the raw material itself is employed for a black paint.

5. *Plumbago of Mr. R. Smith's mine, six miles from Raleigh.*

This plumbago has a specific gravity of 2.652.

Exposed to red heat without access of air, it loses -	9.46
After long incineration leaves of a whitish ash -	74.29
Consequently the fixed carbon is only - - -	16.25

The ash has a silky lustre, and preserves the form of the original scales of graphite. The term plumbaginous talc, might perhaps with propriety be applied to this substance.

II.—ANTHRACITE OF RUSSIA.

At a meeting of the National Institute, Washington, March 1849, the writer exhibited a specimen of anthracite from the town of Gruschofka, in the country of the Don Cossacks, Southern European Russia, and instituted a comparison between it and the anthracite of our own and other countries. He observed that it was usual for anthracite to break with as much facility across the surfaces of deposition as in directions parallel to those surfaces; and that when surfaces of deposition were exposed by fracture, they exhibited less brilliancy than the surfaces of fracture in other directions. The reverse of this was true of the Russian specimen exhibited, and the lustre of its surfaces of deposition was owing to the presence of innumerable very minute organic remains resembling scales. In this particular, it resembles several bituminous coals previously examined, and especially that found near Greenupsburg, in Kentucky, save that in the latter the scales are without lustre.

The specific gravity of the Russian anthracite is 1.66, in which property it is surpassed by few of the anthracites of Pennsylvania.

It gives by analysis,	Volatile matter, -	7.17	per cent.
	Fixed Carbon, -	91.23	"
	Earthy matter, -	1.60	"
		100.	

Consequently the fixed is to the volatile combustible matter, as 12.72 to 1.

A coal with these properties must possess great heating power; and will rank with some of the best varieties of Pennsylvania anthracite.

III.—KENHAWA CANNEL COAL.

Coal below the Falls of the Kenhawa, Virginia.

This coal is exceedingly compact in texture, breaks with clear conchoidal fractures, has a jet black colour, and will receive a beautiful polish. It is so clean as not to soil white muslin on being rubbed, and bears handling and transportation without liability to disintegrate; its specific gravity is 1.27; heated rapidly to a bright red heat without access of air, it loses 45.53 per cent. of volatile matter, giving off a gas burning with brilliant flame and leaving a coke of no greater bulk than the coal which had been used, but the original form of fragments is wholly lost; when coked slowly it loses only 41.22 per cent. of volatile matter, but the form of the pieces is still as completely obliterated as before. After complete incineration it leaves of greyish white rather dense ash 10.13 per cent. At a medium rate of coking, therefore, the composition will be—

Volatile matter - - - - -	43.37	per cent.
Fixed Carbon - - - - -	46.50	"
Earthy matter - - - - -	10.13	"
	100.	

Ratio of fixed to volatile combustible, as 1.07 to 1.

This coal will produce its heating effects with great rapidity, and will probably be found free from clinker.

A specimen of coal from the Elk river, a tributary of the Kenhawa, gave by slow and rapid coking respectively 41.11 and 43.75 per cent. of volatile matter.

It may here be stated that a great amount of heat is evidently rendered latent, when carburetted hydrogen gas is produced either from coal, rosin, oil, or other material. The quantity of fuel required to heat gas retorts, while converting the volatile part of the coal into gas, is, to a certain extent, a measure of the heat of elasticity of such gas.

The rapid absorption of heat while gas is evolved, is proved by the blackness maintained by any coal as long as gas continues to be produced.

The Kenhawa Cannel coal illustrates this effect in a manner sufficiently remarkable, the coal remaining black while giving off the most brilliant flame of gas. An analogous illustration of the effect mentioned, is given where liquid carbonic acid, generated under great pressure, (as in the experiments of Thillorier,) is suddenly relieved from pressure and escaping into the atmosphere, becomes in part converted into gas absorbing so large an amount of heat as to transform another part of the liquid acid into a solid with an enormous reduction of temperature, (70 or 80 degrees below zero.)

IV.—CANNEL COAL FROM BEAVER, PA.

This coal presents only in part the massiveness and the smooth conchoidal fractures of other cannel coals. It displays in part the surfaces of deposition belonging to ordinary bituminous coals, and has, diffused throughout, minute silky vegetable impressions. Its specific gravity is 1.343.

It contains of Volatile matter - - - - -	38.25
Fixed Carbon - - - - -	51.46
Earthy matter - - - - -	10.29

Hence the fixed is to the volatile combustible matter, as 1.34 to 1. The ashes of this coal are nearly white.

V.—COALS OF LITTLE SANDY RIVER, KENTUCKY.

1. *Coals from near Caroline furnace, Greenup county.*

This coal presents the following characters:

Its texture is close; structure foliated; surfaces of deposition dull, with mineral charcoal, or having a pitchy lustre; fracture even; and the main partings nearly at right angles to the surfaces of deposition. It has a specific gravity of 1.304. Subjected, by very slow degrees, to a bright red heat, it gives a copious development of gases, and loses—

Of Volatile matter - - - - -	38.00	per cent.
Its Fixed Carbon is - - - -	55.61	"
Earthy matter - - - - -	6.39	"
	100.	

The fixed to volatile combustible is 1.46 to 1. The ashes are moderately dense, and of a reddish gray colour.

2. *Another specimen of coal from this locality gave specific gravity*, 1.292.

Two trials of Volatile matter gave a mean of	47.4	per cent.
Fixed Carbon - - - -	48.8	"
Earthy matter - - -	3.8	"
	100.	

Consequently the fixed was to the volatile combustible as 1.03 to 1.

3. *Coal from Kentucky furnace, six miles south of Greenupsburg.*

This coal has the following external characters: Its structure is foliated or slaty. Its surfaces of deposition exhibit very abundant vegetable impressions, and consequently but a dull lustre. Its specific gravity is 1.310.

It gave of Volatile matter by slow coking - -	38.05
Fixed Carbon - - - - - -	56.86
Earthy matter - - - - - -	5.09
	100.

The ratio of fixed to volatile combustible, as 1.49 to 1.

The earthy matter is of a deep brown colour, and much inclined to vitrification in clinkering.

VI.—COAL OF MOUNT CARBON, ON BIG MUDDY RIVER, JACKSON COUNTY, ILLINOIS, (13 *miles by the route of a proposed railroad to the Mississippi river.*)

This coal has the following exterior character. Its structure is lamellar; its surfaces of deposition are stongly marked with mineralized charcoal; some of its crop fractures have their laminae of iron pyrites completely coating the coal.—The coal bears handling well, and is but little liable to fall into slack. It has a specific gravity of 1.29. It gave upon analysis of—

Volatile matter by rapid distillation - -	40.85	per cent.
Fixed Carbon, two trials - - - -	55.59	"
Earthy matter - - - - - - -	3.56	"
	100.00	

Consequently the fixed is to the volatile combustible matter as 1.36 to 1, which brings it into the class of the Indiana and Kentucky coals already in extensive use on the Ohio and Mississippi. The presence of the sulphuret already noticed gives rise to the formation of a red ash, some portion of which will at intense ignition fuse into a dark coloured clinker.

Professor B. Silliman, Jr., has given an analysis of this coal with the following results:

Specific gravity		1.352
Volatile matter	36.97	
Fixed Carbon	57.30	
Light white ash	4.50	
	100.	

This analysis makes the ratio of fixed volatile combustible, 1.52 to 1.

Mr. David Mushet, of Colesford, England, has also given an analysis as follows:

"Flame, &c," (volatile matter)	36.97
"Carbon"	57.53
"White clayey ash,"	5.50
	100.

It is probable that in both the two preceding analyses the coking was performed less rapidly than that by which was obtained 40.85 per cent of volatile matter.

VII.—COAL OF TRUMBULL COUNTY, OHIO.

Analysis of the coal from Brier Hill, in Trumbull county, gave the following characters and composition:

The structure is foliated, the fracture even, oblique to the surfaces of deposition, the lustre brilliant to pitchy: of vegetable impressions it contains many, but they are not well developed on account of the uneven fracture along the surfaces of deposition. Its specific gravity is 1.32. When coked very moderately at first, it gave scarcely any enlargement of the original bulk of coal, though the form of the fragments was totally lost. It gave a copious evolution of gas, and afforded

Of Volatile matter,	38.13	per cent.
Of Fixed carbon,	58.41	"
Earthy matter	3.46	"
	100.	

Hence the fixed is to the volatile combustible as 1.53 to 1. The ashes are light, silicious, and of a pale fawn color. Experiments on a large scale can alone prove how far the slight proportion of waste in this specimen is capable of being verified by experience in the practical way.

VIII.—ARKANSAS COAL.

This coal is found at the mouth of Petit Jean River, a tributary of the Arkansas, emptying into the latter river in latitude about 35° north and 15° 50′ west longitude from Washington.

This coal has a columnar structure, deep black color, bright lustre; texture somewhat loose; surfaces of deposition marked in part by sulphate of iron. Its specific gravity is 1.541.

In coking, it varies according as the heat is more or less rapidly applied. If slowly heated it scarcely changes the forms of its fragments, and only exhibits slight cracks on some of its faces. When rapidly coked, it bursts open in various directions, and the fragments in some cases fall apart, while in others they remain slightly attached to each other. The gas given off in coking, burns with a short yellowish flame, which continues but for a short time. The interior of the crucible becomes covered with plumbago during the rapid coking of this coal. The effect of a red heat is to decompose the sulphate of iron, giving rise to sulphurous acid and peroxide of iron; the latter remaining in the coke, giving it a reddish tinge, while the former is volatilized.

When slowly coked this coal gives of Volatile matter, -	12.08	per cent.
When rapidly coked, " " -	15.79	"
And the mean of these two is,	13.93	"
Fixed Carbon, - - -	76.35	"
Earthy matter, - - -	9.72	"
	100.	

Ratio of fixed to volatile combustible = 5.48 : 1. This should seem to place the Arkansas coal about on a level with Dauphin and Susquehanna, or Neff's Cumberland coal of the American Series, (p. 96,) or with the Duffryn coal of the British Series, (p. 97,) and if so, its evaporative power would be somewhere between 9.34 and 10.14.

IX.—ANTHRACITE OF PEMBROKESHIRE, SOUTH WALES.

This anthracite strongly resembles that of Beaver Meadows, Pennsylvania. Its color is deep black; its fracture is even or splintery. It manifests little or no tendency to part along the surfaces of deposition more than in any other direction.

It specific gravity is 1.400.

It contains of Volatile matter, - - -	7.76	per cent.
Fixed Carbon, - - -	90.85	"
Earthy matter, - - -	1.39	"
	100.	

Consequently the fixed is to the volatile combustible matter as 11.7 to 1.

The ashes are dirty yellow, intermingled with white. It was remarked that the coal seemed to cover itself with ashes, (slight as is the quantity of the latter,) and to require a long time to effect a complete combustion in the muffle. A strong draught or suitable blast would no doubt remedy this defect.

X.—ANTHRACITE FROM TOWN HILL, ALLEGHANY COUNTY, MD.

This specimen has the appearance of having been subjected to intense pressure, and thereby rendered flaky and tender, a result often observed in Pennsylvania, where either the coals or the accompanying shales have been contorted, broken, and compressed while sliding over each other.

It has a specific gravity of 1.702, which is sufficient without its loose shelly texture, its steel grey color, its streaked and shining surface, to indicate that it is rather anthracitous shale than pure anthracite.

By analysis, it gave Volatile matter, -	6.42	per cent.
Fixed Carbon, - -	62.87	"
Earthy matter, -	30.71	"

Hence the fixed is to the volatile combustible matter as 9.79 to 1. As the hygrometric moisture is not here separately determined, it is of course embraced among the volatile combustible.

The earthy matter is shaly, preserving the forms of the fragments of coal before incineration. This anthracite might possibly answer for some purposes where the large amount of residue would not constitute an objection—but for most of the uses of anthracite, this would wholly preclude its adoption.

XI.—BAY OF FUNDY COAL.

Coal from the King's seam, South Joggins'* shore, Bay of Fundy, Cumberland county, Nova Scotia. This coal is compact; lustre dull or pitchy; structure columnar; fracture even and perpendicular to the surfaces of deposition. Specific

* See page 10.

gravity 1.387. Coked very slowly it undergoes but little enlargement of bulk, and the forms of the fragments are nearly preserved. It gives by proximate analysis,

Volatile matter, - - -	35.51	per cent.
Fixed carbon, - - -	57.66	"
Earthy matter, - - -	6.93	"
	100.	

Consequently the ratio of fixed to volatile combustible is 1.62 to 1. The ashes are of a very dark brown, almost black, color, partly fused into clinker adhering to the platinum capsule.

XII.—SPRING HILL, NOVA SCOTIA, COAL.

The locality of this coal is referred to at pages 10, 14, and 16 of this work. In exterior characters the coal is foliated, and its surfaces of deposition highly charged with mineralized charcoal. The partings or main cleats are oblique to those surfaces and exhibit a shining lustre. The coal appears to bear handling well without disintegration. Its specific gravity by the mean of two trials is 1.351.

It gives of Volatile matter, - - -	31.30	per cent.
Fixed carbon, - - -	61.14	"
Earthy matter, - - -	7.56	"
	100.	

Consequently the relation of the fixed to the volatile combustible matter is 1.96 to 1. The ashes are mixed of purplish and yellowish white portions, light and slightly coherent.

XIII.—COAL OF LITTLE RIVER, CAPE BRETON.

This coal, of which specimens have been forwarded within a few months from J. W. Dawson, Esq., of Pictou, is characterized by a foliated structure, compact texture, resinous lustre, and dead black color; some of its surfaces are, however, shining, as if from the effect of rubbing under heavy pressure. Its specific gravity is 1.358. In coking it gives a copious discharge of gas which burns with great brilliancy, indicating a good portion of bicarburetted hydrogen. By a pretty rapid coking it affords of

Volatile matter, - -	31.99	per cent.
And leaves Fixed carbon, - -	5[illegible].42	"
Earthy matter, - -	10.59	"
	100.	

Consequently the fixed is to the volatile combustible matter as 1.27 to 1. The ashes are of a chocolate color, heavy, but not easily vitrified.

XIV.—COAL OF NEW BRUNSWICK.

This coal is from the mines near the head of Grand Lake, referred to at page 11 of this work. Its structure is lamellar; its surfaces of deposition are dull black, with minute fossil impressions copiously interspersed.

The specimen having been kept for more than three years, had begun to exhibit efflorescent sulphate of iron and ammonia. Its specific gravity is 1.421. Coked with moderate rapidity it yielded

Volatile matter,	34.87 per cent.	
Fixed carbon,	52.05	"
Earthy matter,	13.08	"

Consequently the fixed is to the volatile combustible matter as 1.45 to 1. The ashes are of a deep red color.

XV.—DEBITUMINIZED COAL, CLOVER HILL, VA.

At the Tippecanoe pits, Clover Hill, in the southern part of the Virginia coal field, is a dike of trap running due east and west, on each side of which below the surface of the ground is found a stratum of fuller's earth. Where this trap dike cuts the coal seam it has converted the coal in immediate contiguity with the fuller's earth, partially into coke, possessing the following characters:

Its color is a dead black, scarcely any surface showing more than a faint glimmering lustre. It might readily be mistaken for a very dense artificial coke, but it preserves, in some degree, the columnar structure of the coal. Its specific gravity is 1.61—about the same as that of many anthracites. Subjected to a bright red heat, it retains the form of its fragments entirely unchanged, but loses—

	Volatile matter .	14.83 per cent.	
And when incinerated, gives	Fixed Carbon .	76.89	"
Leaving,	Earthly matter .	8.28	"
		100.	

Hence the fixed is to the volatile combustible as 5.18 to 1, which would place this material on a par, in point of constitution and probable evaporative power with the coals of Cumberland, Md., and of South Wales. The ashes are nearly of a pure white colour.

XVI.—COAL FROM THE SAME SEAM AS ABOVE, AND WITHIN A FEW FEET OF THE COKE AT TIPPECANOE PIT.

To ascertain the relation of the coal to the coke in this mine, the following analysis was made. The coal has the following character:

Its lustre is shining or resinous; its cross fructures are very brilliant, and but little mineral charcoal is seen on its surfaces of deposition. Its colour is jet black.

Its Specific gravity is 1.31.

Volatile matter - - - - -	33.65	per cent.
Fixed Carbon - - - - -	61.51	"
Earthy matter - - - - -	4.84	"
	100.	

Consequently the fixed is to the volatile combustible as 1.82 to 1. The ashes are of a reddish brown colour, and are slightly inclined to pass into clinker.

Summary of Analysis.

The following table exhibits a synoptical view of the preceding recent analyses arranged in the order of the ratios of fixed to volatile combustible matter, the latter including, of course, the hygronometer moisture of each sample. The volatile matter of the two plumbaginous specimens is doubtless nearly all water, but probably some portion of it is combined with the earthy matter or oxides in the state of hydrates.

Locality of Coals.	Specific Gravity.	Volatile matter.	Fixed Carbon.	Earthy matter.	Ratio of Fixed to Volatile Matter.	Character of Ashes.
Kenhawa Cannel Coal, Va.	1.27	43.37	46.50	10.13	1.07	Greyish white.
Chalmer's Plumbaginous slate, N. C.	....	11.18	10.35	78.49	1.27	Flesh colored.
Little River, Cape Breton	1.358	34.99	54.42	10.59	1.27	Chocolate color.
Cannel Coal, Beaver, Pa.	1.343	38.25	51.46	10.29	1.34	Nearly white.
Mt. Carbon, Big Muddy River, Ill.	1.29	40.85	55.59	3.56	1.36	Dark brown, fusible.
Grand Lake, New Brunswick	1.421	34.87	52.05	13.08	1.45	Deep red.
Little Sandy, Caroline Furnace, Ky.	1.304	38.00	55.61	6.39	1.46	Reddish grey, dense.
Little Sandy, Kentucky Furnace, Ky.	1.310	38.05	56.86	5.09	1.49	Deep brown, fusible.
Trumbull Co., Chio	1.320	38.13	58.41	3.46	1.53	Pale fawn, light.
South Goggins, Bay of Fundy, N. S.	1.387	35.51	57.66	6.93	1.62	Very dark brown.
Smith's Slaty Plumbago, N. C.	2.652	9.46	16.25	74.29	1.72	Silky white, talcose.
Coal near the Coke, Clover Hill, Va.	1.31	33.65	61.51	4.84	1.82	Reddish brown, fusible.
Ferrish's Deep River Coal, N. C	1.313	32.82	63.78	3.40	1.94	Light salmon colored.
Spring Hill, Cumberland, N. S.	1.354	31.30	61.14	7.56	1.96	Purplish to yellowish.
Horton's Semi-bituminous, N. C.	1.311	23.63	72.57	3.80	3.07	Dark grey.
Debituminized Coal, Clover Hill, Va.	1.61	14.83	76.89	8.28	5.18	Almost pure white.
Petit Jean River Coal, Ark.	1.541	13.93	76.35	9.72	5.48	Chocolate brown.
Town Hill Anthracite, Md.	1.702	6.42	62.87	30.71	9.79	White, shaly.
Pembrokeshire Anthracite, S. Wales	1.400	7.76	90.85	1.39	11.70	Yellowish and white.
Wilcox's Anthracite, N. C.	1.549	6.64	83.76	9.60	12.61	Reddish grey.
Gruschofka, Russia	1.660	7.17	91.23	1.60	12.72	Bright salmon, light.

PRACTICAL HINTS FOR THE SELECTION OF COALS FOR DOMESTIC AND OTHER USES.

From a late article in the Edinburgh Review, it appears to be a new idea in Great Britain that anthracite is preferable for all domestic purposes to any other fuel whatever. This idea the reviewer has, it appears, obtained from the elaborate and valuable work of R. C. Taylor, Esq., on the "Statistics of Coal." It is by no means new in this country, as the practice of all the Atlantic cities, and the multitudes of inventions designed to facilitate the application of anthracite to domestic purposes, fully attest. But not every variety of anthracite is equally adapted to all domestic purposes.

1. For open grates, where a lively fire with considerable flame is thought desirable, and where the moderate intensity of heat will not endanger the conversion of a great portion of the ashes into *clinker*, the *red ash* coals may be employed to advantage. A study of the Report on American coals will show that the more rapid and intense is the fire, during the combustion of any given coal, the greater will be the proportion of clinker it makes.

2. In furnaces for heating houses, and in general for close stoves having any considerable capacity, and liable to produce a very high white heat, the white or grey ash anthracites are preferable.

3. In the earlier use of anthracites, both red and white ash, an error was very generally committed in attempting to use them in too large lumps. As this fuel burns almost solely by the contact of air with the surface of the incandescent coal, it is essential to the attainment of its maximum effect that large vacant spaces should not be left between the lumps. As bituminous coal gives off large quantities of gas which fill up such open spaces, the evil is less liable to occur with that fuel.

In selecting coal for gas works, those varieties are to be chosen which possess large proportions of volatile matter and as little as possible of sulphur. The rich cannel coals are generally preferred for this purpose.

For smiths' work, coals are generally preferred which, in being heated to redness, agglutinate their lumps firmly together. When a hollow fire is not required, however, the coals of low bituminousness, and which have but little tendency to intumescence or cohesion of lumps, may be employed; and the higher heating power of such coals will always give them a preference where economy of fuel is an important consideration. Coals possessing a large portion of iron pyrites (bisulphuret of iron) must be avoided in smiths' work. The decomposition of the bisulphuret in the coal sets free one atom of the sulphur, which attacks and consumes the iron, rendering it brittle, and preventing sound welding.

For forming bricks, a portion of anthracite dust has frequently been employed to advantage.

For burning lime, anthracite is employed in the state of small nut or pea coal. The white ash coal should be selected for this purpose, if we would avoid discoloration from an intermixture of oxide of iron with the lime.

For steamships, coals of high heating power under a given bulk, of great purity, that is free from earthy matter, of little tendency to clinker, and entirely free from the danger of taking fire by spontaneous combustion, ought in all cases to be chosen. Anthracites are least liable to this evil, but many of the cannel coals and free burning bituminous coals are also nearly exempt from danger on this account. When a coal, after an exposure of some time to the atmosphere, begins to exhibit efflorescent white or greenish white salts of iron on the exterior, and to fall rapidly into small fragments, it is to be suspected.

Housekeepers and others should endeavor to acquire some familiarity with the aspect of coal, in order to distinguish lumps of slate from true coal. All the slate they buy, is not merely a fraud upon their finances, but a tax upon time, in putting in and taking out so much waste materials from grates and furnaces. The formation of clinkers, which destroy the linings of stoves, brings a new source of annoyance and of useless expense.