PART IV.—MINES, MINING AND UTILIZATION OF COAL.

XL. COAL MINING METHODS—PROSPECTING AND OPENING MINE.

Section 1. Prospecting.

2130. The location, position, extent and thickness of a bed of coal are determined either by a study of the outcrops of the coal or by drilling. In the great majority of cases, the mining of any region originates through the observation of outcrops of the coal bed worked, while later developments often are the results of explorations with the drill.

2131. Coal Outcrops.—To a large extent in Indiana the development of mining through observations of the natural outcrop have been accidental. In many cases the coal outcrops in a bluff, so that it could hardly escape the notice of the least observing. The frontispiece is an illustration of this. It is only rarely that such a thickness of coal is as well exposed as in this case, though a few other exposures equally good or even better were observed. In such cases the location and position of the coal are determined without special effort on the part of the prospector. In another class of outcrops the exposure is due to the cutting of a stream in its bed. In this case the coal is usually first observed as "float" or coal fragments in the stream channel. If these be carefully followed up they will usually lead one to the point where the bed of coal and the bed of the stream cross each other. Sometimes these outcrops are only exposed at times, as after a freshet, and at other times will be covered by the dirt and gravel being carried down by the stream.

2132. Outcrops of the two classes mentioned will hardly average more than one or two to the township, though the drift covered part of the coal field. Outcrops are rare in any case in that part of the field, but the majority will be found to be of a third class. In this no good exposure of coal exists. The outcrop consists of a line of black dirt or smut a few inches thick on the average, usually underlain by the white or gray under clay. Singularly enough, even though a bed of coal be four or five feet thick, it will commonly pinch down to a mere smut mark, while the under clay usually shows more or less nearly its whole thickness in outcrop. It thus is quite generally as much or more observable than the overlying coal, and in many cases, where the coal is not even represented by a smut mark, it forms the sole criterion of the presence of coal. In Plate LXXX is shown at the left, from a photograph taken at a cut at right angles to the face of the hill, the pinching down of a 5-ft. bed so that where it reached the undisturbed surface just to the left of the plate, it is hardly discernible above the thick outcrop of fire-clay. At most points along the bluff, no trace of an outcrop was observable.

2133. In general, such outcrops should be looked for at points where the land shows the most marked declivity, or where due to any cause fresh exposures occur on a hillside. Gentle slopes seldom yield outcrops. Where streams undercut their banks, and in the roadside gutters, where roads descend hills, are the most favorable places to find outcrops.

2134. In some cases where, over a given tract of land, no coal outcrop can be found, other factors must be brought to bear. Thus, turning to the report and maps on the township in which one is prospecting, it will be noticed that, according to the map, the outcropping rocks at the point in question belong to a certain division of the coal measures. Turning to the columnar sections for that township and the discussion which follows it will be noted that in that division perhaps there is a limestone, or a massive sandstone or some other recognizable layer which can be found outcropping in the tract being examined. Having found the outcrop of such a layer it gives the clue to the position of the nearest coal.

2135. Having found the coal bed, the next thing is to ascertain its extent, thickness and quality.

Where the outcrop is a clear-cut exposure, the thickness and quality are readily obtained. Its quality should be tested by actual trials for steam, household and blacksmith purposes, and, where possible, for its gas-making properties. In exposures of the second class, usually an hour or two's digging will suffice to expose the full thickness of the coal, when it can be examined as above. In exposures of the third class, it is usually easier to go to a point up the hill and back of the outcrop and drill down through the coal. If it shows a satisfactory

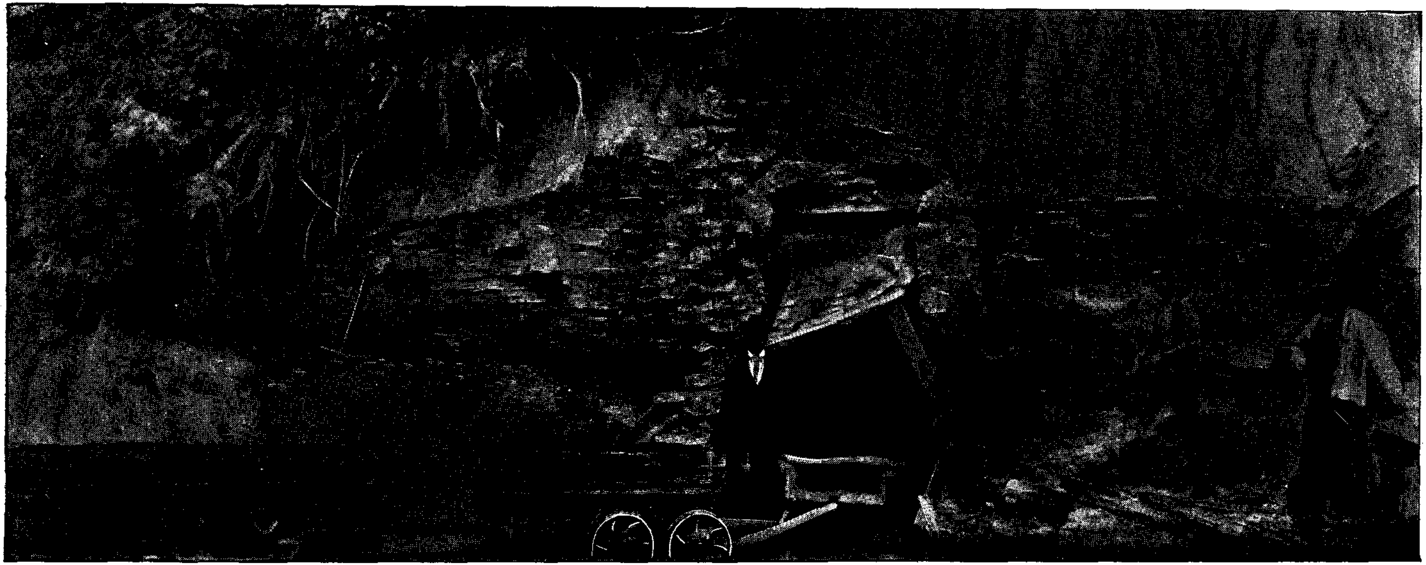


PLATE LXXX. Exposure of Coal IV at Crawford No. 1 mine, Parke County.

The part of the plate at the right shows the face of the coal, 5 ft. thick, parallel to its line of outcrop, but at the back of an open cut 20 to 30 ft. deep. The part of the plate at the left is taken at right angles to the preceding, and shows one side of the open cut. Notice in this the pinching down of the coal toward the left (or place of outcropping.)

thickness, an open cut may be made on the outcrop, or, where necessary, a test tunnel driven into the solid coal to ascertain with more exactness its thickness and quality.

2136. It is next important to find out if the coal bed extends under the whole area and how it dips. These may sometimes be determined from the study of the outcrops, but more often the drill is brought into play. Where outcrops are abundant, an instrumental survey is made along the line of outcrop. In this way the lowest exposed point of the coal bed is determined; and if the thickness and quality of the coal be tested at each outcrop, a very good idea may be obtained as to its extent and workability in general.

2137. THE DRILL.—The drills used in prospecting are of two kinds: the common, jumper or churn drill, as it is variously called, and the diamond or core drill. In the first drill a hole is simply ground down through the rock by the pounding of the solid bit. In some cases the bit is made of a piece of gas piping, in which case something of a core is obtained.

The driller can, as a rule, recognize when he passes from one kind of rock to another by the action of the drill, and the sand pump soon brings up the ground-up sediment, from which the character of the rock may be determined. As a matter of fact, the experienced driller can generally tell by the action of his drill in what kind of rock he is drilling.

2138. SOURCES OF ERROR WITH CHURN DRILL.—The principal source of error in the use of this drill is the inability of most drillers to recognize with accuracy the character of the rock brought up by the sand pump. Very few of the drillers have had any more than a picked-up knowledge of rocks, and when, as is very common with coal measure rocks, the rock of whatever kind contains an admixture of other materials, only a few of our drillers can correctly determine and report upon the character of such a rock from a hand specimen, and how much less when ground up to a fine powder. The way different rocks drill to a certain extent offsets this lack of information. Thus, the powder from a gray shale and a limestone may appear identical to the naked eye, but the drill enters one perhaps a score of times faster than the other, and thus enables the driller to distinguish between them.

2139. In the case of many of the deeper drillings, where steam is used, and where it is the custom usually to stop drilling and clean out the bore hole every five feet, records are usually unreliable.

2140. Interpretation of Churn Drill Records.—It is often possible to obtain valuable information from a very poor drilling record, where one is familiar with typical sections of the particular horizon being drilled. Thus, the driller can usually distinguish coal from sandstone or light-colored shale, but often fails to distinguish between good coal and bone coal or bituminous shale. Thus, he may report "very hard rock" or "hard sandstone" overlying five feet of coal. Suppose that we know from a study of exposures or mine sections that at about that horizon occurs a coal bed 2 to 3 ft. thick, overlain by about an equal amount of black bituminous shale, and that in turn by limestone, the drill record, though very imperfect, and by itself misleading, allows us to recognize what coal bed was passed through and its depth; only, we write limestone for "hard rock," and instead of 5 ft. of coal write 5 ft. of coal and black shale, in about the proportion of 1 to 1, the shale overlying. Churn drill records are usually of value in proportion as other data exist for their interpretation. So that the record of an isolated drilling should usually be taken with great allowance.

2141. Notwithstanding what has been said, the records of drillings by some drillers who use a churn drill are thoroughly reliable, in some cases more so than records of core drillings by inexperienced persons. Of this character are most of the churn drill records obtained from the larger operators.

2142. The Diamond or Core Drill consists essentially of a drill which, instead of being a solid rod, is a hollow tube, whose lower edge is set with bort or black diamonds, and instead of pounding up and down is made to revolve, cutting a cylindrical hole and leaving a solid core of the rocks passed through, which can be raised and examined with as great minuteness as is desired. Here, again, the lack of an accurate acquaintance with rocks leads to some surprisingly erroneous records. These drills are made to revolve by hand, horse power, steam or electric power. Where properly interpreted the core drill will yield almost as accurate a record as a test shaft.

2143. Use of the Drill.—In practice some operators use the diamond drill exclusively, others the churn drill exclusively, and still others use the core drill in prospecting and the churn drill in developing. This is perhaps the most economical method. In some cases the churn drill is used in preliminary prospecting until what appears to be a workable field is found, when it is tested with the core drill.

2144. In developing it is customary with the shallow beds common in Indiana to go over the whole territory to be worked, the closeness of the drilling depending on the local conditions. In some cases every ten acres is drilled upon before any steps are taken for opening the mine. The object is not alone to determine the extent and thickness of the coal, but as much, or often more, to obtain the topography, or hills and hollows of the coal. This requires that the position and level of each drill hole be obtained, measured from some point as base. An excellent plan then sometimes followed is to make a topographic map of the coal. This is done by plotting the drill holes on a map on whatever scale be desired, and drawing contour lines through points of equal elevation. Such a map proves of the greatest help later in locating the mine entrance and in planning for entries and for drainage.

Section 2. Opening the Mine.

2145. Manner of Entrance.—Methods of making an entrance to the coal divide themselves into three classes, according as the entrance is horizontal, vertical or inclined, and the entrance is known respectively as a drift, or adit, or water level, a shaft, or a slope. The purposes of these openings are, first, to give entrance to men, mules, timber, etc., to the mine; second, to give outlet for the product and waste of the mine; third, as openings of ingress and egress for the air needed for the ventilation of the mine; fourth, as openings for the removal of the water that finds its way into the mine; fifth, as an escapement for the miners in case of accident. In small mines one opening often serves for all purposes, but as soon as a mine begins to operate extensively it becomes necessary to have more than one opening, and often a number of openings are made into a mine for the different purposes enumerated above. Often by the use of partitions in some of the openings the expense of a number of openings is saved. In general, the main opening is the one which serves as an exit for the product and waste of the mine.

2146. To discuss the method of entrance intelligently, it should be kept in mind that the preparation of the coal for market and its delivery to the transporting vehicle is usually done as soon as it comes from the mine, and to do this without rehandling requires that the coal, when brought from the mine, have an elevation of from 15 to 20 ft. above the top of the transporting vehicle when loaded. In case the coal is shipped by coal cars, as is usual in Indiana, it should be brought to from 20 to 30 ft. above the rails of the loading switch.

2147. Selecting Character and Point of Main Entrance.—In the close competition in the coal trade to-day, the correct or incorrect opening and laying out of the mine may determine whether it can be worked at a profit or a loss. We can only point out here the main factors which must be taken into consideration, as in any particular case so many details are concerned that only a competent mining engineer on the ground can plan the work. As the opening, though made primarily to allow entrance to the coal, is mainly used for the withdrawal of the coal, it is so placed as to allow the removal of the coal with the least effort and with the greatest rapidity. Other things being equal, the opening is made at the lowest point of the coal bed, as shown by the drillings or study of the outcrop. This allows down-grade haulage from all parts of the mine, and as the haulage ways are usually utilized for the drainage of the mine, allows of a simple system of drainage. If the coal outcrops, the entrance will be by drifting, and is driven at the lowest point of the outcrop. If this outcrop is very near drainage level, however, the coal would have to be elevated to be screened and loaded, and then a slope may be driven, or the fact of its outcropping entirely neglected and a shaft driven at some distant point, usually the point at which the coal is at the lowest level. Again, the best or only method of approach to the mine for a shipping switch may not be in the valley, but up on the high-land, in which case a shaft may prove most economical, even though the coal outcrops well above the adjacent valley. In some cases two or three beds are to be worked, and often the lowest point of one is some distance from the lowest point of the other beds. In such cases it may be found best to run inclined tunnels from the lower beds to the upper, and take all the coal out of the mine by way of the upper bed, or it may be found best to use drop shafts from the upper to the lower beds, and hoist all the coal from the level of the lower bed. In some cases the possible positions of a switch are all at some distance from the lowest point of the coal, in which case the coal may be raised by shaft at its lowest point and then hauled to the railroad, or the haulage ways of the mine may be made to center at the lowest point, from which the coal is then drawn by rope hauling to a shaft, slope or drift situated beside the switch. It will thus be seen that many factors are often concerned which may make the problem a complicated one, and its solution difficult.

2148. Shafts.—The shafts are rectangular openings sunk perpendicularly from the surface through the intervening strata to the coal. Among the small mines these are of all sizes and shapes. One round shaft was found in Knox county. Generally in these small mines the shaft is sometimes square, from 4 to 6 ft. in diameter, sometimes a little longer in one direction and one end partitioned off for ventilation, sometimes long enough in one direction to allow its being divided into a compartment for hoisting coal, one for hoisting water, and sometimes a third for ventilation; or the two main compartments may

Fig. 954. Cut showing top of shaft after being equipped.

Note gates to shaft; posts and caps for timbering rooms; screens seen from below, etc. (Brazil Block Coal Co.'s Shaft No. 5.)

be separated by a tight partition, and one side used for the upcast air shaft. With the larger mines the shaft has two compartments, and often three. In size they will vary between 6 by 10 ft. to 8 by 12 ft. or more. Usually the shaft contains the two hoistways only, but often a third compartment is made for a pumpway, airway or manway. The shaft is usually sunk by hand in this State, but it is only a question of time when mining or quarrying machinery, as rock drills, etc., will be used.

2149. In sinking, a large iron hoisting bucket is used, usually swung on pivots to facilitate emptying. In some cases the permanent engines are set up and used for hoisting, while often this office is performed by horse power or by any old engine at hand or obtainable.

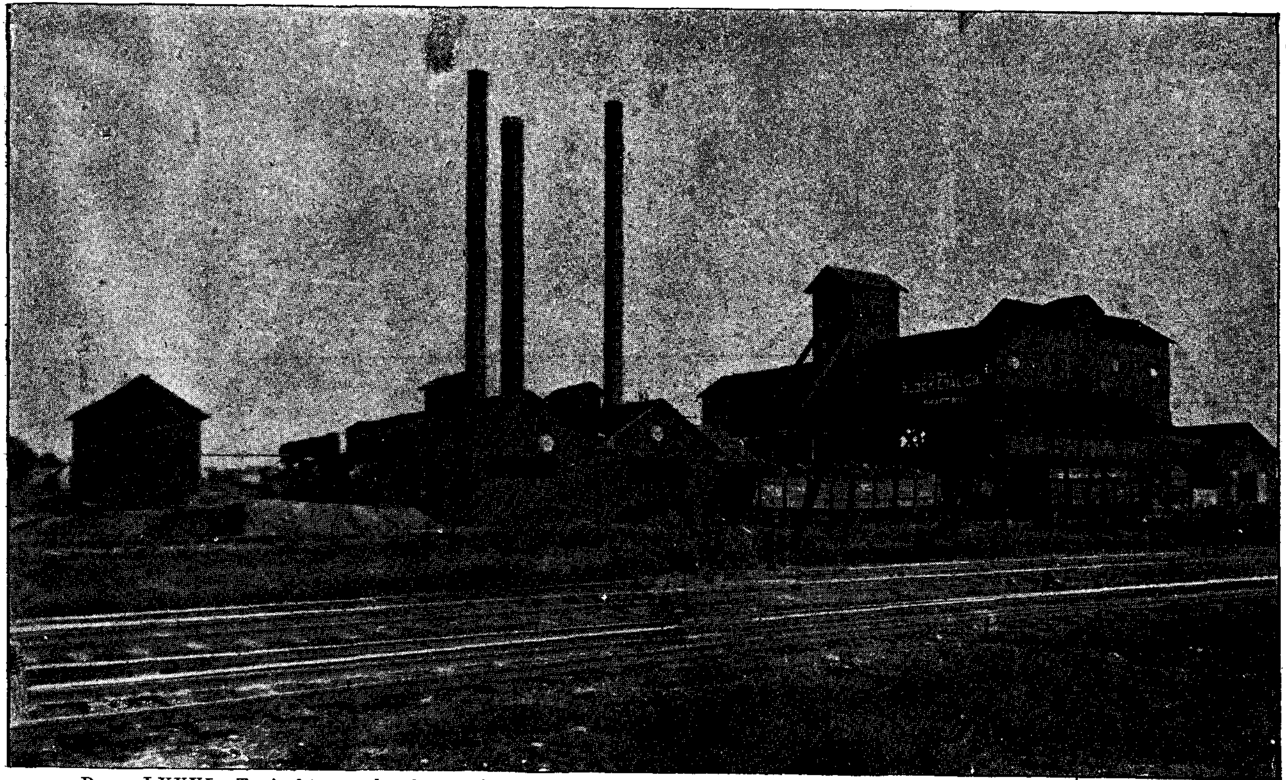


PLATE LXXXI. Typical top works of coal mine in Indiana. Brazil Block Coal Co's Shaft No. 1. (Photo by Mr. J. F. Newsom.)

In some cases the shaft is heavily timbered to the bottom, or it may only be timbered through the surface and other soft strata. Where quicksands are encountered, it is usual to use one or another of the methods of freezing such beds by the use of freezing mixtures circulated in pipes driven down. The shaft can then be sunk through the frozen sand as though it were a solid bed and heavily timbered. The equipment of the shaft will be mentioned further on. Plate LXXXI shows typically the external appearance of a shaft mine.

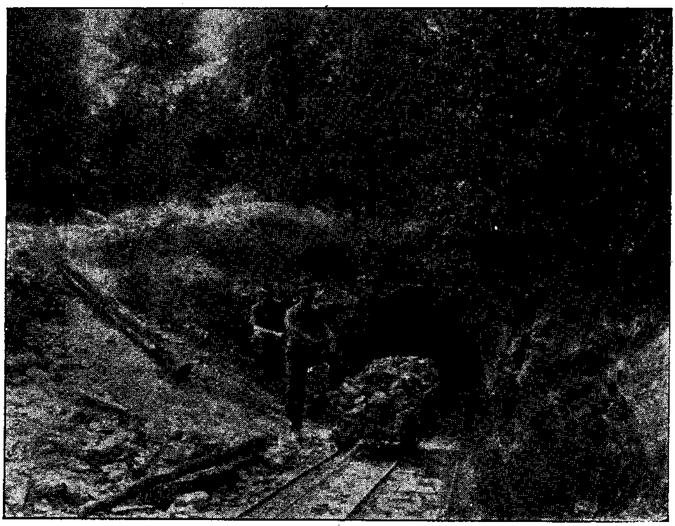
2150. SLOPES.—A slope is an incline plane driven down to the coal, either following the dip of the coal or being driven through the rocks overlying the coal, as shown typically in Plate LXXXII.

2151. In shape and general character it is usually similar to the main traveling ways of the mine, of which it is in reality only a continuation, except in its always being equipped with a rope of some kind and hoisting machinery for drawing the mine cars up its incline. It is thus an inclined opening of approximately the same height as the main traveling way or entry leading to it, and of the same or double width, according as it is to contain one or two tracks. For a large output, two tracks are always necessary. It may thus be driven from 4 ft. 6 in. to 7 ft. high, and from 6 ft. to 15 ft. broad. In sinking, it is usual to make an open cut for a short distance where the slope starts in soft material. The following figures (Plate LXXXII) will give an idea of the form of slopes common in Indiana.

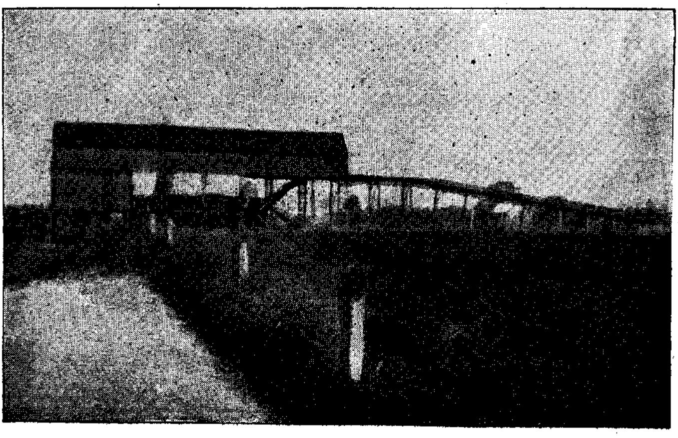
2152. THE SUMP OR SUMPT.—At the bottom of a shaft or slope it is usual to dig an opening or cistern to serve as a reservoir for the drainage of water of the mine, and from which it is pumped. If the shaft or slope is not sunk to the lowest point of the coal, the sump is placed at that lowest point when it is reached.

2153. THE DRIFT OR ENTRY.—As a drift is simply an entry which reaches daylight without a change of grade, one description will serve for both. The entries or traveling ways are passages or tunnels leading from the main opening of the mine to the various parts of the mine, and serve as haulage ways for the coal, as a passage for the air ventilating the mine, for the drainage and as a passage for the power used, as well as for a traveling way for the men and animals. There are usually one or more main entries from which at definite intervals cross or side entries are driven, as will be explained later. For the purposes of ventilation, it is usual to drive two parallel entries, or sometimes three, one of these serving simply as an "air course," by which name it is known.

Slope at Big Vein mine, Boonville, Warrick County.



Slope at Brazil Brick and Pipe Co's mine, near Brazil.



Slope at Caledonia mine, Boonville, Warrick County.

PLATE LXXXII. Types of slopes in Indiana.

2154. Fig. 955 shows a typical cross-section of an entry as commonly found in Indiana. The height will vary with the thickness of the coal, unless the coal is thin, when it is usual to make the entries at least 4 ft. 6 in. in height, as required by law. When the coal is thick, the entry is often 6 or 8 ft. high, and in some cases, where the shale roof is tender and tends to fall readily, the entry may become

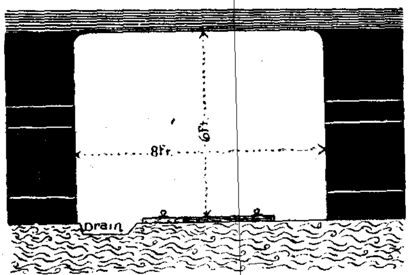
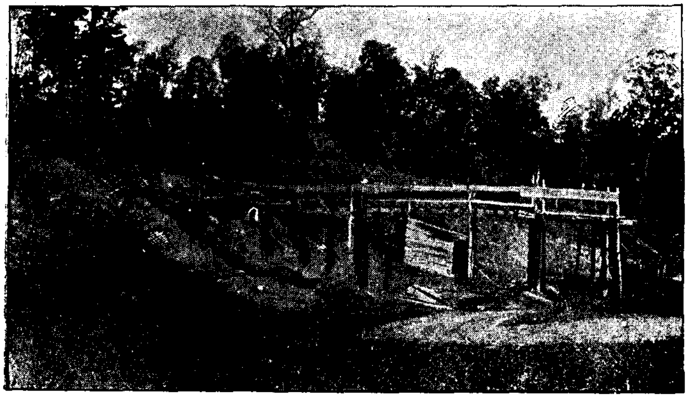


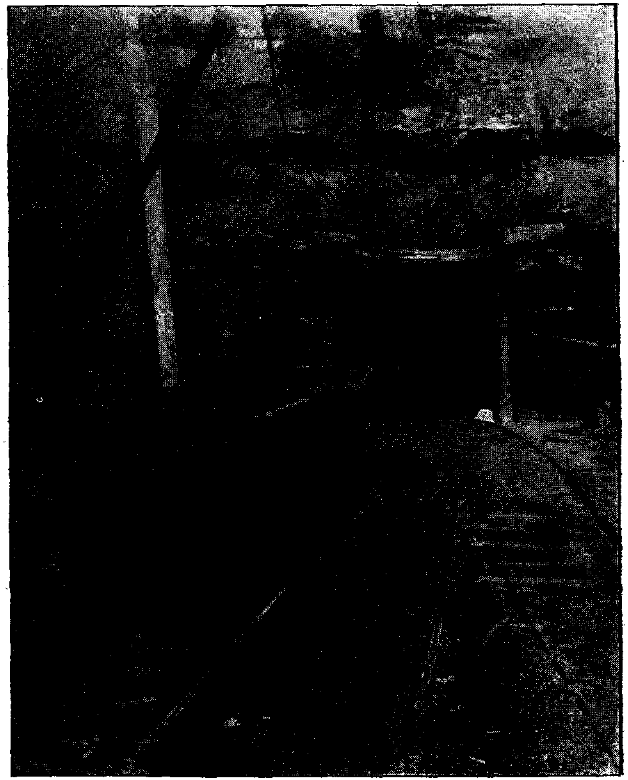
Fig. 955. Cut showing typical cross section of entry.

15 or 20 ft. in height. In the latter case it is usual to cover the entry with rough slabs or "lagging" to prevent accidents from roof falls. In width, the entries vary greatly, commonly being at least 6 ft. wide and often much more. At the "pit" bottom, or foot of the shaft, and at other places in the main entries, the entry is widened to allow the laying of two tracks to allow the mine cars to pass. Such places are commonly known as "double partings." Where coal is worked on both sides of a shaft, the law requires that a passage be cut around the foot of the shaft, so that persons may pass from one side to the other without passing under the cages, thus avoiding risk of accidents from falling coal. In many cases, also, rooms are dug out near the foot of the shaft, in which are placed the pumps, hauling machinery, etc. In the case of pumps, these rooms or alcoves are often placed a little above the coal, so as to keep the pump above water in case of the mine being flooded. In case the coal bed does not run level or with a uniform grade, it is often necessary to take down the roof or raise the floor sufficiently to keep the entry level or on a uniform grade, or at least to keep the grade as low as possible. In some cases this has required the raising of the floor to a depth of over 20 ft., as in the case shown in Fig. 3 in Part I. Entry driving is usually a slow and expensive process, as it is necessary not only to pay the miner for the coal obtained at the usual rate, but a certain amount per linear yard in addition. Plate LXXXIII shows the mouths of typical drift mines as found in Indiana.

McClellan mine, near Cardonia, Clay County. (Note block coal at right of cut.)



Robling mine, near Winslow, Pike County.



Phoenix mine at Alum Cave, Sullivan County.

PLATE LXXXIII. Types of drifts in Indiana, large and small.

XLI. METHODS OF WORKING COAL.

2155. In a general way, the method of pillar and room, which is everywhere followed in Indiana at present, consists first of driving entries or haulage ways in the coal in various directions, usually at right angles, and at convenient distances apart. Then, on either side of certain of these entries, rectangular spaces of coal are worked out. These spaces are known as the rooms, and the coal left between the rooms to support the roof is called the pillar. Afterward it is usual to "draw the pillar," or remove the coal it contains. This is made clearer by an examination of Plate LXXXIV, which represents typically a common method of laying out such a mine in this State. The shaft is shown in the lower left-hand corner, from which there extends the "main entry." For the purposes of ventilation it is customary to drive at least two entries. From these, at distances apart of from 300 to 600 ft., side or "cross entries" are driven, and from these cross entries the rooms are turned off, as shown. It will be noticed that the pillar between the main entries is left quite thick or "heavy;" between the cross entries thinner than between the main entries, yet heavier than between the rooms. The rooms are usually started in quite narrow, from 6 to 12 ft., then, after going in from 9 to 15 ft., they are widened out their full width. In Plate LXXXV are shown types of rooms taken from different mines in Indiana. "B" is probably the most common form of room. In this case the room will range from 15 to 30 ft. in width, average about 24 ft., with a pillar whose thickness is about half the width of the room. The "neck" of the room is about 6 or 8 ft. wide and 10 to 12 ft. long; then the room is opened out at an angle of 45°, and all on one side of the neck, so that the track will run down the room close to the pillar or rib, a great convenience when the pillar is drawn. Often the room is opened out each way from the neck, as in the two rooms "C." The length of the room varies greatly, about 150 ft. being a common length.

In the practice in this State, in mines where the coal is dug with the pick, it is usual to assign one man to each room. In some cases the pillar is left thin, as in "A," and is not removed. In other cases the pillar is not so thin near the entry, but the rooms are driven wider and wider until when completed there is practically no pillar left at the end of the room (a very dangerous practice), and in this case, also, the pillar is not removed. In either of the last two cases the coal of the pillar is lost—a practice which can never be considered as good. Every 45 ft. an opening or "breakthrough" is cut through

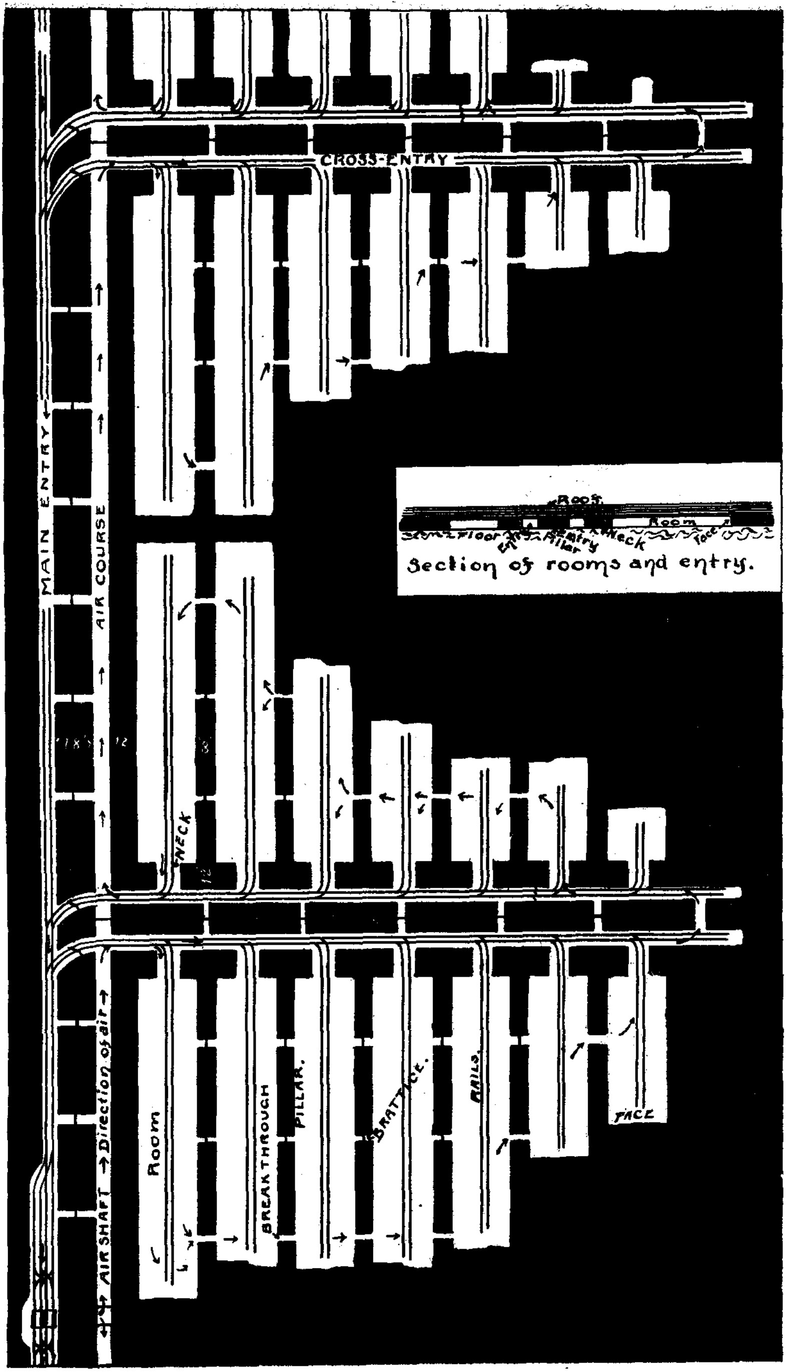


PLATE LXXXIV. Typical plan of room and pillar mine as commonly followed in Indiana.

the pillar for the purpose of ventilation. Where machines are used the rooms are often driven double, as in Fig. "D," the room being 40 to 60 ft. wide.

When the under-clay is very soft, the weight of the roof forces the pillars down into it, causing it to squeeze out or "creep," filling up and closing the entries, and making the pillars a total loss, if not indeed shutting off large districts of half-worked coal. (See Fig. 956.)

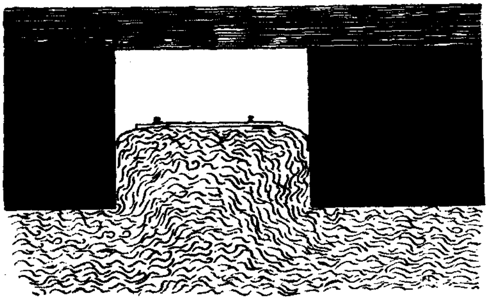


Fig. 956. Sketch showing "creeping" of fire-clay in entry. (Broadhurst mine, Vigo county.)

Various methods of laying out the rooms and pillars are adopted to overcome the difficulty. In too many cases the evil is assumed to be unavoidable, and no effort is made to surmount it except to work the coal out as rapidly as possible, with the idea of getting as much of the coal as can be gotten before the creeping prevents further work, and leave the rest. Such a method, or lack of method, is wasteful in the extreme, and can not be too much condemned.

2156. Probably the best method is to drive the entries through the solid coal to the limits of the area to be worked, leaving very heavy pillars between the two entries of a pair. Then rooms are started at the ends of the entries and the work is carried back toward the shaft, the pillars being drawn as fast as the rooms are completed. In this way the entries can be kept open to where the coal is being mined until all the coal has been won. The difficulty of this method is the large expenditure required before any returns are received from the mine.

2157. In Plate LXXXV, at "E" and "F," are shown two of the methods used in this State under the above conditions. "E" is the method used at the Grant mine, Vigo county. In this case a 30 ft. pillar is left next to the main entry; then every third pillar is left

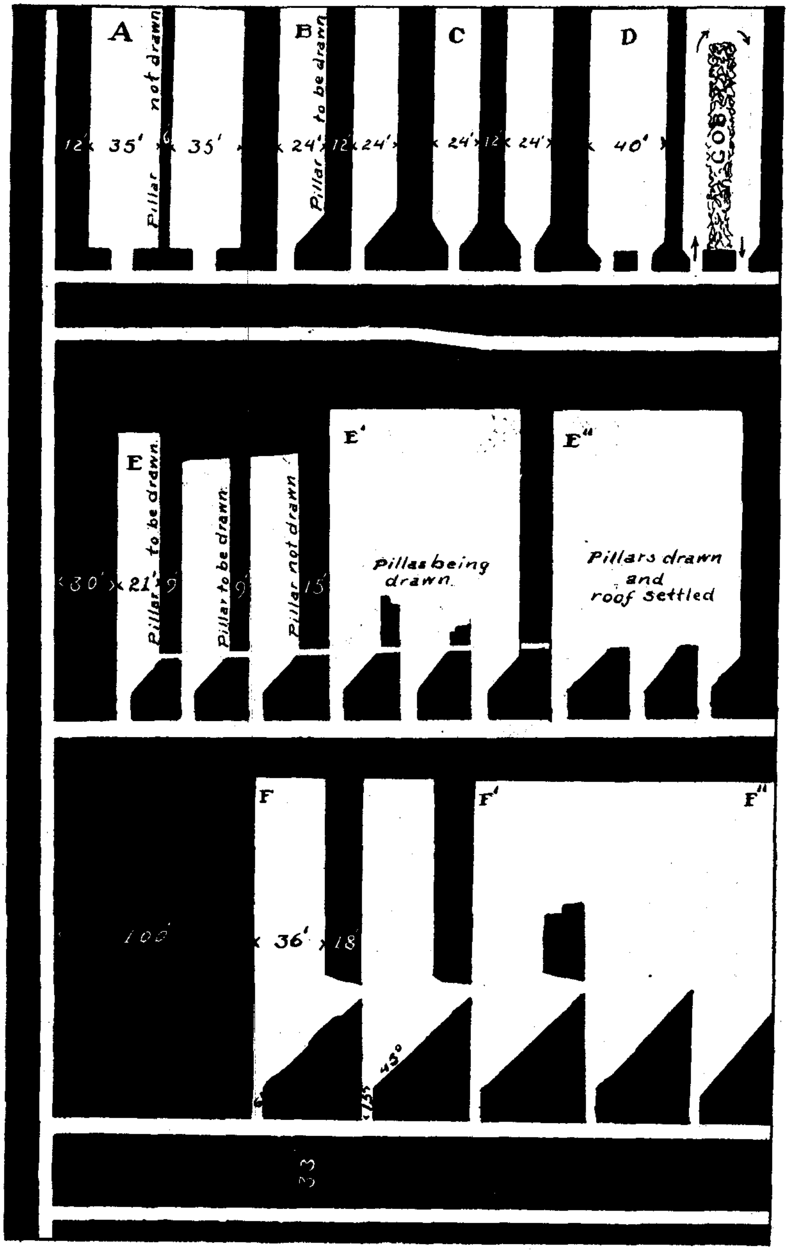


PLATE LXXXV. Types of rooms used in working coal in Indiana.

15 ft. thick, the other room pillars being made only 9 ft. thick, and then drawn. When the two thin pillars are drawn, it makes a room 90 ft. wide, and the roof being allowed to settle in the broad rooms to a certain extent relieves the pressure in that particular region. The 15 ft. pillar is lost, and for that reason, if for no other, the method can not be commended.

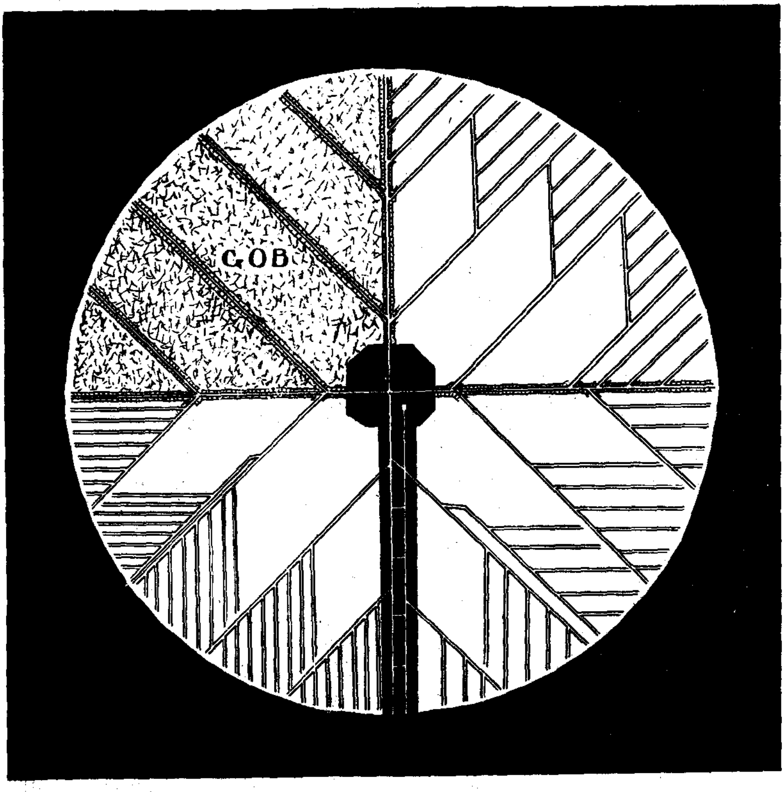


Fig. 957. Figure showing diagramatically some of the methods used in "long wall advancing." In the upper left-hand corner is a method used where the roof is strong, while the other quarters show methods used where the roof is weaker in different degrees. (Gob is omitted from the other three quarters for the sake of clearness.)

2158. At "F" is shown the method used at Cox No. 3 mine, and being adopted elsewhere, and which is considered the best advancing method practiced in the State to overcome creep. In this case the main entry pillars are left very heavy, being 100 ft. thick. The cross-entry pillar is left 33 ft. thick, the room pillar 18 ft. thick. The rooms are turned off 54 ft. apart, being driven in 15 ft. before being widened out; they are then opened out at an angle of 45° and carried through to the next room. By this method there is little danger of the entries becoming closed, and all the pillars are drawn unless there is a loss of some of the entry pillars.

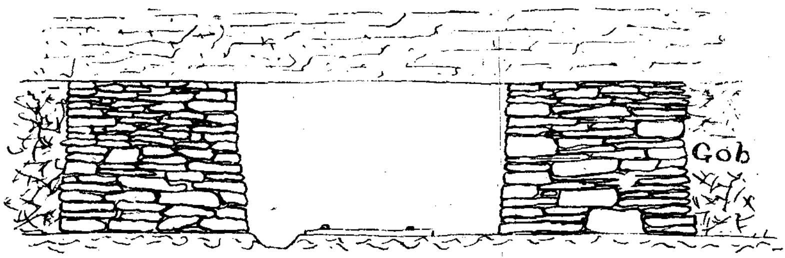


Fig. 958. Cross section of entry with gob walls when first made.

2159. LONG WALL MINING.—In long wall advancing the coal is all removed as the work advances, and the mining is done along a more or less evenly advancing face or "long wall," the roadways being maintained by side walls built of "gob" or the refuse rock obtained in mining, or, if that be unsuitable or insufficient, by rock

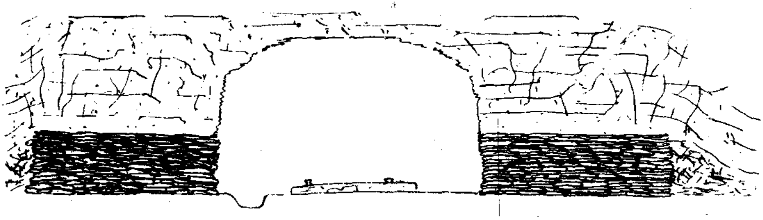


Fig. 959. Same, after gob has settled under weight of roof, and sufficient of the roof has been taken down to give the necessary height in the entry for hauling.

taken from the roof, or if necessary, by timber or other material carried into the mine. The rest of the gob is thrown into the spaces between the good walls, and then the roof settles and fills the space left by mining. In Fig. 957 is shown diagramatically the principles of long wall advancing. It is usual to leave a very heavy pillar about the shaft, though sometimes even that coal is removed, the roof allowed to settle, and then the entries dug out of the settled material. In some cases heavy entry pillars are left along the main entries, but as these pillars are generally lost, the more usual practice is to use gob-packed entries entirely. Such an entry, when first built, will look as in Fig. 958. After the roof has settled and sufficient height has been obtained by taking down roof, the entry may look as in Fig. 959. When the roof is very solid, the gob roads, turned off from the entries at 45°, may be some distance apart, and a track laid along the working face of the coal, so that the mine cars are loaded at points along the face and hauled to the nearest roadway, and so out to the shaft. Where the roof is very weak the roadways must be placed quite close together and the cars only go to the end of the roadway. In this case the coal has to be hauled to them. The lower left-hand corner of Fig. 957 shows the method with very weak roof.

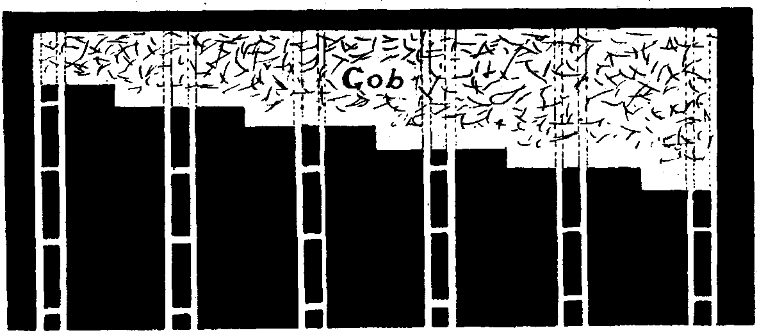


Fig. 960. Type of long wall retreating, in which parallel entries are driven to land lines of the area to be worked, and then the coal between the entries is mined out, working back or "retreating" toward the shaft.

2160. As the work advances from the shaft, most of the old roadways are gobbed up and abandoned. Where the seam is uniform the work may be carried forward in a circle, as in Fig. 957, until the extent of the face may make it better to work the coal in districts. In a coal possessing marked slips or joints it may be found best to work the coal in districts. In such a case parallel entries are usually driven a convenient distance apart, and then, leaving heavy entry pillars or not, the coal between the entries is worked out as in long wall. This system is apt to be wasteful of coal along the main entries, difficult to ventilate, etc., but may be necessary where the output of a mine is irregular or the roof or coal not uniform through a mine.

2161. Long wall is carried on either "advancing" or "retreating." In the latter case pairs of entries are driven to the limits of the territory to be worked, then all connected by a heading, and the coal is then worked out towards the shaft. By this method practically all the coal can be obtained. The disadvantage is principally the one of large initial expense, while the advantages are many, as the mine is more easily ventilated, the haulage roads are more easily maintained, the miner being able to devote his whole time to mining and other work at the face rather than in spending it in building walls, and for many other reasons which need not be dwelt upon here. (See Fig. 960.)

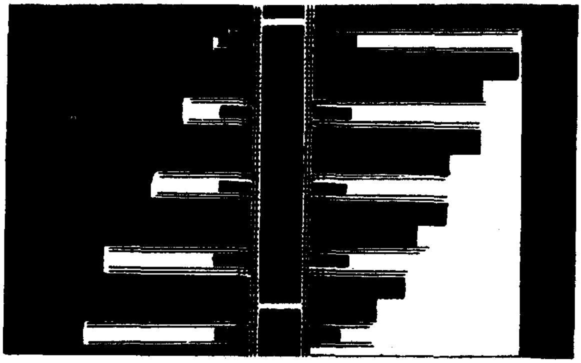


Fig. 961. Type of combination of long wall with pillar and room method.

In Fig. 961 is shown one of the numerous modifications of working by long wall and pillar and room combined. In carrying the work forward the method is to drive double rooms, with the pillar between perhaps twice the width of the rooms; then the pillars are all drawn together in districts, much as in long wall retreating. So many of the modifications of the methods given are due to local conditions or local customs that no attempt will be made to show them.

2162. As with any other engineering problem, no method, however excellent in itself, is the best system for every place. In practice, long wall mining is constantly growing in favor, and there can be little doubt that, in modified forms to meet local conditions, long wall mining is bound some day to largely supplant room and pillar mining. The attempt to support the weight of 100 to 200 or more feet of strata by a small fraction of one of the most fragile beds while we remove the rest of that bed can not be characterized as an excellent way of providing security to life and property.

2163. Some of the advantages of long wall over pillar and room mining are: Removal of a much larger percentage of the coal; the amount of narrow driven work in long wall advancing has been estimated to be only about one-twenty-fifth of the same work in pillar and room; less tracking is required; hardly any separate air courses are required; practically no bratticing is required; comparatively few doors and stoppings; the cubic capacity of open mine in long wall is only a small fraction of what it is in pillar and room, and hence a much smaller quantity of air will suffice for ventilation; the settling of the roof tends to assist in breaking down the coal after it has been undermined. Some of the disadvantages of long wall mining are: The settling of the roof where the seam is shallow is apt to allow surface water to reach the mine and flood it, or, if carried on under valuable buildings or other property, the settling is apt to be uneven, resulting in more or less deterioration, if not destruction, of such property; where, as is common in Indiana, the demand, and consequently the output, is very fluctuating, it is often difficult or impossible to keep the working face open.

2164. It is probably the shallowness of most of the mines of Indiana, combined with the fluctuations in output, that has prevented the adoption of long wall methods. As time goes on, however, it will be necessary to follow the coals down their dip to the westward, and this will mean deeper and deeper mines, so that that objection is apt to be a constantly decreasing one. The difficulty of a fluctuating demand and output will have to be met by the introduction of panels or districts into the system.

XLII. VENTILATION.

2165. Object of Ventilation.—The object of ventilation is twofold: First, the furnishing of the miners with pure air to replace that vitiated by their breathing, by the gases given off by the coal and by the operations of mining; and, second, to dilute the explosive gases given off from the coal or shale till they are nonexplosive.

2166. Natural Ventilation.—Most of the small mines of the State make no provision whatever for ventilation. Fortunately, due to the difference in temperature common between the air inside and that outside of the mine, there is usually a slight tendency for a mine to ventilate itself. Thus, even where the workings consist of only an entry driven in, there will tend to be a certain amount of ventilation, as illustrated in Fig. 962. Thus in summer, as illustrated in the figure, the warm air from outside will pass into the drift at the top, and, becoming cool as it goes back, settles to the bottom, and finally returns close to the floor and leaves the drift as a current of cold air that can sometimes be felt very preceptibly for several yards from the mouth of the drift.

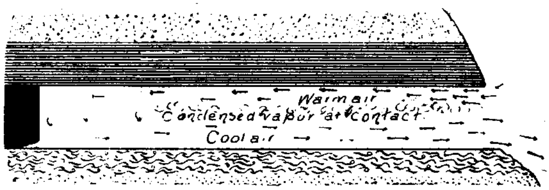
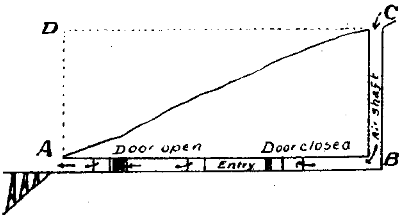


Fig. 962. Diagram showing natural ventilation of an entry driven into the side of a hill.

A more efficient method, and one usually adopted in the small neighborhood mines if they plan to work the coal at all extensively, is that of having an air shaft, as shown in Fig. 963. Thus, if AB be



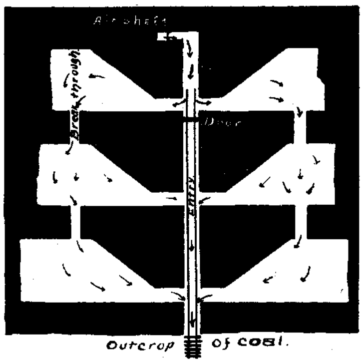


Fig. 963. Vertical cross section of small mine to show circulation of air by means of air shaft. (Summer time.)

Fig. 964. Plan of same mine, showing circulation of air through mine.

the entry, an air shaft, CB, is sunk to meet the entry or some chosen part of the workings. In the summer time the air will generally be warmer outside than in, and, consequently, a column of air in CB is heavier than a column of the warmer air outside of equal length, AD. As a result, the pressure at B is greater than at A, and the air will move from C to A. BC then becomes the intake or downcast. Fig. 694 shows the way the air is made to circulate through the mine. In the case shown the air is entering at the air shaft or at C, and a door across the entry throws the air into the rooms either side; from these, openings to the adjacent rooms, called "breakthroughs," allow it to pass through one after another of the rooms until it finally escapes at the mouth of the entry. If, as is the case in winter, the air outside be colder than the air inside, the current will be reversed and the air will enter at A and pass out at C. BC then becomes the upcast. In this case the door near the mouth of the drift would be closed, throwing the air into the first pair of rooms. It is, of course, necessary to open the door each time a car passes. As the rooms progress, new breakthroughs are made and the old one stopped up, in that way the air being carried as near the working face as possible.

The same principle holds good for a slope or shaft, providing that the air shaft extends to above or below the mouth of the slope or shaft. Of course, the longer the air shaft, the greater the difference in the pressure at A and B for a given difference of temperature inside and outside the mine. In many cases the attempt is made to increase the height of the column of air, BC, by building a chimney above C of boards, barrels or in other ways. Where the height or character of the hill prevents this method, the plan is sometimes followed of driving double entries and building a chimney from the mouth of one of them. The first difficulty with any natural method of ventilation is that as soon as the temperature outside and in becomes equal, the air ceases to circulate, and in any case the current becomes less and less as the temperature inside and out approximate each other. In the second place, as the workings increase in extent, the distance the air has to go increases the friction or drag, so that an air shaft which would provide fairly good ventilation in a mine just starting will soon prove inadequate. Then it becomes necessary to take another step in the method of ventilation; that is, the introduction of a furnace.

2167. THE FURNACE.—This method consists in building a fire at the bottom of the air shaft. Thus, by heating the air in the air shaft, it becomes light and the pressure at B is reduced in consequence, so that the air will enter at A and pass out at C, and BC becomes permanently an upcast. This fire may be a few coals in a wire basket hung at the bottom of the shaft, or an elaborate brick furnace burning many tons of coal a day. Even as late as 1880 the furnace was the means used to ventilate some of the largest mines in Indiana. To-day all the larger and many of the smaller mines are ventilated by fans, and a great saving made. As the ventilation of a small mine by a furnace involves practically the same principles and is accomplished in the same way as by an air shaft depending on natural ventilation, and as the ventilating of a large mine by a furnace requires the same method of laying out mines and directing currents as when an exhaust fan is used, furnace ventilation need not be discussed further here.

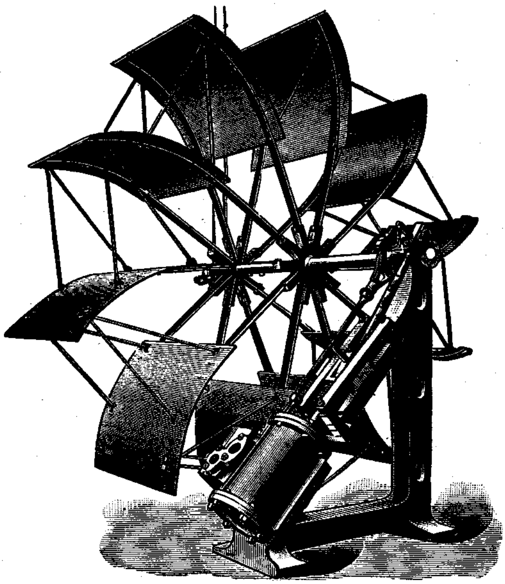


Fig. 965. Type of fan common in Indiana. Kindness of Crawford & McCrimmon, Brazil, Ind.

2168. VENTILATION BY FANS.—As stated above, the efficiency of revolving fans over other methods of ventilation is so great that they have practically superseded all other methods for the large mines. These fans are usually large paddle-wheel-like arrangements, with curved blades working in an inclosed space. They range from 4 ft. up to 20 ft. or more in diameter, 10 or 12 ft. being a common size in Indiana, and are run by a small independent steam engine, which is usually attached directly to a crank on the axis of the fan. They either blow or exhaust. Exhaust fans are seldom used with shafts, for the reason that when so used the main shaft usually becomes the downcast, and in very cold weather the cold air being drawn down the shaft tends to freeze the water which will almost always be found dripping there, rendering it necessary oftentimes to chop out a great deal of ice before the cages can be moved. Again, in case of the tipple catching fire, the smoke and fumes are drawn down the shaft and all through the mine, with often most serious results to those in the mine. As yet, the fans in this State are all of the type indicated. As the demand for greater efficiency in all parts of mine machinery in-

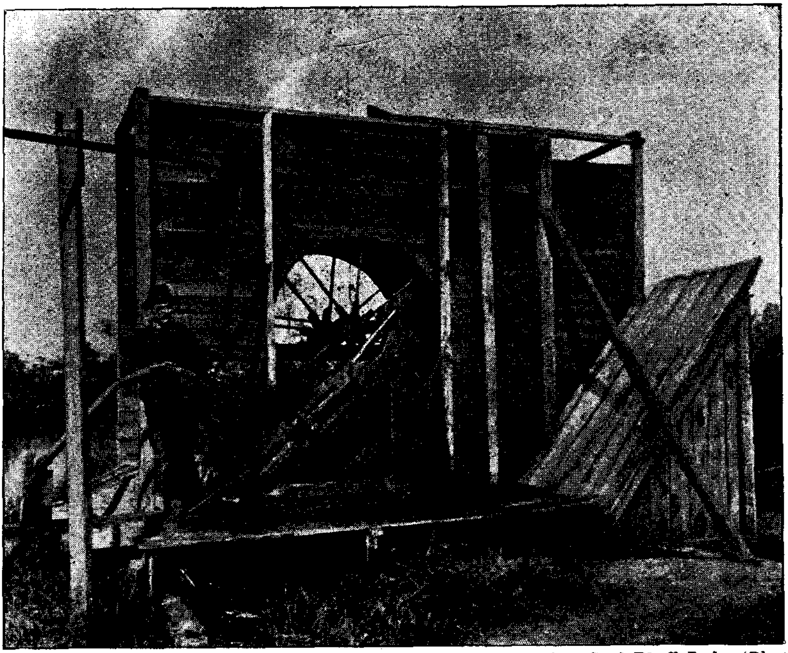


Fig. 966. Outside appearance of ventilating fan house, Peerless mine, Coal Bluff, Ind. (Photo by Mr. J. F. Newsom.)

creases, no doubt they will give way to more efficient forms of fan. They bear about the same relation to a fan of proper design that an old-fashioned water-wheel does to a modern turbine.

2169. Steam Jet Ventilation.—One other method of producing a current is in use to a small extent; that is, ventilation by a steam jet. In this a pipe is carried from the engine or boiler part or all the way down the air shaft and turned so that the open end is upward. Steam being allowed to escape from the pipe with some force produces an upward current in the air shaft and secures some resemblance to ventilation. For a very small mine the ventilation thus produced may be ample; but in any case the efficiency of such a method is so small as compared with the efficiency of a fan driven by the same amount of steam that it might almost be compared to trying to run a train by the pressure of steam escaping in the rear.

2170. Ventilation by Double Entry.—With the introduction of better methods of producing a current came better methods of utilization of those currents. This led to the abandonment of the single

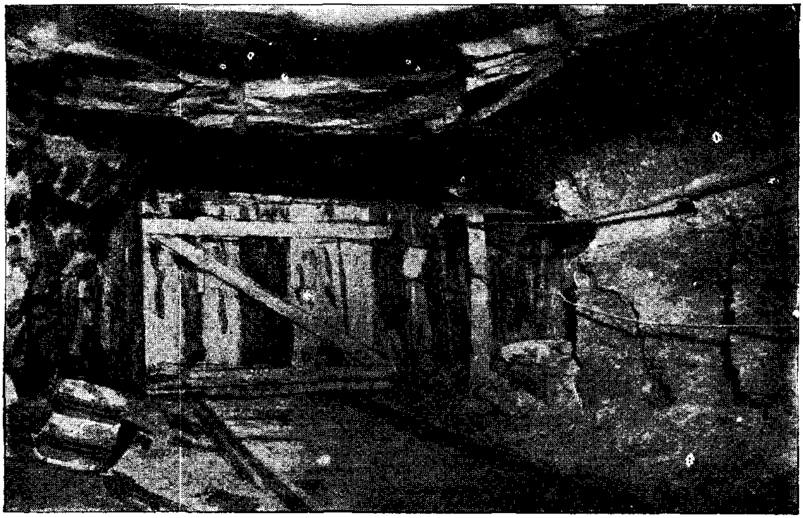


Fig. 967. Type of cut-off door commonly used in directing air currents in mines in Indiana. Brazil Block Coal Co.'s No. 1 mine. From flashlight photo by Mr. J. F. Newsom.

entry system, as figured in Fig. 964 (though the most of the neighborhood mines still stick to that plan), and the adoption of the double entry plan. This is the method in common use in all the large mines of the State. The method is exhibited in Plate LXXXIV. Essentially it consists in driving parallel entries which, being connected at the advancing end, serve as a circuit for the circulation of the air. In practice these entries are from 8 to 50 ft. apart, and connecting breakthroughs are driven every 45 ft., as required by law. As each new breakthrough is made, the one last used is stopped up or "bratticed" air-tight. As with the rooms, the ventilation is only partial while working ahead of each breakthrough, and is often very bad, particularly in driving a new breakthrough in a heavy pillar, where the ventilation is almost nothing.

2171. DOORS.—In case the air current is required to cross an entry without connecting with it, it is carried over the entry in a combination of box and overhead tunnel, usually, known as an over-cast. Doors are used to direct the current in desired directions at the intersections of entries. These doors are usually in charge of boys known as "trapper boys," who open and close them to allow the passage of the mine cars. Many of the better equipped mines now use mechanical devices to open and close these doors. These, as far as observed in this State, consist of an elevated rail up on to which the car runs, when its weight forces the rail down and opens the door. As the car leaves the track a counterpoise weight carries the rail back and closes the door. Of course, every time the door is opened the air current is for the time interrupted. In Plate LXXXIV the course of the air can be followed by noting the arrows.

2172. REGULATORS.—At points where the air course divides it is important to have the proper proportion go in each direction. If, as is usually the case, due to the difference in length or shape of passages traversed by the two currents, the frictional resistances are not equal, it is evident that the most of the current will follow the course offering the least resistance. To offset this, "regulators" are placed in the passages, by which the size of the passage at that point can be changed so that by compelling the air that is to pass through the shorter course to enter through a smaller opening of the proper size, the amount of air that enters can be proportioned to the needs of each entry.

2173. SPLITTING THE AIR CURRENT.—It is too often the practice to drive all the air around the whole mine. Better practice divides or "splits" the air so that one part goes through one part of the mine, another part through a different portion of the mine, etc. The advantages of this are: A better distribution of the fresh air; the friction of passages and rooms is divided among the different splits, thus greatly reducing the work required of the fan; on account of the smaller amount of friction, much less power is required to drive the air; with the reduced friction it is not necessary to give the air a velocity that renders it difficult to keep the lamps going, etc. On the other hand, too frequent splitting will reduce the current till it becomes sluggish and ineffective.

2174. TRIPLE AIR COURSES.—Where power haulage is used, especially electric, it is often very desirable to avoid the use of doors for directing the air currents. This is accomplished by the use of a third air course. Many systems are in use. Fig. 968 shows the system as practiced in more or less modified form at some of the large mines of Pennsylvania. In this case the air is driven out central entries to the extreme points of working, from which it works its way back through the rooms to the main haulage ways and out. In some cases the fresh air is carried in through the side entries, and is drawn through the rooms and out by way of the third entry. In some cases the central entry only is used for haulage, and the air is carried out the side entries.

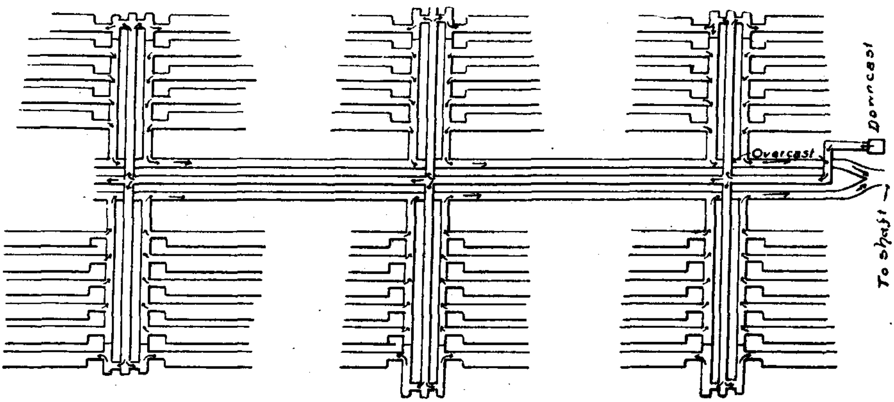


Fig. 968. Diagram showing method of securing ventilation with the minimum number of doors by the use of three entries.

2175. Long Wall Ventilation.—As already stated, the ventilation of a mine worked long wall is comparatively simple and effective. Where the work is being carried forward more or less nearly in a circle, the air may simply be carried out in opposite directions to the faces, then split and carried around the working face through a quadrant where the currents unite and return to the shaft in directions at right angles to their outgoing directions. Not only does this require the minimum distance for the air to pass and thus a minimum of power to drive it, but the miner is working always in the current and not a varying distance ahead of it.

In the line of improvement and higher efficiency it has occurred to the writer that greater efficiency could be secured by abandoning the air course system and substituting piping the air to just the points where it is needed. By such a system the mine could be worked single entry. There need be no breakthroughs, no brattices, no doors, practically no leakage. The air in all cases could be carried to the face of the rooms where it was needed, and only to those rooms. The length of piping required would at any one time be practically the same as is now required to serve the machines in a mine using compressed air machines. Size of pipe and pressure to give the greatest efficiency would have to be calculated. By this method each miner would receive pure air unvitiated by passing through other working places. To save using large sizes of pipe to reach workings at a distance from the fans or air pumps, high pressures could be used in the main lines, or by the use of small shafts or large drill holes the fans either on the surface or below could follow the workings, especially if electric fans or pumps are used. Lacking the time to determine the feasibility of the plan, these suggestions are simply given for what they are worth.

2176. MINE GASES.—In this State, due principally to the fact that the mines are so near the surface, little trouble is met with from the accumulation of mine gases, and but little account need be made of them in planning the ventilation. In some of the deeper mines—and the number of these will increase as time goes on—the mine gases become a source of danger. The gas most commonly met with is that known as marsh gas, a combination of carbon and hydrogen, which, when mixed with a small quantity of air, becomes the explosive fire-damp. When pure marsh gas, it will burn without explosion, or if sufficiently diluted with air, it will not explode. Both methods are used of getting rid of the gas—first, by burning it as it escapes from "blowers" or holes in the rock or coal in a pure state; second, by diluting it with an abundance of pure air. The first method is too often followed, and can not be too highly condemned. The extinguishment of such a "blower" of gas where there is not adequate ventilation quickly leads to the formation of an explosive mixture which explodes as soon as a light is reached, with, as often as not, fatal results to many or all of the miners in the mine—for those not killed by the explosion may be suffocated by the black damp or gas that is formed by the exploding of the fire-damp. The best remedy is an abundant air current through all parts of the mine and a competent fire boss. In extreme cases, a boring might be made from the surface at the point of escape and the gas drawn off by piping and burned at the surface.

XLIII. DRAINAGE.

2177. Natural Drainage.—Very few mines of any extent in this State drain themselves—first, because there are now very few large mines working the coal from the outcrop, and where the coal is so worked it is only here and there one that has the coal dipping from every point to the mouth of the drift. If this point is but a few feet above the lowest part of the mine, natural drainage may often be secured by digging a ditch in the bottom to the required depth from the lowest point of the coal to the outcrop.

2178. Siphon Drainage.—Where the lowest point of the coal is so far below some other point of the entry between there and the mouth of the entry as to make natural drainage impracticable, the result may be accomplished by means of a siphon. This is simply a tube whose joints are air-tight running from the lowest point of the coal to a still lower point outside of the mine at which the water is to be discharged. The conditions necessary are that the discharge end of the pipe be lower than the intake end; that no point in the pipe be more than about 20 ft. higher than the point of intake, and that the joints be air-tight. A hand pump placed at the highest part of the pipe pumps the air out and sets the siphon going, after which it runs itself. As far as noted, no siphons are used in Indiana. There appear, however, to be a few mines in which their use would save the expense of pumping. In Pennsylvania siphons are in successful operation in lengths of up to almost a mile. Their use in this State would not be so much draining mines as in draining parts of mines where the coal occurs in isolated basins.

2179. Water Bailers.—The shaft being the usual form of mine entrance, and the coal usually being below adjacent drainage level in Indiana, most of the mines require that the drainage water be hoisted out of the mine. The simplest means of accomplishing this is with some sort of a bucket or box. In most of the small mines a barrel is used. The sump to which the mine drains is placed below one compartment of the shaft, and a barrel or box alternates with the cage in the other compartment in rising and descending. In many cases the box is attached below the cage and a box full of water raised every time the cage is raised. This plan is even adopted in some of the largest mines.

2180. PUMPS.—In by far the majority of cases in this State it is necessary to resort to pumping to free the mine of water. This is due to the fact that most of the mines are shaft mines, and the coal is generally below the level of adjacent drainage. The common practice is then to lead the water from all parts of the mine by ditches in the entries to the sump or sumps placed at the lowest points of the coal. In perhaps a majority of cases one sump is usually placed at or near the foot of the shaft. Steam pumps are principally used. These are placed in the mine near the sump and force the water to the surface. The steam is furnished from the boilers on the surface. In many cases the sump and pump are long distances from the shaft, the steam being carried in pipes through the entries and the water driven up through a driven pipe. On account of the loss of power in conveying steam such long distances, we look for the introduction of electric pumps or compressed air pumps in those mines using one or the other of those forms of power which find it necessary to place pumps at some distance from the shaft and boiler house. Some of the mines require as many as five large pumps to keep them free of water, especially where connected with old workings. In some of the latter cases, where possible, it would seem to be economy to build heavy retaining dams to shut off the old workings and let them fill up. Such dams should, of course, be strong enough to stand any pressure that may be brought against them, which might in some cases be equal to the pressure of a column of water of a height equal to the depth of the mine. As a rule, this should not be done where no accurate map of the old mine has been made. In some cases the coal forms too ready a passage for water to make such shutting off effective.

As old mines tend to fill up with water and thus become a source of danger to later mines which, working up to the same lines, might break through into the old workings, and thus be themselves flooded, with a possibility of loss of life, it has long been a law that before the abandonment of any mine a map of it should be filed with the Mine Inspector. As this often entailed an expense of several hundred dollars after a mine had ceased to produce, the law was not effective, and has recently been replaced by one which requires such maps to be filed each year of all mines operating.

It is not an uncommon occurrence in Indiana to have mines flooded from surface waters. This not only renders the mine idle, often for weeks or months, but leads to considerable expense in pumping it out. Such flooding may usually be avoided if two points are kept in mind: Never locate a shaft or any opening to the coal so that its top is below the level of highest water of adjacent streams; leave the coal under stream channels where there is any possibility of breaking through by the settling of rooms, till the last. Entries may usually be driven under such streams with safety, but there is always danger, if an attempt is made to open rooms, that when the roof settles the stream will simply be turned into the mine. In the map given of shaft No. 8, Plate LXXXIII, the broad band of unworked coal across the center of the mine is under Otter creek.

In the laying out of the mine, drainage plays an important part, as it is desirable that the mine be so planned that the coal is mined up the dip as much as possible, and then the rooms will drain themselves. Where the entries are driven directly up or down the dip, it is often customary to drive the rooms not quite at right angles to the entry, but inclining slightly up the dip, thus securing better drainage.

XLIV. A WORD OF SUGGESTION TO HOLDERS OF UNDEVELOPED COAL LANDS.

2181. Many of the readers of this report are owners of land in the coal area, which you have reason to believe is underlain by workable coal of good quality. You have, perhaps, or are contemplating opening up a little bank, primarily to supply yourself with coal, and secondarily to furnish a little to your neighbors, if they desire it, to help pay for the expense of opening up. If so, a word of suggestion may not be without value. Remember, in the first place, that if the coal is worth developing at all, it is worth developing properly, and for several reasons: First, a mine properly opened up does not require to be reopened every fall, as a majority of the small mines do; second, you will generally save any possibility of having to abandon your mine just when you have it in shape to get coal rapidly by finding you can not drain it, having opened at the wrong place as regards the dip; third, though not always at first, in a short time the economy in mining and getting the coal out will more than pay for the extra trouble of proper openings; fourth, by proper methods all the coal may be taken out. There are, however, other reasons which are even stronger. Your property is to-day perhaps out of reach of transportation facilities, and would actually sell for little if any more with the coal under it than it would without the coal. That will not always be so. The extensive mining of ten or twenty years from now will be carried on where to-day are only small neighborhood mines, or not even that. It may be that the rapid failure of natural gas in

Indiana will result in the early development of many such regions. Suppose that five or ten years from now your land is brought within reach of the market by the introduction of a switch of a railroad. You value it to-day at say $50 an acre. Suppose there is a 5 ft. bed of coal under it, what will it then be worth per acre? At a royalty of ten cents per ton, from $500 to $750 per acre; at a royalty of five cents a ton, half that. Under these conditions you may desire to operate on your own land extensively, or you may desire to lease or sell to parties who will. Now if, while operating on a small scale, you have done so in a proper way, it may make your property more desirable than surrounding property, which otherwise is as good, or possibly a little better. On the other hand, if you have followed the all too common method of gouging into the coal without any regard for system or the future consequences, your property will certainly be at a disadvantage as compared with similar property about you. In the first case the mine can become a paying one almost from the start. In the latter case not only do you lose the value of the coal removed, which, of course, you do in the former case, but usually several times the area actually mined out is rendered valueless by the lack of a proper system in mining; and, further, it often means a large extra expense to drive entries through these old works. So that, as a rule, experienced companies would prefer to start a mine in untouched coal rather than at points where it has been improperly mined. In view of the effect on the coal value of the land, the methods sometimes adopted are as reasonable as it would be to chop a single board off from a standing pine tree.

These are only part of the arguments in favor of opening up even a small country bank systematically or not at all. Having decided, however, to open up a bank, the following suggestions are worth considering:

First. Open the mine at the proper place, as regards drainage in particular, even if it requires some trouble and expense.

Second. Drive double entries and of sufficient size to allow a large output later if desired, and leave heavier entry pillars than would be done if the coal were to be worked out continuously and quickly. In case the coal is reached by a shaft, it may not be necessary to make that at once as large as would be required to ship several hundred tons a day, as it can readily be enlarged afterward. With the entries, however, it is different. If the entries are small, with small pillars between and at the side, they can only be enlarged at the expense of the pillars, perhaps already too small.

Third. Do not gouge promiscuously into the side of the entries or turn off rooms from your main entry as soon as under cover. Carefully plan a system of cross-entries, and follow your plans if possible, even if you never mine out more than one or two rooms.

Fourth. Take especial pains to preserve the roof of your entries, by substantial timbering, if necessary, and by proper drainage keep the mine as free from water as possible.

Fifth. With mines that are only worked a few months in the fall and winter, it may not be advisable to attempt to work by the long wall method, but it might prove an advantage if the mine were planned so that, if desired some time in the future, the long wall method could be readily adopted.

Sixth. Time and attention given to preparing the coal by proper screening, cleaning of sulphur, shale, etc., is not time wasted, but may prove the best sort of an investment.

XLV. MINING AND REMOVING COAL.

This chapter will discuss the methods of mining the coal, of hauling and raising it to the surface.

Section 1. Coal Mining.

2182. General Methods.—Several methods of "breaking out" the coal are followed. The most common method is to under-cut the coal as far as the miner can, and then it is either wedged or blocked down, or holes are drilled in the coal, which is then blasted or shot down with powder.

Often the coal is undermined in the under-clay, or in the bone coal, where that occurs at the bottom of the seam, as it often does. Frequently the coal is sheared at one side of the room or at the center of the room. Where the coal contains partings of clay or shale, or bone coal, the "bearing in" may with economy be done in it. Often the bearing in is done in a layer of soft coal or in a layer which is hard and brittle and so chips easily. Such a layer is known as the "bench mining," as the different divisions are known as benches. In such cases it not infrequently happens that after the removal of the bench mining across a broad room the bench above will, of its own weight, sag down, becoming fractured and yielding readily to the pick. In such case it is often the custom to raise the underlying bench by wedges; in this way the coal is mined readily and without powder. It is an aim in mining not only to get the coal out as rapidly as possible, but to get out as large proportion of large coal, or, as it is known, "lump coal." For this reason the use of powder is avoided where possible. In mining the block coal the use of powder is seldom necessary, as the natural jointing of the coal greatly facilitates its breaking out. In such coal the direction of entries and rooms is generally laid out on directions so as to facilitate taking advantage of the slips. In long wall mining it is seldom necessary to more than "bear in" under the coal, the wedging action of the roof, which is gradually settling behind the work, breaking off the coal in huge chunks, requiring neither powder, bar nor even wedge to bring them down.

In some cases the coal is not undermined or dug in any way, but is simply drilled and shot down with powder, or, as it is called, "shot on the solid."

The various methods of mining are not usually confined to special districts, but are adopted to meet the special requirements of the seam being mined, so that often quite different methods are used in different parts of the same mine. Much also depends on the miner himself and his previous practice.

2183. MINING BY MACHINERY.—In the use of mining machinery Indiana has been in the vanguard. In 1896 inquiry showed that in percentage of coal mined by machinery Indiana stood second of the eastern or central States, being surpassed only by Montana and Alaska of the western, in the latter there being but one mine, which used machines, so, of course, the whole output was machine mined. The machine in most common use in Indiana is the Harrison compressed air machine. Any one who has watched the operation of a common compressed air rock drill will understand its action. This machine is shown in Plate LXXXVI. It is simply an air cylinder in which compressed air drives a piston-rod or bar which chips out the coal. It is mounted on wheels and is operated on a platform sloping to the face of the coal. The operator half lies on the platform, and by means of the handles and by the use of his feet bracing against the wheels, directs its blows. An assistant shovels the slack out of the way and attends to moving the platforms. (There are usually two to save time in shifting the machine.) In moving the machine from one room to another, a light truck is used. For shearing, the machine is mounted on a pair of high wheels.

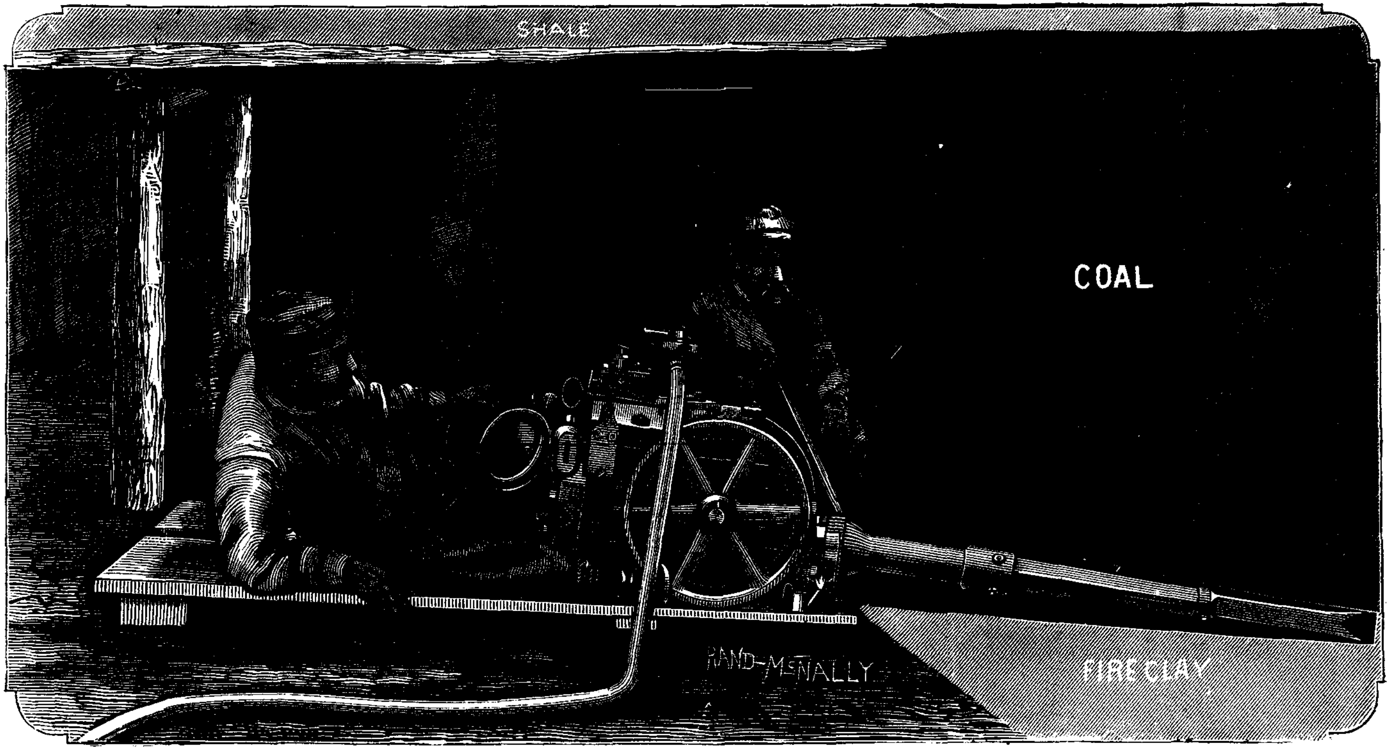


PLATE LXXXVI. Harrison compressed air mining machine at work.

These machines use a pressure of up to 75 lbs., the air being compressed in air compressors of 120 H. P. capacity. It is then conveyed into the mine and to the various rooms by iron piping. With a pressure of 75 lbs. at the compressor, the pressure at the machines

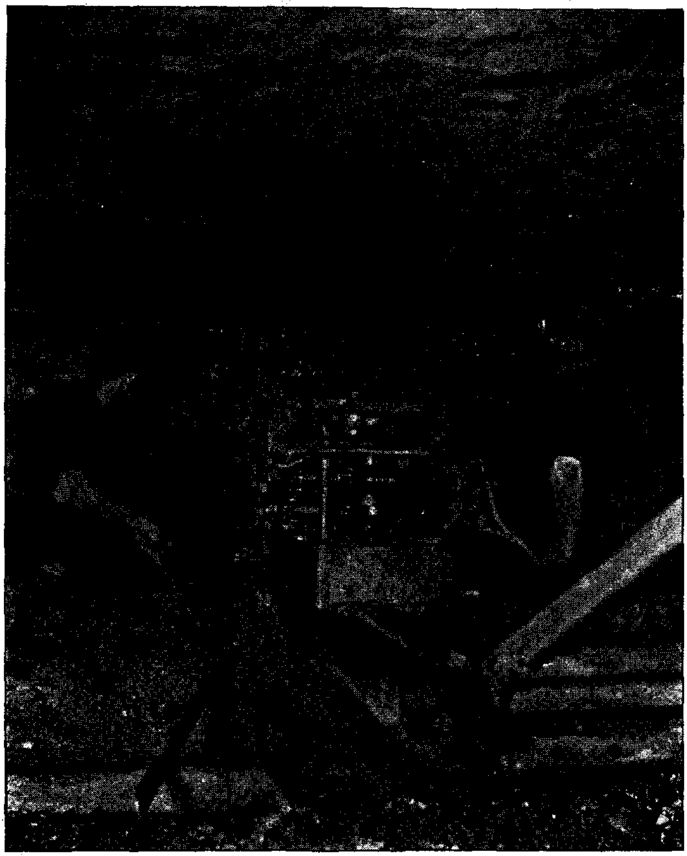


Fig. 970. Electric chain machine at work in Mecca mine. From flashlight photo by Mr. W. Paul Zimmerman.

will range from 60 lbs. down, according to the number of machines working, distance from compressor, etc. One compressor is sufficient to drive a dozen or more machines, which deliver about 200 blows per minute each, and will undercut to a depth of 5 ft. or a little more.

The extended use of the machine testifies to its efficiency. One of the objections to it is its tendency to produce deafness in those operating it.

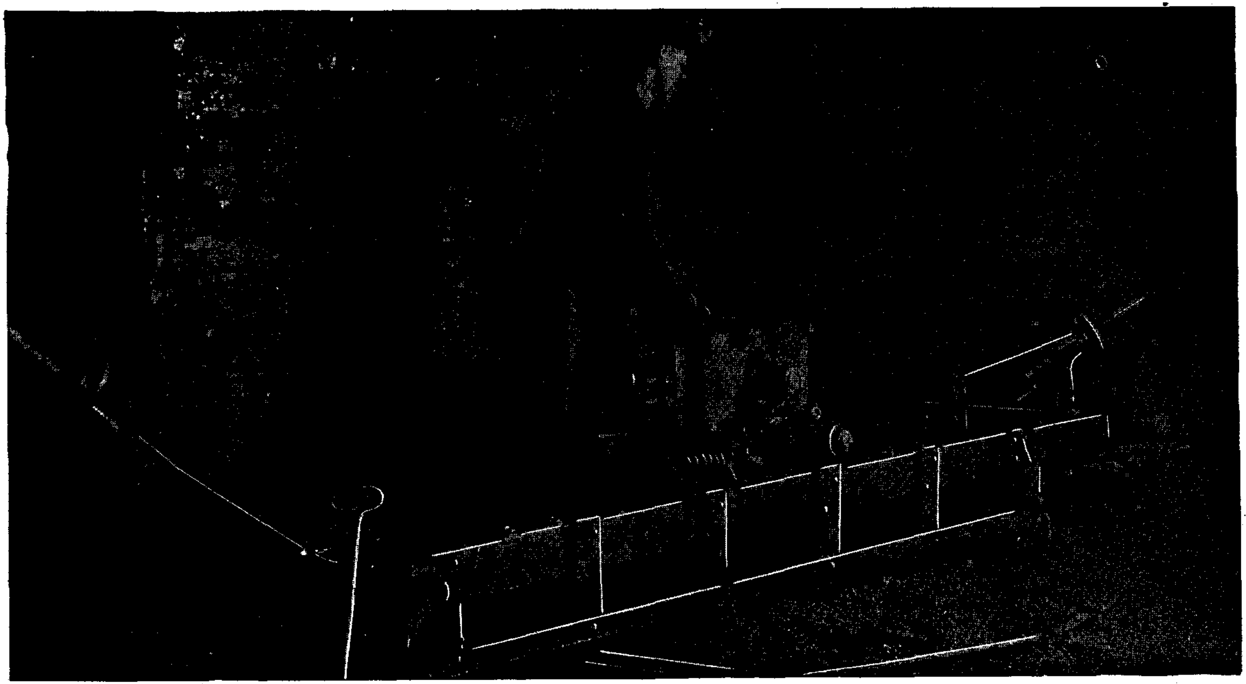


PLATE LXXXVII. Jeffrey Electric Mining Machine at work. Maximum undercut, 7 feet deep, 44 inches wide, 4 inches high. Makes complete undercut, in and out, in less than four minutes.

Several types of electric machines are in use. These usually are what are known as bar or chain machines, the latter predominating. In principle the chain machine consists of a low horizontal frame, as shown in Plate LXXXVII, around which is driven a chain set with teeth much like an endless band saw. In fact, it is in principle only a saw, and may be said to have originated in some unsuccessful attempts to use a circular saw for the purpose, only that in the coal cutter, on account of the damage to which the teeth are liable, they are replaceable. These teeth are set somewhat after the manner of saw teeth, so as to make clearance for themselves and the frame, which in this case requires that every third tooth be set to cut between the paths of the other two. In this machine, as the teeth cut, the frame or cutter-head around which they are carried is advanced under the coal, making a cut about 3 ft. 6 in. in width and 4 in. high and undercutting the coal to a depth of up to 7 ft. Such a cut will be made in four or five minutes, depending somewhat upon the coal. These machines cut faster than the pick machines, but require more power and are several times as heavy, a disadvantage in moving from room to room. The machines of this type in use in this State are the Jeffrey, the Independent and the Morgan Gardner.

Another form of the electric machine is the Legg or bar machine. In this a bar set with teeth is made to revolve forward and downward; at the same time it is fed forward. It has the disadvantage over the preceding machine of cutting across the bedding of the coal and of having to grind up all the sulphur balls it meets.

Of the forms of machines not used in this State might be mentioned those designed for use only in narrow work and those designed for long wall mining. These will undoubtedly come into use with the adoption of long wall mining, but need not be dwelt upon here.

In the Mecca No. 1 mine, and elsewhere, there have recently been installed electric drills. (See Fig. 971.) In such a drill the driving power is a small electric motor supplied from the dynamo in the power house. Similar drills are made to be operated by compressed air. With either of these power drills from 30 to 60 ft. an hour can be drilled, requiring one man and a boy to operate it. Such a drill will weigh about 150 lbs., being built to stand the rough usage they are liable to sustain.

2184. Timbering.—In addition to mining the coal, the miner has usually to timber his room and load his own coal. With some roofs, especially where it is a black sheety shale overlain by limestone, no timbering is needed for a room of 40 ft. or under width. The writer has seen such rooms in this State, where the roof has stood for years without a prop in rooms 40 ft. wide, and still it shows no signs of weakness or flaking. In other mines that have been in operation many

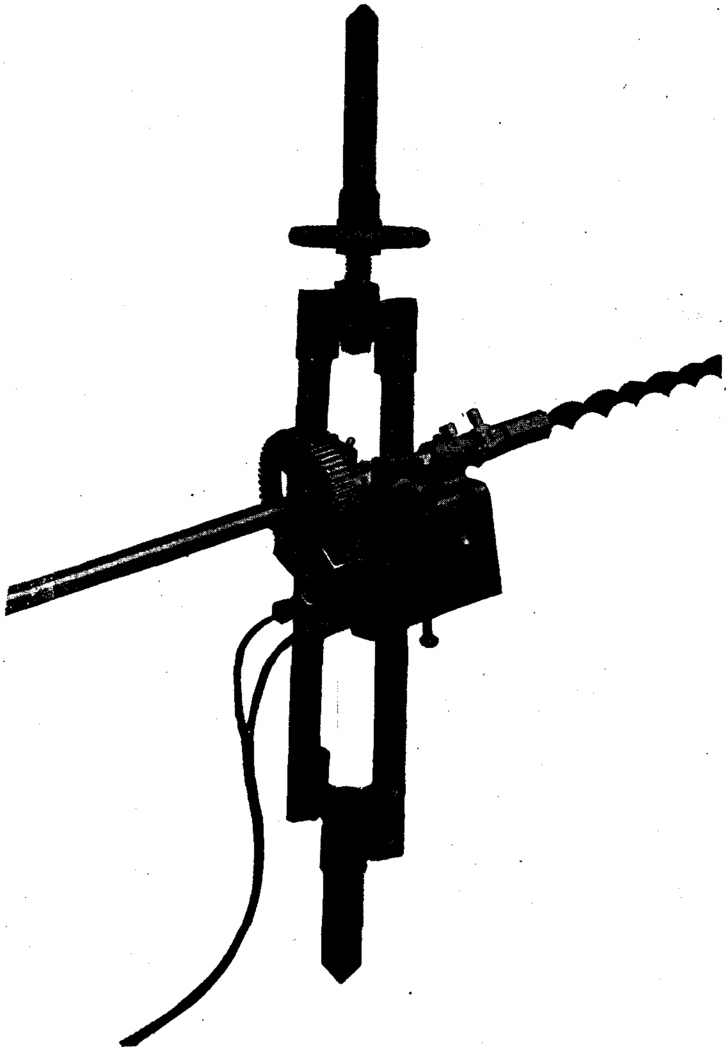
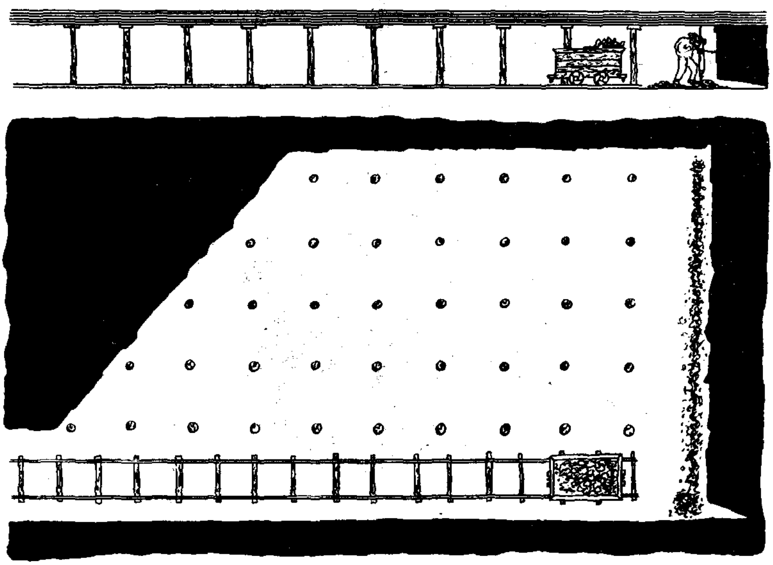


Fig. 971. Jeffrey Electric Drill.

years it is not uncommon to find that the roof in the entries has flaked down until the entry has become fifteen to twenty feet high. In most of the mines of the State some timbering is necessary; a not uncommon average would be one post to from every square yard to every four square yards. As the object of timbering is to keep the roof intact, two points are usually kept in mind: First, to see that the posts are set in regular rows at regular distances apart to insure an equal distribution of the load; second, to see that the posts have flat square bearings, and that where wedging is resorted to to make them tight, such wedging does not interfere with the whole top of the post sustaining an equal pressure. In order to make the bearing broader, it



Figs. 972-972. Cross section and plan of typically timbered room. Scale 12 ft., 1 in.

is usual to put a piece of flat board on top. In this State the custom is for the miner to set his own posts, which are furnished to him at his room by the operators or company. It is specified by the law that the company shall keep a blackboard, on which the miner puts down the number and length of timbers required by him, and they are later distributed to him by the day men. In some mines the roof needs to be timbered so closely to the working face that it would seriously interfere with the use of certain forms of mining machines, especially the electric chain machines, which require quite a little room to work in. In a majority of cases where the roof is shale the part of the roof immediately overlying the coal is not as solid as that a few inches or more above. This part of the roof tends to come down, and is called the "draw slate." In some cases it is taken down before the posts are set up; in other cases it flakes down afterwards, usually a column of it remaining over the posts. Where the roof is a clay shale only a foot or two thick, overlain by sandstone, it is quite common for the shale to come down, leaving the sandstone for a roof.

Figs. 972 and 973 show a typically timbered room in plain and cross-section.

In long wall mining, with a strong roof, and with a sufficient supply of proper material to build walls, no timbering is required. Fig. 974 shows a section of long wall mining face in a thin seam with strong roof.

Where the roof is tender, timbering is usually resorted to, the entry walls are built as usual and the rest of the gob thrown around the posts.

Section 2. Removing Coal.

2185. Loading.—In this State, where pillar and room is universal, it is the common custom to run the mine cars right to the working face, where they are loaded. The mine cars used in the State are of a variety of patterns and sizes. (See especially Plates LXXX, LXXXII, LXXXIII.) They are planned to hold from one-half ton to two tons. In loading, it is most common to shovel the coal in, regardless of size, such coal being called "run of mine." Another very common practice is to build up the sides of the car with the large lumps, often to a height of a foot or two above the side of the car, and shovel the finer coal into the center. Due to the rule common with the miners' union, the cars are distributed to the rooms in regular rotation, so that each miner during the day will send out the same number of cars. This practice leads the more industrious to make each load sent out as large as possible. In some cases, to prevent the overloading of the hoisting cages, the companies place beams in the entry at a given height to serve as a check to overloading the cars. In some cases the slack or small coal is shoveled into the bottom of the car and topped up with lumps. In some cases forks are used instead of shovels in loading, so that the slack and smallest coal is left in the mine.

In long wall, with strong roof, the cars are run along the working face on a temporary track, as shown in Fig. 974. Where the roof is very tender, so that the posts have to be set too close to the face to allow the passage of a car, small boxes or "buggies" without wheels are used, as these can be pushed along the face by hand to the end of the adjacent roadway and there loaded into the regular cars.

2186. MINE HAULAGE.—In the small country banks it is the common practice to push the cars to the mouth of the mine by hand, using wooden rails. The cars in such cases, of course, are small. In mines just opening or only working two or three men, each miner

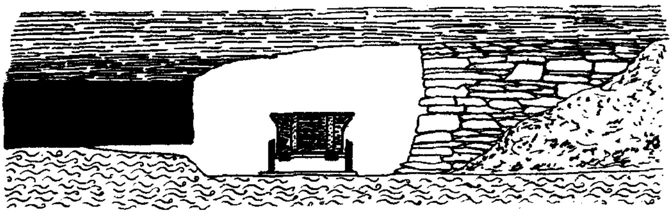


Fig. 974. Section at face in long wall mining with strong roof, showing position of track, gob wall, etc.

usually pushes his own car out. When the number of miners reaches say five or six or more, one man, or, if the grades are light, a boy, is employed to push the cars out. As mining advances, or with a larger number of miners, mules or horses are introduced, the mule being the common animal. This system expanded becomes the system in common practice in a majority of the larger mines. Where large cars are used, or with very heavy grades, one car makes a load. In other cases two cars make a load or "trip." These mules are usually driven and cared for by boys of from fifteen to twenty, known as "drivers." In some cases the mules stay in the mines continuously; more commonly, however, they are brought out each night, as they are found to do better by this practice, especially in keeping their eyesight. They are either lowered on the cages or enter the mine through the inclined manway, a separate division of that being prepared for them. Reference has already been made to the "trappers," boys whose duty it is to open and close the ventilating doors. Mention has also been made of patent self-opening doors. The rail used is usually a light iron T-rail, with wooden rails in the rooms. Turnouts or "double partings" are placed at convenient intervals to allow the passing of full and empty cars.

Three methods of power haulage are used in this State, viz., first, tail rope; second, endless rope, and third, electric.

2187. TAIL ROPE HAULAGE.—This system is the one in the most common use. See Fig. 975. In this system the cars are hauled to the foot of the shaft or mouth of the mine by a heavy wire rope, known as the "main rope," and the empties hauled back by a lighter rope known as the "tail rope." The hauling engine has two drums and is usually placed near the foot of the shaft, as in the figure. The

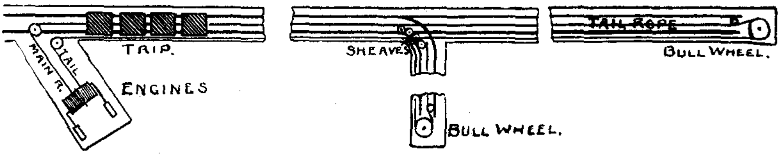


Fig. 975. Diagram showing working of tail-rope system of mine haulage,

tail rope is, as stated, somewhat lighter than the main rope and twice as long. It runs from the drum of the engine, at the side of the track, to the point at which hauling is done, where it passes around a wheel 4 to 8 ft. in diameter, known as the "bull wheel." When the trip is drawn out the tail rope is attached to the last car, serving as a brake if needed, and on the return it serves to draw the empty cars back. Tail rope haulage may be of almost any desired length, some hauls in Pennsylvania being as much as three miles long, though in this State most of the hauls are between one-half and one mile in length. Usually quite a number of cars are taken at each haul, ranging in this State from five to twenty-five. In some cases the coal is hauled from the cross entries as well as the main entry. In that case a joint is made in the rope opposite each of these cross entries, and an additional length of rope twice the length of the cross entry is used in each cross entry. Many ingenious devices have been brought forward to make a satisfactory coupling. In some cases, though not in this State, an engine is placed at each end of the haul.

Mules are used to draw the cars to the double partings, where the trips are made up. A suggestion from the practice at the Loyal Hanna mines, to which the writer's attention was called by Mr. McKinny, may not come amiss. It is there the practice to make a double parting in the main entry just beyond the last cross entry in which rope haulage is installed. Until work has been driven forward and the haulage system perfected in the next cross entry all the coal mined beyond this point is brought to this double parting. A partial trip is made up, and to the front car is attached a wire rope as long as the trip to be hauled out of the adjacent entry. As the trip being hauled out of that entry approaches the main entry it runs slowly and as it reaches the main entry the end of the wire rope just mentioned is attached to a hook in the front car. In this way the partial trip in the main entry is added to the trip in the cross entry without stopping the latter. The tail rope is transferred from the last car of the cross entry trip to the last car of the main entry cars. The engineer is signaled by means of wires running beside the track and within reach of the driver in charge of the trip.

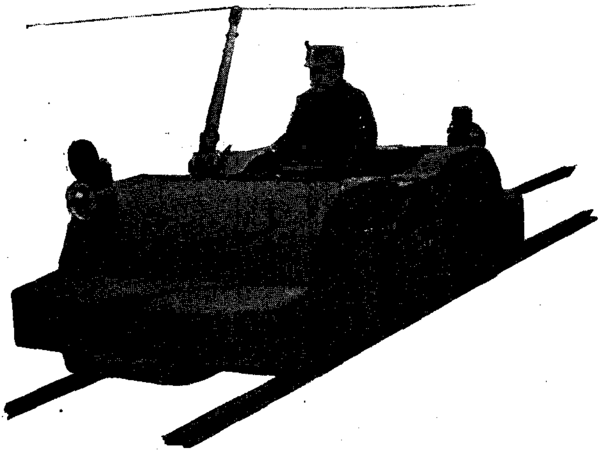
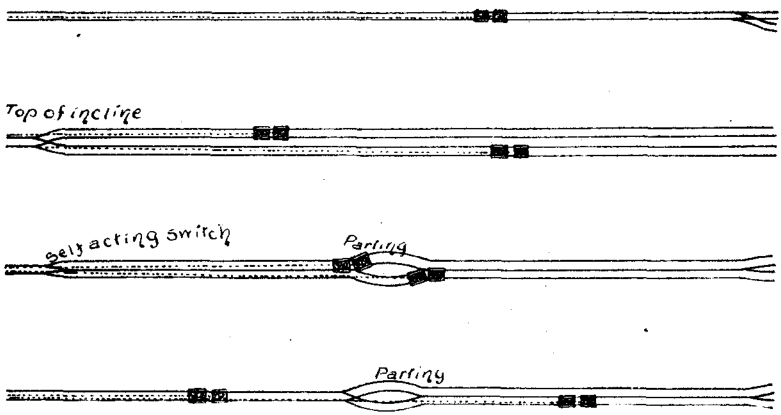


Fig. 976. The Jeffrey's electric locomotive, for use in the mines.

2188. ENDLESS ROPE HAULAGE.—As ordinarily understood, there are no endless rope haulage plants in this State. The nearest approach to it is at the Brazil Brick and Pipe Works' slope (see Plate LXXXII). This differs from tail rope only in that instead of winding the two ropes up on a drum, one rope is used which is given a turn around a large grooved drive wheel, and is driven in alternate directions according as the trip is going out or returning. It has the usual advantage of an endless rope of requiring one-third less rope and also the disadvantage of an endless rope of being always taut, much of the wear resulting from that fact.

As usually understood, endless rope haulage supposes a single taut rope running continuously in one direction. Two entries are required for the haulage, the full trips being drawn out one entry and returning through the other. The system is similar to that in use with cable street cars in some of the large cities, modified to meet the special conditions.

2188a. Electric Haulage.—Electric haulage is in operation in the Brazil Block No. 1, Hymera, Mecca and other mines. The principles of electric street car haulage are adopted, modified to suit underground conditions. Fig. 976 gives a view of a Jeffrey motor. The trolly arm is of course very short and is placed on one side of the motor, the trolly wire being usually placed over one of the rails. The main advantage of electric haulage is that the system can readily be extended to any part of the mine and can keep pace with the advancing face. As the motor can also be used much as a switch engine, with a little care, there is a gain in that direction.



Figs. 977-980. Plans of tracks used in slopes.

Electric haulage appears to be gaining in favor, especially where used in connection with electric mining machines, electric drills, electric pumps, etc. In order to shorten the haulage of the coal, a system of radiating entries has been used in the Brazil Block Coal Co.'s No. 8 mine. The plan of this mine was prepared by Mr. P. J. Mooney, and it is reported to have proven very satisfactory, it having been found to have many other advantages besides the one mentioned. See Plate LXXXVIII, p. 1473.

2189. Hoisting by Slopes.—In slope mines the coal is drawn up an inclined way, usually by steam. In some of the small mines horse power is used, when they are known as "gin mines." To an upright drum is attached a long heavy arm, and a horse attached to this is driven in a circle, winding up the rope on the drum. In a few cases a windlass and hand power are used. While resembling rope haulage in many respects it differs in these: Usually the haul is comparatively short, one rope usually being used, the grade generally being sufficient to carry the cars back and drag the rope after them. In Figs. 977 to 980 are shown some of the plans of tracks. In some cases just a single track is used. Such a slope is very slow unless the grade be so light that many cars can be handled at a time. More often the track is made double all or part of the way, or at least has a "turnout," so that cars going up can pass others going down, as shown in the figures.

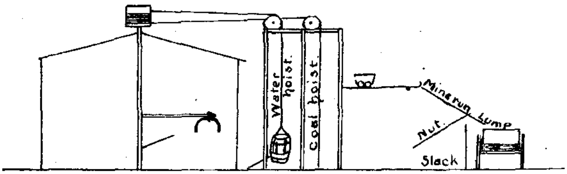


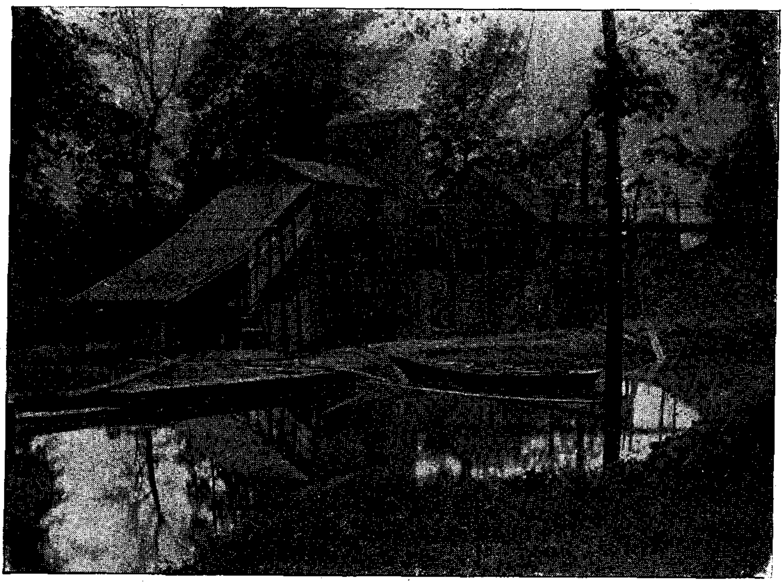
Fig. 981. Vertical plan of head works of typical "gin shaft."

2190. Shaft Hoisting.—It is interesting to trace the evolution from the crude box hoisted by windlass to large shaft equipments hoisting 1,000 tons or more a day. Thus at one end we have the crude wooden box holding perhaps a couple of bushels, and requiring a dozen trips to raise a ton, the shaft a square hole just large enough to allow the passage of the box. Then comes the "gin shaft," where horse power is used, and which may otherwise be like the other except that a little larger box is used.

Next the shaft is made double, and the rope, instead of winding up on the drum, is given a few turns on the drum and passes back to the other side of the shaft. At first it may be that there is a cage only in one side, and in the other a barrel for hoisting water. Next the box is replaced by a platform similar to that of a common freight elevator, upon which the boxes are placed. Or if cars have been adopted for the mine, tracks are laid on the platform or cage and the cars are pushed on to that, one cage rising as the other descends (see Fig. 981).

In the next case the horse gives way to a steam engine provided with a drum. The early engine may be a thrashing engine that hoists coal one part of the season, runs a thrashing machine during another, and runs a buzz-saw during another. Sometimes they are fitted up to hoist coal or saw wood as may be desired, by a shift in the belting. Next comes the regular single-acting hoisting engine, then the double-acting hoisting engine. By means of a cord or chain wound on the

Stock mine, northeast of Boonville, Warrick county.



St. Mary's mine, at St. Mary's-in-the-Woods, Vigo county.

PLATE LXXXIX. Types of well equipped "small mines" or "country banks," in Indiana.

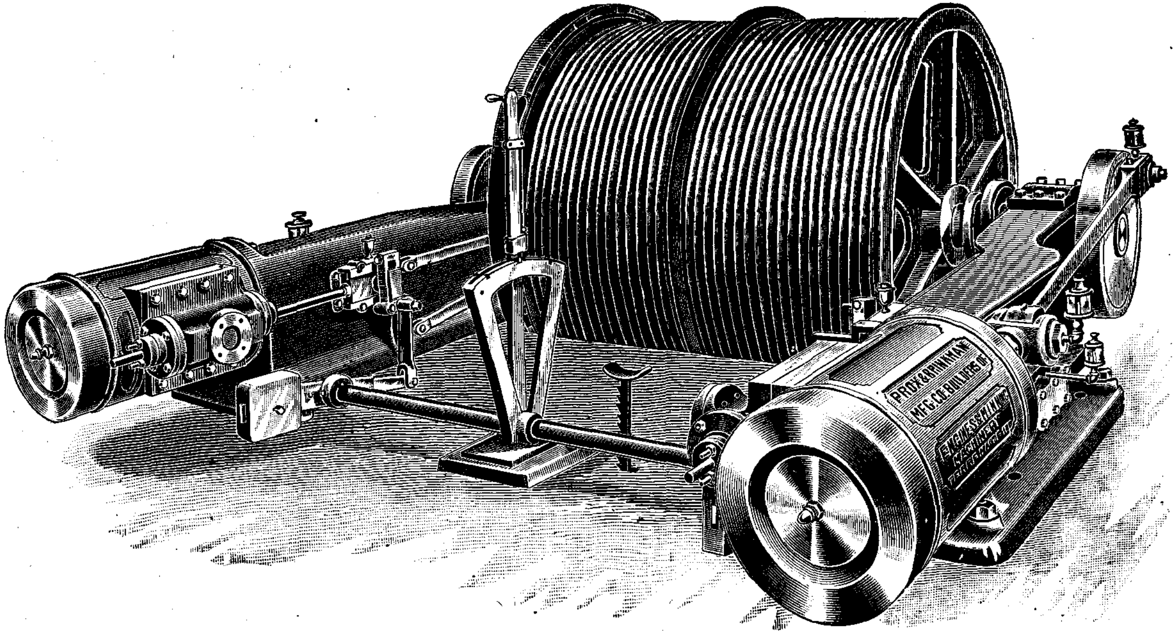


Fig. 982. Type of hoisting engine commonly used in Indiana. Kindness of Prox & Brinkman Manufacturing Company, Terre Haute.

axle, which raises or lowers a pointer, the engineer knows where the cages are. Improved dials and other pointers are also in use to a small extent.

The next improvement is in self-dumping cages. In the smaller mines the car is hauled off from the cage on to a platform, dumped and returned to the cage, or, sometimes, to save time for the cage, the platform is arranged so that as a full car reaches the top and is hauled off from one side, the car which preceded it, now empty, is pushed on from the other side; then, as the cage descends, the full car is emptied and pushed around to the opposite side of the shaft ready to be put on the cage as soon as it reaches the top. With the self-dumping cages, they are usually arranged so that, as the cage with the car which it holds fast approaches the top, a trigger or guide throws or allows it to fall forward, emptying the car of its load. See Plate XC. The starting of the cage downward throws the platform and car back into position. At the foot of the shaft is usually a group of "pit men," whose duty it is to load the full cars on to the cages and unload the empty cars. When the full car is loaded on to the cage the engineer is signaled by pulling a wire.

The law throws many safeguards about the shaft. Thus, requiring a certified engineer at the hoisting engine, the use of a prescribed set of signals, slow hoisting when men are on, not more than six men to ride at once, no one to ride on a cage when it is hoisting coal, the frequent examination of the rope, safety catches on the cages, gates at the head of the shaft and at any landings other than the lowest, a passage around the shaft if it is used from both sides, etc.

Where mining is carried on more extensively than in this State, double-deck cages are often used.

In this connection the writer is led to ask the suggestive question: Why could not, at least in some cases, the usual large and expensive hoisting shaft be replaced by a much smaller shaft through which the coal is hoisted by means of a conveyor? Such conveyors are already used on a small scale for elevating small coal at the tipples of many of the mines, and they can be and are made to do all kinds of heavy work.

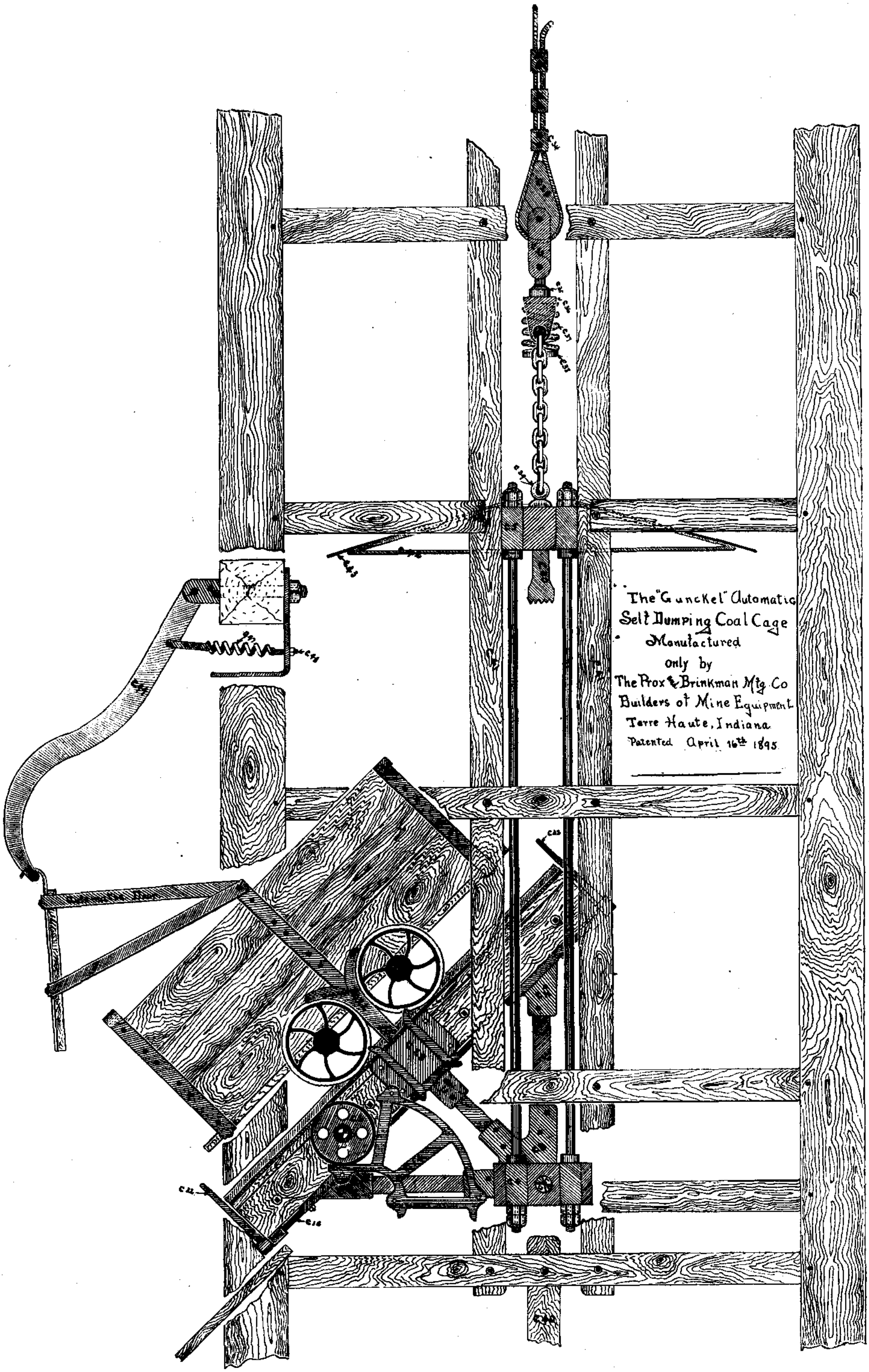


PLATE XC. Diagram showing action of one of the self-dumping cages used at many of the mines in Indiana. Kindness of Prox & Brinkman Manufacturing Company.

XLVI. PREPARING COAL FOR MARKET AND MARKETING IT.

2191. Screening the Coal.—While for some purposes the coal is used just as it is mined, known as run-of-mine, as a rule it is desired by the trade sorted according to size. This is accomplished by screening. In the smallest mines this is done by the use of tined forks instead of shovels or by sticks nailed lengthwise on a frame an inch or two apart, and that being set up at an inclination, the coal is

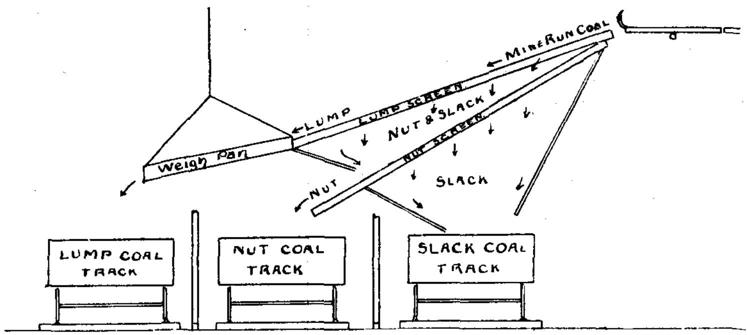


Fig. 983. Diagram showing manner of screening and delivering coal to cars in ordinary practice in Indiana.

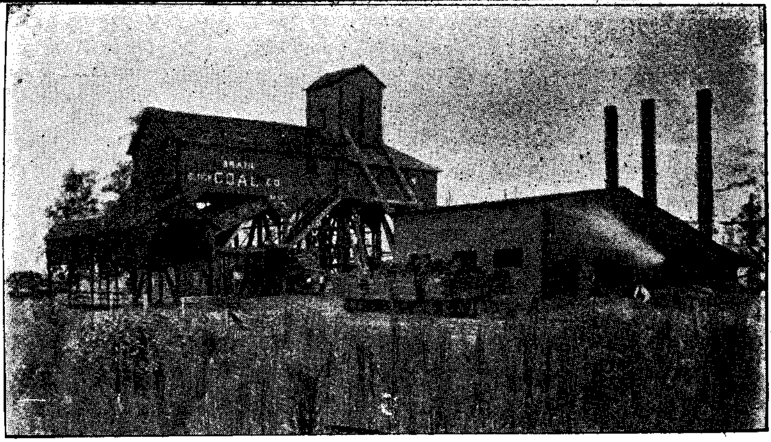
dumped over it, the finer coal passing through, being known then as screenings or slack. It is then but a step to the use of iron bars set a standard distance apart. In common practice two sets of bars are used separating the coal into three sizes. The first set of bars are set one and one-fourth inches apart, and all coal that passes over them is known as "lump coal." The coal that passes through then falls on another set of bars placed three-fourths of an inch apart. The coal that passed through the first screen but over the second is known as "nut" coal. What passed through the second screen is known as "screenings" or "slack." The arrangement of these screens and the way the coal is delivered to the cars is shown in Fig. 983.

As the screenings not only separates the coal into different sizes, but to a certain extent serves to separate the smaller pieces of shale ("slate") and pyrite ("sulphur"), it is becoming more and more a matter of economic importance that this screening be done as well as possible. This has led to the introduction of improved screens.

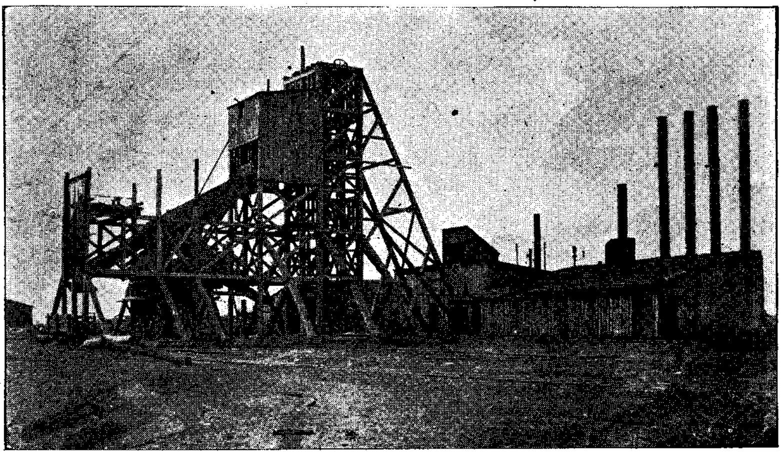
In this State these screens are of two kinds, shaking and revolving. In the shaking screens they are suspended near the ends by short rods with freedom of oscillation, and a slight shaking motion is given them by a small engine through the medium of eccentrics. Various devices are resorted to to counterbalance the motion and to prevent the shaking of the frame work or building. In the revolving screen the screen is made in the form of a cylinder arranged to revolve in a nearly horizontal position, the coal being delivered at one end of the cylinder and what is too large to pass through the mesh passes out at the lower end. The revolving screens are used especially in separating the smaller sizes of coal. With the shaking and revolving screens only a small angle from the horizontal is required, and the coal is delivered to the cars in an almost steady current. These screens are usually made of punched sheet iron. By these screens, by a simple change of plate, there can be obtained a considerable range of sizes. Thus, the coal may be delivered all over 6 in. or over 4 in.; over 4 and under 6 in., etc.

In common practice the coal cars are carried by the cages to a height of 25 or 30 ft. above the ground, where they are drawn off by hand on to a platform, then pushed forward a short distance to a short tipping platform, which, being supported on an axle, allows the car to swing forward and empty its load over the screen. This platform, the tipping platform, screens and weighing apparatus are all usually enclosed, and form together what in this State is commonly known as the tipple. Where self-dumping cages are used the platforms are not needed.

2192. Weighing the Coal.—By legal enactment the coal is required to be weighed run-of-mine. The statute having been found invalid by the supreme court, the usual practice is to weigh only the lump coal. It is, of course, understood that the miner is paid according to the weight of coal sent out by him. Each miner has a number, and when he sends a car out he hangs a metal tag with his number on a hook on his car. In some cases the coal is weighed before being dumped, platform scales being placed in the way between the top of the shaft and the tipping table. In other cases where self-dumping cages are used and it is desired to weigh run-of-mine, the coal is first dumped into a weighing pan suspended from a scale beam. After being weighed the end is raised and the coal allowed to pass on down over the screens. Probably the most common method is to have the suspended weighing pan at the bottom of the first screen, so that it receives all of the lump coal, which, being weighed, is allowed to run



Brazil Block Coal Co.'s shaft, No. 5, at Cardonia, Clay county.



Harrison mine, at Hymera, Sullivan county.

Brazil Block Coal Co.'s shaft, No. 1. (See Plate LXXXI.)

PLATE XCI. Types of head works of shaft mines in Indiana.

into the car. Still another method frequently used is to have the car for lump coal stand on a railroad platform, and as each mine car is emptied over the screens the added weight of lump is credited to the man whose number is attached to the car. The law gives the miners the privilege of employing one of their own number to assist in the weighing and serve as their representative to secure correct returns. He is known as the check weigh-man. It is also required that the scales be tested each morning.

2193. Washing and Cleaning the Coal.—Competition and a more exacting trade are constantly leading to better methods of freeing the coal from shale and pyrite. It is still true that in most of the mines the freedom of the coal from these impurities is secured first through the watchfulness of the miner in his room, he being expected to throw out any foreign matter found in the coal, and of what escapes him of the larger pieces much is thrown out by the man who attends to the loading of the railroad cars or "flats." With the shaking screens the coal passes slowly and gives a good opportunity for the removal of the shale. In rare cases boys are employed to pick over the coal as it passes over the screens.

The greatest proportion of impurity, however, is to be found in the smaller sizes of coal, and it is for the cleaning of these that the washer is introduced. This depends for its action upon the difference in specific gravity of coal and the foreign substances. Thus, Indiana coal will average in weight about 80 lbs. to the cubic foot, "slate" twice as much, and pyrite four times as much. If thrown into water all will sink. If, however, the water is rising, the coal will be kept at the surface, though the others will still sink, if the current be not too strong. In practice, in this State, a common form of washer consists of a hopper or inverted cone-shaped box, arranged so that water enters at the bottom and flows off at the top, thus producing an upward current of the required strength. The fine coal being carried by endless conveyors from the tipple is emptied on to the surface of the water in the hopper. As these start to sink, the upward current carries the coal back to the surface while the heavier impurities continue settling to the bottom, from whence, by means of valves, they are drawn off from time to time. The coal is carried off by the escaping water at the top on to a screen, which allows the water to escape while the coal is passed along. Then by means of conveyors it is carried to revolving screens, where it is separated into as many sizes as desired. From these it may be conveyed to bins, which serve for storage unless the demand is steady. In many cases the coal is crushed before going to the washer. Where water is scarce the same water is used over and over. In some cases the waste goes into a crusher, after which it is returned to the washer. In this way some of the coal which contains so much sulphur as to sink when first passed through is broken up so that the coal can be separated and a saving effected. (See Fig. 984.)

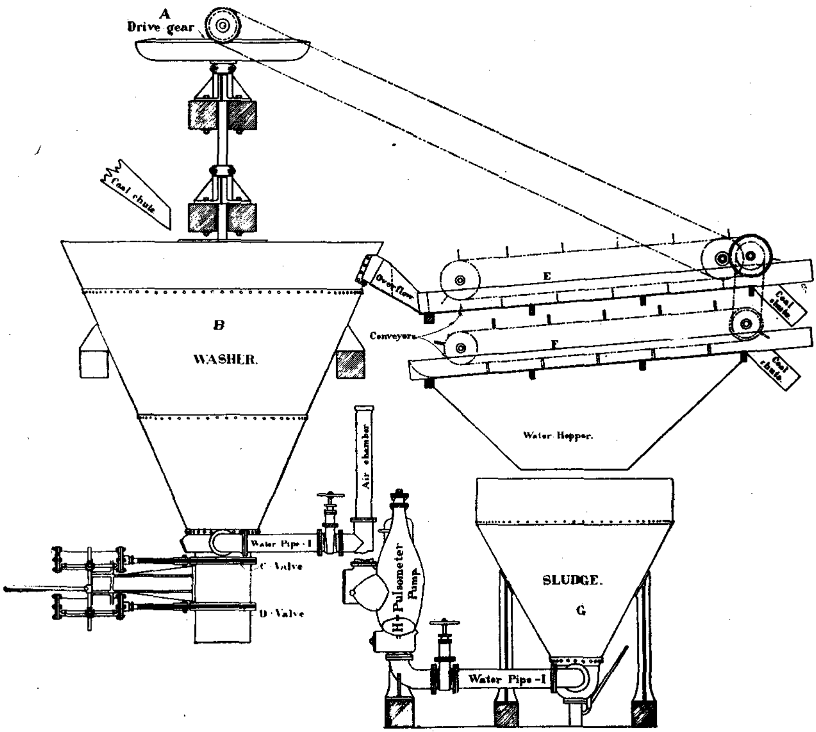


Fig. 984. Diagram of washing plant and accessories, illustrating the main features of the plant at Cox No. 3 mine. Kindness of the Jeffrey Manufacturing Company.

The impure caking coals, when crushed and washed, are found to answer many purposes for which it was formerly necessary to use the much purer block coal.

2194. Transportation from the Mines.—As a rule, the coal is loaded directly from the tipple into railroad cars. These hold 20 or 25 tons, the latter predominating. There is a tendency towards the use of greater and greater carrying capacity, so that cars holding 30, 35, 40 or even 50 tons are becoming common.

In some cases the mines are situated close to the main track of some railway, and a very short switch is all that is necessary. In other cases the mines are situated eight or ten miles from a railway, and switches have to be built. Usually switches to single mines are not over three or four miles long. Where a group of mines can be reached or approached by a single switch, and the conditions seem to warrant a large output, long switches are used. Thus, the Stringtown, Fountain county, mines were reached by a switch from Danville, Ill., which had to cross the Wabash river. Of the longer switches may be mentioned the New Pittsburg switch, or "branch," in Sullivan county; the Caseyville branch in Vigo, Clay and Parke counties; the Center Point branch, in Clay county; the Linton and Dugger branch, in Greene and Sullivan counties. These range from five to twenty miles long. It is a common practice for the railway company to furnish the rails, while the mine owners furnish the ties and grade the proposed switch. There are usually three and sometimes four tracks under the tipple, unless it is a double one; that is, one that loads on each side to switches from different roads, when there are more. The empty cars are run past the tipple, and run back under the tipple by gravity, as they are wanted. A few of the coal companies own or lease locomotives to do the switching about the mines. Such locomotives are either old engines leased from the railroad company or "pony" engines obtained for the express purpose.

As a rule, the railway company furnishes the cars and does the switching; in a few cases the mine operators have owned the cars used.

In some cases coal is drawn to the railway from the mine in the mine cars. About half a mile is the longest haul of that kind observed.

Lack of railroad transportation is the one element that perhaps more than any other prevents the development of many of the mining regions of the State. In some few cases these are not far from railroads, but are so placed with reference to surface topography that the natural difficulties attending the building of a switch at that point have hitherto prevented the undertaking. In other cases these areas are at some distance from the railroad. In either case the suggestion is made that connection might be made by means of an electric tramway. As is well known, an electric motor can climb hills or take curves entirely impracticable to an ordinary locomotive. Such a tramway could therefore be built at a small part of the cost of a standard gauge switch, and in places impracticable for the latter. Such electric haulage might be but an expansion of haulage system in the mine, or it might be limited entirely to outside haulage. Where the haul is a long one, a group of mines may be served, and during the dull season, merchandise and farm products might help out on the cost of operating the road, or, if it is independent of the mines, as an additional source of profit. In Pennsylvania the mine cars are often drawn from one to five miles before being emptied, steam mine engines often supplying the power.

XLVII. UTILIZATION OF WASTE PRODUCTS.

2195. Manufacture of Fuel Gas.—Under the head of utilization of coal is discussed the manufacture, transportation and utilization of fuel gas, and the conclusion is there reached that, with the methods now being introduced, gas making for fuel purposes can be successfully carried on in the Indiana coal field for the supply of the rest of the State. If so, the problem of utilizing all of our friable coals would seem to be largely solved. With most of our coals it is doubtless true that they will require washing before using for this purpose.

2196. Coking.—This has also been discussed under the head of utilization of coal, which see.

2197. Briquette Making.—Of the mines of the State having more fine coal or slack than can be disposed of, many find that such slack will not produce a marketable coke, and many of the block and semi-block coals will practically not coke at all. A method of utilizing such coal would seem to be by making it into briquettes.

Briefly, this consists in grinding the fine coal in specially prepared machinery; then in washing this fine material; then in cementing it with different substances, one of the most successful being a mixture of tar, oleine and soda; others are pitch and magnesia cement; 100 or 200 lbs. of such a mixture is added to a ton of wash slack or culm, the mixing being very thoroughly done by a sort of pug-mill at a suitably high temperature, and the whole then pressed into brick-like or small blocks, or into ovoid or egg-shaped eggettes. The hydraulic press principle is used in producing most of the cubical, oblong or irregular forms. The eggettes are produced by running the material between heavy rolls whose faces have corresponding semi-oval shaped cavities. Briquettes are extensively made in Europe, though only to a small degree in this country. Some of their advantages are that a greater weight can be neatly packed in a given space, can be easily handled, stored or transported. When properly made, they produce no smoke in combustion and but little ash, and for domestic purposes have many of the advantages of anthracite coal.

Briquettes usually make a hotter fire than coal. They are successfully used in the production of gas, producing a much richer illuminating gas than is generally made from coal, and that notwithstanding the cheap and inferior material used. The suggestion is made, though I do not know of its having been tried, that the non-caking coals which we are especially discussing, when treated with tar or some such mixture as mentioned above, might produce a desirable coke. Experiment with anthracite culm is found to make a stronger coke than any other coke.

The chief advantage of briquetting in this State, however, would seem to be as a method of utilizing what otherwise might be wasted and to compete with anthracite for domestic use.

2198. Powdered Coal.—A method of utilizing fine coal which is proving very successful with anthracite culm is to grind it to a powder and feed it into the furnace through a pipe, mixed with air in a blast. This does away with grates, opening and closing furnace doors, with the cooling which results, and where properly prepared, secures very complete combustion of the coal. This is offset to a greater or less extent by the cost of grinding the coal to a dust.*

This coal dust has also been successfully utilized in burning brick by kneading with the clay, whereby a considerable saving is effected in amount of fuel used and in the time of burning.

2199. Utilization of Under-Clay or Shale.—The great increase of late years in the usage of clay products—as in paving brick, roof tile, hollow tile for building—makes suitable clays and shales marketable articles. Such clays sometimes sell for almost as much as the coal. In many mines it is necessary to take up a foot or two of the underlying clay, the handling of which, particularly if it has to be taken from the mine, may involve considerable expense, as well as greatly reducing the efficiency of the shaft. It might, therefore, pay well to have tests made of the clay as to its suitability for the manufacture of some clay product. In this connection it should be remembered that very different qualities are demanded for clays used for different purposes. Thus, a clay that was shown by test to be undesirable for vitrified brick, might prove very desirable for tile. Often

*Combustion of Coal, W. M. Barr, p. 239; Indianapolis, 1879.
Science, Dec. 28, 1888.
Ann. Rep. of Chief U. S. Bureau of Steam Engineering for 1876.

something that may be lacking in the clay may be easily supplied by mixing a small quantity of some other clay with it. Thus utilized, it will usually not only pay for its removal, a clear saving, but will also pay for its preparation and marketing, with a profit besides.

Many coal beds of excellent quality which are too thin to work by themselves will become available if worked in connection with their accompanying clay or shale.

2199a. Utilizing the Bituminous Shales or Bone Coal.—A large number of the coal beds have closely associated with them black bituminous shale, or less often bone coal. A few of the beds are almost invariably overlain by from one to several feet of the bituminous shale, while bone coal one or two feet thick often underlies or overlies certain coal beds over large areas. Such shales or bone coal are usually rich in gas, if distilled at a high temperature, or in oils if distilled at a low temperature.

In 1895 a test was made at the New Albany gas works of the black shale of Devonian age occurring there. The gas obtained was richer than from Pittsburg coal, and the yield 45 per cent. as much. An analysis of the black shale at New Albany by Mr. Hans Duden showed:

Volatile organic matter	14.16
Fixed carbon	9.30
Water	.50
Ash	76.04

Analyses of the bone (cannel) coal or roof shales overlying some of the coal beds, by Mr. Cox, show as follows:

Volatile organic matter	25.00	32.00	25.00
Fixed carbon	28.00	34.00	39.00
Water	5.50	7.50	4.00
Ash	41.00	26.00	32.00

An examination of these analyses shows about double the percentage of gas that was found in the New Albany shale, and from three to over four times the amount of fixed carbon, with correspondingly low amounts of ash.

Such shales, to be economically employed, would require specially designed and constructed plants, and would, of course, yield no coke. Analyses would indicate that in such specially prepared plants as used in some parts of Europe a ton of some of these bone coals would yield as much gas as a ton of Pittsburg coal, and of much higher illuminating power, the reduced cost of material more than offsetting the value of the coke now produced. This, of course, is largely an assumption, based on what is or has been done elsewhere, and has yet to be proven for this field. It is, however, given as a suggestion which might lead to the utilization of what is now a waste product at the mines. It is also possible that the coke left in the process might be used in the manufacture of producer or water gas.

XLVIII. THE FINANCES OF COAL.

James Epperson and George H. Ashley.

NOTE.—The major part of the labor of this chapter, that of collecting the data, is principally the work of Mr. Epperson. It had been expected that he would also arrange the matter collected, but it was found that, with his other work, it would be impossible to have it ready when the rest of the report went to press.—G. H. A.

2200. The various items to be considered may be taken up under the following heads:

I. Cost of coal in place.
II. Cost of opening and equipping mine.
III. Labor cost of coal at the mine.
IV. Operating materials, etc.
V. Office expenses.
VI. Summary of cost of coal on car at mine.
VII. Selling price at mine.
VIII. Cost of transportation.
IX. Selling price at important points.
X. Summary of cost of a ton of coal.
XI. Outside items.
XII. Earnings of miners.

I. Cost of Coal in Place.

2201. (a) Royalty Paid in Different Parts of Indiana.—The value of unworked coal in the ground is usually taken as the royalty paid for it when extracted. This varies greatly at different places and has shown a steady tendency to decrease. In the early days of the block coal field much coal was worked on which a royalty of 20 cents a ton was paid. Mr. Cox, in his report on Clay county, p. 61, in estimating the value of block coal, valued it at 1 cent a bushel, or 25 cents a ton. Whether such a valuation was based on royalties paid, he does not state. In his report on Greene county, and in Mr. Collett's report on Sullivan county, they give ½ cent a bushel, or a shilling a ton, as the royalty then paid in those regions. Some of the mines in the same area to-day are paying from 3 to 5 cents a ton mine run. A shilling a ton is still not an uncommon royalty for small mines, but at present few of the large mines pay over 10 cents a ton. While exact data were not obtained, it is probable that the major part of the coal mines under recent leases does not pay over 5 or 6¼ cents a ton of screened coal. In the south part of the State royalties even run below that, perhaps the lowest noted being in Gibson county, 3 cents a ton of screened coal. In Pike and Warrick counties, 3⅓ cents a ton, equivalent to ⅛ cent a bushel of mine run coal, is often the royalty, some of the mines, however, paying double that. The former royalty ten or twelve years ago, according to Mr. Woolley, was from ⅜ to ½ cent on mine run coal.

2202. (b) Value of Coal Lands.—No reliable rule can be laid down as to the value of coal lands, nor were sufficient data obtained to show how coal lands vary in price over the field. In a general way, lands that sell for from $30 to $60 an acre without coal will sell at from $40 to $100 an acre where known to be underlain with coal. But many factors influence this. Lands at some distance from railroads or working mines may often be obtained very cheaply, as at $25 an acre or less, while coal lands adjoining properties being worked may be held at a very high figure. When it is recalled that an acre of ground containing a 5 ft. bed ought to yield at least 6,000 tons of coal, which at 5 cents a ton would give a royalty of $300, or at 10 cents a ton a royalty of $600 an acre, it is evident that lands that seem bound to be worked within a very few years are often held for a large fraction of the estimated royalty on the coal under them.

In general, it may be safe to say that on the average the owner of the coal is paid 4 or 5 cents a ton.

II. Cost of Opening and Equipping Mine.

2203. It has not been possible to get estimates for all the items that come under this head. As suggestive of some of the more important expenses to be met, the various items that have occurred to us are mentioned, and where figures have been obtained they will be given.

2204. (a) Cost of Drilling, Surveying, Locating Lands, Recording Deeds, Leases, Etc.—This preliminary work varies greatly in cost. There are many cases in Indiana where entries have been driven or shafts sunk without any preliminary drilling, and in such cases the cost of these items has been merely nominal. On the other hand, most of the older companies have found as a result of their experience that money expended for such preliminary exploration generally gives very high returns. Mr. Hamilton Smith, in a letter published in the State Agricultural Reports for 1856, in speaking of the operations of the American Cannel Coal Company at Cannelton, says: "This does not include the expense attending surveys, experimental shafts, borings, levelings and engineering generally, wherein this company have expended at least twenty-five thousand dollars, from first to last, and perhaps have lost more than that sum by not employing competent coal viewers and making the necessary preliminary examinations at an earlier period." Further on he mentions cases of losses due to these causes. In one case, after $20,000 had been expended, it was found, after a month's work, that the coal could not be worked for lack of suitable roof.

2205. (b) Cost of Land for Surface Plant.—Whether the coal to be worked is leased or purchased, it is usual for a coal company to own the land upon which is situated the shaft and other buildings, comprising what is known as the surface plant. It may be safe to say that from five to ten acres are usually owned for such a purpose. Some plants located next to a right of way to a railroad may often get along with much less. Land for this purpose may then be reckoned at from $200 to $1,000. In some cases the land is given by the owners of the coal, in order to have the coal worked.

2206. (c) Cost of Lease of Right of Way for Switch.

2207. (d) Cost of Sinking Shaft.—In a general way, it may be said that the cost of sinking the shaft will run from $5 to $50 a foot. At one of the mines over 100 ft. deep the labor cost $11 per foot.

Where the work is done by the day the cost will generally depend on the character of the rock gone through. The surface material, while easier to sink through in some ways, generally requires immediate timbering, and this adds to the time required and expense. Where the ground is fairly dry and solid, the shaft timbers, perhaps 10 by 12 in., may be set from 1 to 3 ft. apart and lagged behind with 2 in. plank. Where the ground is soft and wet, the timbers require to be set skin to skin, and in some cases it has been found necessary to put a shoe on the lowest timbers, sinking them in the method usually adopted for sinking caisson. Such soft ground usually increases the cost of sinking to a considerable extent, and when combined with large bodies of water, has in several cases in this State led to the abandoning of shafts partly sunk and the selection of new sites. Where a shaft encounters considerable water it may be necessary to sink small auxiliary shafts into which the water may be led from the main shaft, and from which it may be pumped. These items are mentioned as showing a few of the additional items of expense that may not be calculated upon in first estimates. The writer recalls cases in this State where peculiarly hard rock has been encountered, and shafts are said to have cost over $40 a foot for short distances. In a general way, it may be safe to count on the sinking, timbering and setting of guides of a shaft to average about $20 a foot. Mr. Hamilton Smith, writing from Cannelton in 1856, says: "For shafting and purposes of ventilation or proving coal, we usually pay $1 per foot for the first thirty feet, increasing 50 cents every ten feet."*

2208. (e) Sinking Air Shaft and Escape.—In this, much the same conditions have to be met, except that the shaft is smaller, and as it is frequently not dug until the mine is in operation and equipped with pumps, etc., it is sometimes possible, by drilling to the workings below, to draw off any water encountered without so much difficulty as in the first shaft. One such an air shaft, 5 by 7 ft., was sunk to between 200 and 300 ft. at a contract cost of $8 per foot. At another mine a 50 ft. air shaft and manway cost $4.50 a foot. Occasionally tunnels are used in mines working two beds; one such, 120 yds. long, cost $1,000.

2209. (f) Erection of Tipple and Equipment.—This should include tipple frame and cover, braces, sheaves, screens and weighing pans, scales and scale houses. The only estimate at hand is one made by Mr. Carrol, which gives the cost of "tipple, blacksmith shop, etc.,"

*Indiana Agricultural Reports, 1856, p. 538.

at $1,300. It is not known just what items this will include and what not. If improved screens are used, the cost will, of course, be much higher. Mr. Carrol estimates shaking screens in two sections with eccentrics set on driving shaft 180° apart, to counteract vibration, and having a 5 in. stroke, with engine complete, about $1,250. This may also include revolving screens, conveyors or elevators, etc.

2210. (g) Scales will vary from $75 to $1,000 for the more expensive railroad scales. At one of the mines the screens and scales cost close to $200. At another mine scales alone cost $250, while railroad scales are quoted at from $700 to $1,000.

2211. (h) Cages.—These vary greatly, from the simple platform built by the mine blacksmith and carpenter to the more elaborate and expensive self-dumping cages. (See general estimate.)

2212. (i) Boilers and Housing.—Mr. Carrol estimates the cost of four plain shell boilers 40 in. by 30 ft., with house and brickwork complete, at $1,500. To this should be added pond and piping for water supply, tracking from shaft for coal supply, etc.

2213. (j) Hoisting Engines, Cables, Etc.—Mr. Carrol's estimate for hoisting engine, ropes, self-dumping cages, including engine foundation, is $2,800. A double hoisting engine at one of the mines cost $1,200. In another case a 40 H. P. single engine cost $300.

2214. (k) Blacksmith Shop and Accessories.

2215. (l) Powder House.

2216. (m) Fan and Engine, Fan House.

2217. (n) Pumps and Piping.—At one of the mines two pumps cost, respectively, $165 and $190. At one of the mines using six pumps in and around the mine, two of these cost $1,000. In another case a duplex mine pump, 7 by 4 by 10, is quoted at $136.

2218. (o) Switch to Connect with Railroad.—Grading and ties usually furnished by mine operators, and often rails, the latter, and sometimes the former also, to be returned in rebates on shipments. Making cuts and fills will vary from 10 cents to $1 a yard, according to material and conditions. In one case a switch 1,100 ft. long, on very level ground, cost $190 for grading, and ties $200.

2219. (p) Mine Cars.—Mr. Hamilton Smith gave the price of 20-bushel cars in 1856 as about $25. At one of the mines using 150 cars for a daily output of 350 tons the cars cost $22 each, or $3,300 for the mine. At another mine, with an output of 250 tons a day, 40 cars are used, costing $17 each, or $680.

2220. (q) Mules and Stables.

2221. (r) Equipment with Mining Machines.—See general estimates.

2222. (s) Equipment of Power Drill.

2223. (t) Equipment with Rope or Electric Haulage.—See general estimates.

2224. (u) Equipment with Washing Plant.

2225. (v) Equipment of Storage Bins.

2226. (w) Fencing, Telephone to Main Office, Etc.

2227. (x) Equipment of Main Office.

2228. (y) Company Store and Stock.

2229. (z) Estimates of Cost of Opening Actual Plants.—........ mine, shaft about 50 ft. deep, average equipment, pick mine, bar screens, mule haulage; cost of tipple, machinery and sinking shaft, a little over $14,000.

.... mine, shaft about 50 ft. deep, well equipped for large outputs; mining machines, improved screens, self-dumping cages, etc., etc.; machinery estimated to have cost, when new, $10,000.

.... mine, slope; tipple and machinery, about $18,000.

.... mine, shaft about 250 ft. deep, including air shaft, and all ready to ship coal, $32,000.

.... mine; electric equipment alone is given as costing as follows:

1 dynamo, 135 H. P., 250 volts, 400 amperes	$1,400
1 dynamo engine	1,000
2 motors at $1,200, 35 H. P., 7 tons	2,400
3 mining machines at $1,000	3,000
Belt and switch-board	300
1 fan, electric	125
1 pump, electric	125
Total	$8,350

This is in addition to:

1 double hoisting engine, 65 H. P.

1 single engine, 20 H. P., to run elevators to carry coal to boiler-room.

1 single engine, 35 H. P., for short rope haulage.

6 boilers, 10-ft. steam fan and engine, self-dumping cages, etc., etc.

Mr. Hamilton Smith, writing in 1856, says: "The cost of opening a coal mine by an 'adit level,' preparing the galleries and entries for delivery of say three thousand bushels daily, building inside and outside cars, purchase of mules and erection of necessary buildings, construction of railroads not over one mile in length, and all prepared for permanent and economic use, will range here on the Ohio river from say \$40,000 to \$60,000." (This does not include borings, surveyings, etc.)

2230. In 1897, 124 mines yielded a product of 4,078,085 tons of coal, which is estimated to represent an invested capital of \$1,600,000, or about \$12,000 as the average capital invested in each mine. Judging from such data as were obtained, this estimate is much too low. The data obtained suggest that to open and equip a mine with shallow shaft, simple but good machinery, for a daily output of 200 tons, will hardly cost less than \$10,000, and may cost much more; while to open a deep mine and equip it throughout with modern machinery may cost from \$50,000 up.

In 1897, it will be observed according to the estimate given above, one ton of coal was mined for every 37 cents of capital represented. At 6 per cent. this represents a cost of a little over 2 cents a ton. Taking individual cases, we find that the interest at 6 per cent. on investment runs from 2.6 cents per ton to 4.5 cents per ton, with an average of 3.7 cents. It would therefore seem safe to take 3 cents a ton as representing the interest on equipment.

2231. Costs of machinery, of course, are readily obtained from the manufacturers, to which must be added the cost of setting up, etc. To indicate how rapidly such items as the last mount up, the following itemized account of the cost of setting up a dynamo and engine is appended:

The pit for the engine foundation is 15 ft. long, 9 ft. wide, 7 ft. deep, and cost to excavate it	\$10 00
10,000 brick at \$5.50 per thousand, for engine foundation.	55 00
Freight on brick, \$12.50; sand, \$1; hauling sand, \$2; screening, \$2	17 50
Cement and freight	39 00
Masons and helpers	23 33
Unloading engine from car	8 50
Placing on foundation	4 00
Polishing engine	2 86
	\$160 19

The pit for generator foundation is 6 ft. long, 8 ft. wide and 7 ft. deep, and cost to excavate	$6 45
4,000 brick at $5.50 per thousand for foundation	22 00
Freight on brick, $5; cement and freight, $14...........	19 00
Sand, 50 cents; hauling sand, $1; screening, $1.........	2 50
Mason and helpers	10 08
Unloading generator from car........................	4 00
Placing on foundation, $2; polishing and sandpapering, $5.55	7 55
Total	$71 58
Setting up engine	160 19
Setting up generator	71 58
Total	$231 77

III. Labor Cost of Coal at the Mine.

2232. (a) For Narrow Work.—Before the coal can be regularly mined, there is always a certain expense for narrow work, entries and the necks of rooms. As the entries are constantly being extended and new rooms being turned, this becomes a regular source of expense, as not only is the coal paid for at the regular rates, but a given amount extra, known as yardage. At present, in the bituminous coal field, this amounts to $1.37 per yard for entries 7 to 9 ft. wide and down to 84 cents for 12 ft. entries for pick work, and for machine work 98 cents and 61 cents, respectively. The turning of rooms costs $3.30 for pick or 98 cents for machine mining, varying, of course, according to width or length. The amount of yardage differs greatly at different mines, but, figured down to cost per ton of coal of output, came, for the data at hand, to from 1.6 to 2 cents a ton. Perhaps the latter figure would be safe. This does not include tracking, etc.

2233. (b) Laying Track, Ditching, Brushing Roof, Etc.—This will be considered in connection with the subject of day labor about the mine.

2234. (c) Mining and Loading Coal.—In his letter in 1856, Mr. Hamilton Smith gives the following list of prices paid at that time at some points in Indiana and elsewhere:

Hawesville, Ky...........2¾ cents per bushel=68¾ cents a ton.
Uniontown, Ky...........4 cents per bushel=100 cents a ton.
Cannelton, Ind............2½ cents per bushel=62½ cents a ton.
Newburg (Warrick Co.?)...3½ cents per bushel=93⅜ cents a ton.
Brazil, Ind...............3½ cents per bushel=93¾ cents a ton.
St. Louis, Mo............4 cents per bushel=100 cents a ton.
Breck'ridge, Ky. (Cannel)..5 cents per bushel=125 cents a ton.

2235. At the time of the strike in 1897 the prices paid in Indiana were as follows:

BITUMINOUS.—Screened lump, generally 56 cents per ton, same as Ohio; over diamond bar screen, with 1¼ in. spaces between bars; bars mostly 1 in. square, set on edge.

In southern Indiana, flat bars 1½ in. between, as equivalent to 1¼ in. spaces diamond setting.

Run of mine price optional with operators, based on proportion of screenings.

Brazil Block.—Coal 3 ft. 1 in. thick and over, 66 cents per ton, lump; coal 2 ft. 10 in. to 3 ft. 1 in., 71 cents per ton lump; coal under 2 ft. 10 in., 76 cents per ton lump; over screens, 72 ft. superficial area, diamond bars, 1¼ in. apart.

Indiana day's work, nine hours.

2236. Following the strike a new scale was agreed upon, and, as that scale is still in force when this report goes to press, it may be well to give the agreements entered into at Chicago and subsequently at Terre Haute and Brazil. They are as follows:

THE AGREEMENT.

Contract between the Operators of the Central Competitive Coal Field and the United Mine Workers of America.

Chicago, January 28.

The following agreement, made and entered into in joint interstate convention in this city (Chicago, Ill.), January 26, 1898, by and between the operators and miners of Illinois, Indiana, Ohio and western Pennsylvania, known as the Pittsburg thin-vein district, witnesseth:

1. That an equal price for mining screened lump coal shall hereafter from a base scale in all the districts above named, excepting the State of Illinois, the block coal district of Indiana to pay ten cents per ton over that of Hocking valley, western Pennsylvania and Indiana bituminous district, and that the price of pick run of mine coal in Hocking valley and western Pennsylvania shall be determined by the actual percentage of screenings passing through such screen as is hereinafter provided, it being understood and agreed that screened or run of mine coal may be mined and paid for on the above basis at the option of the operators, according to market requirements, and the operators of Indiana bituminous shall also have like option of mining and paying for run of mine or screen coal.

2. That the screen hereby adopted for the State of Ohio, western Pennsylvania and the bituminous district of Indiana shall be uniform in size, six feet wide by twelve feet long, built of flat or acorn-shaped bar of not less than five-eighths of an inch surface, with one and one-fourth inches between bars, free from obstructions, and that such screen shall rest upon a sufficient number of bearings to hold the bars in proper position.

3. That the block coal district of Indiana may continue the use of the diamond screen of present size and pattern, with the privilege of run of mine coal, the mining price of which shall be determined by the actual screenings, and that the State of Illinois shall be absolutely upon a run of mine system, and shall be paid for on that basis.

4. That an advance of ten cents per ton of 2,000 pounds for pick mined screened coal shall take effect in western Pennsylvania, Hocking valley and Indiana bituminous districts on April 1, 1898, and that Grape Creek, Ill., and the bituminous district of Indiana shall pay 40 cents per ton run of mine coal from and after same date, based upon 66 cents per ton screened coal in Ohio, western Pennsylvania and the Indiana bituminous district, same to continue in force until the expiration of this contract.

5. That on and after April 1, 1898, the eight-hour work-day, with eight hours' pay, consisting of six days per week, shall be in effect in all of the districts represented, and that uniform wages for day labor shall be paid the different classes of labor in the fields named, and that internal differences in any of the States or districts, both as to prices or conditions, shall be referred to the States or districts affected for adjustment.

6. That the same relative prices and conditions between machine and pick mining that have existed in the different States shall be continued during the life of this contract.

7. That present prices for pick and machine mining and all classes of day labor shall be maintained in the competitive States and districts until April 1, 1898.

8. That the United Mine Workers organization, a party to this contract, do hereby further agree to afford all possible protection to the other parties hereto against any unfair competition resulting from a failure to maintain scale rates.

9. That this contract shall remain in full force and effect from April 1, 1898, to April 1, 1899, and that our next annual interstate convention shall convene in the city of Pittsburg on the third Tuesday in January, 1899.

Adopted.

For Illinois Operators—J. H. Garaghty and E. T. Bent.

For Indiana Bituminous Operators—Walter S. Bogle.

For Indiana Block Operators—C. B. Niblock.

For Pittsburg Thin Vein District Operators—J. C. Dysart, F. M. Osborne.

For Illinois Miners—J. M. Hunter and W. D. Ryan.

For Indiana Bituminous Miners—W. G. Knight and J. H. Kennedy.

For Indiana Block Coal Miners—J. E. Evans.

For Ohio Miners—W. E. Farms and T. L. Lewis.

For Pittsburg Thin Vein Miners—Patrick Dolan, Edward McKay.

For West Virginia Miners—Henry Stephenson.

Members National Executive Board U. M. W. of A.—Fred Dilcher, John Fahy, Henry Stephenson, Edward McKay, J. H. Kennedy and W. D. Ryan.

M. D. Ratchford, President U. M. W. of A.

John Mitchell, Vice-President U. M. W. of A.

W. C. Pearce, Secretary-Treasurer U. M. W. of A.

TERRE HAUTE AGREEMENT.

The following agreement, entered into in the joint State convention at Terre Haute, Indiana, March 26, 1898, by and between the bituminous operators and the miners of the State, witnesseth:

First. That the declaration of the contract by and between the operators of the competitive coal fields and the United Mine Workers of America, entered into at Chicago, Illinois, January 27, 1898, and at Columbus, Ohio, March 10, 1898, be, and hereby are, reaffirmed in the identical terms therein employed.

Second. That further details and scale of prices for pick and machine mining in the State of Indiana, for one year beginning April 1, 1898, shall be as follows:

PICK MINING.

Yardage.

In entries 7 to 9 ft. wide	$1 37
In entries 12 ft. price shall be ⅝ of narrow work, or	84

Wide entries shall not exceed 13 ft., it being understood that this applies to entry work only, and not to rooms where it is necessary to run them 13 ft. wide.

Breakthroughs.

Breakthroughs in entries shall be paid for at entry price. Breakthroughs between rooms, when sheared or blocked, shall be paid for at entry price, but no breakthroughs shall be driven without the consent of the operator. Nothing herein shall interfere with strict compliance with the law governing breakthroughs.

Room Turning.

Room turning	$3 30

Room necks to be driven 12 ft. in and widened at an angle of 45° when so desired by operator. Any distance in excess of above shall be paid for proportionately.

MACHINE WORK.

Yardage.

In entries 7 to 9 ft.	$0 98
In entries 12 ft. wide, ⅝ of price for narrow entries, or	61

When the machine runners in 12 ft. entries are paid by the day, and entry is not sheared, the shooters and loaders shall be paid two-thirds of the yardage. It is understood that this applies to entry work only, and not to rooms when it is necessary to run them 13 ft. wide.

Breakthroughs.

Breakthroughs between entries, same as entry price.

Room Turning.

Room turning.. $0 98

Room necks to be driven 12 ft. in and widened at an angle of 45° when so desired by operators. Any distance in excess of the above shall be paid for proportionately.

When room necks are driven 12 ft. wide, price shall be ⅝ of regular price, or 61 cents.

Day Work Punching Machines.

Machine cutting when paid for by the day shall be for—

Cutter	$2 35
Helper	1 85

Day Work Chain or Cutter Bar Machines.

When paid for by the day shall be—

Cutter	$2 35
Helper	2 11

It being understood that a day's work shall not be less than twenty-seven (27) cuts. All cuts in excess of twenty-seven (27) shall be paid for proportionately.

Price per ton for Machine Mining.

When paid for by the ton the price of coal mined with machines shall be three-fourths of the price paid for pick mined coal, or 49½ cents.

GENERAL.

It is further agreed that if any differences arise between the operators and the miners at any pit a settlement shall be arrived at without stopping of work. If the parties immediately affected cannot reach an adjustment between themselves, the question shall be referred to the President and Secretary of the United Mine Workers of America representing District No. 11, and the President and Secretary of the Coal Operators' Association of the same district, whose action shall be final; but no miner or operator interested in the differences shall be a member of said committee.

That where the coal is paid for mine run, or on screened coal basis, it shall be mined in a careful, workmanlike manner, and when loaded on the miner's car it shall, as nearly as possible, be free from slate, bone coal, sulphur and other impurities.

Payment for all labor shall be made twice per month, not later than the 10th and 25th of each month.

It is further agreed that the operators shall offer no objection to the check-off for checkweighman and for dues for the Federation, provided that no check-off shall be made against any person until he shall have first given his consent in writing to his employer. This applies to all underground day work, as well as miners.

The time of beginning work in the morning and the length of intermission at noon shall be considered a local question.

That these resolutions be compiled in the form of a contract and signed by the President and Secretary of the United Mine Workers of America representing District No. 11, and the President and Secretary of the Bituminous Coal Operators' Association of Indiana, that they be printed and a copy sent to each and every mine and posted.

In witness whereof, we have hereunto subscribed our names this 26th day of March, 1898.

W. D. VAN HORN,
President U. M. W. of A., District No. 11.

Attest: J. H. KENNEDY,
Secretary U. M. W. of A., District No. 11.

J. SMITH TALLEY,
President Bituminous Coal Operators' Association of Indiana.

Attest: J. W. LANDRUM,
Secretary Coal Operators' Association, State of Indiana.

CONTRACT.

Contract between the Operators, Miners and Laborers of the Brazil Block Coal District.

Entered into this 24th day of March, 1898, between the Operators' Scale Committee of the block coal district, and the Executive Board of the United Mine Workers of America, representing District No. 8.

First. That the declaration of the contract by and between the operators in the competitive coal fields with the United Mine Workers of America, entered into at Chicago, Illinois, January 27, 1898, be hereby reaffirmed in the identical terms therein employed.

Second. That the scale of pick mining price of 2,000 lbs. of screened block of the standard thickness shall be 76 cents from April 1, 1898, until April 1, 1899, with payment for low coal upon the following scale:

For all coal 3 ft. 1 in. and over	76 cents.
For all coal 2 ft. 10 in. and under 3 ft. 1 in.	81 cents.
For all coal under 2 ft. 10 in.	86 cents.

That the payment for all coal dug, and for labor performed, shall be semi-monthly within ten (10) days after the ending of each half month. It being understood, also, that the price for digging unscreened coal shall be an equivalent of the price paid for screened coal.

It is understood and agreed by both parties to continue work for the coming year, the same as has been done in the year just ending.

That the mode and manner of weighing this coal and the time for paying the same shall be, and remain for the coming year, the same as is now in force in this district.

It is also agreed on the part of the operators not to require the miners to put down their own road. Also to give each miner as near as possible an equal turn of cars, and not to allow the day hands to load coal on idle days. No miner shall be discharged or discriminated against because of his refusal to do work by the day when called upon by the pit boss.

It is also agreed not to require miners to load or clean falls unless they are caused by some fault of the miner not properly timbering his working place, or his having shot or otherwise caused his timbers to become insecure, in which case it will be the duty of the miner to put his place in good order again.

It is further agreed that if any differences arise between the operator and the miner at any pit a settlement shall be arrived at without stopping of work. If the parties immediately affected cannot reach an adjustment between themselves, the question shall be referred to the Executive Board of the United Mine Workers of America, representing District No. 8, and an equal number of operators, whose actions shall be final; but no miner or operator interested in the differences shall be a member of said committee.

That all narrow work or yardage be paid an average throughout the block coal district, proportionate to the advance in the price of mining.

That the hour to begin work in the morning shall be 7:00 a. m., with thirty (30) minutes' stop for dinner, and begin shooting at 3:30 p. m., from April 1, 1898, to October 1, 1898, and from October 1, 1898, to April 1, 1899, the mines shall start at 7:30 a. m., with thirty (30) minutes' stop for dinner, and begin shooting at four (4) o'clock

INSIDE DAY WAGE SCALE OF EIGHT HOURS A DAY.

The following resolution was adopted at the meeting of the scale committee of Interstate Convention at Chicago, January 28, 1898:

"Resolved, That two operators and two miners of each State meet at Columbus, Ohio, on the second Tuesday of March, or March 8, 1898, at the Chittenden Hotel, to formulate a uniform day work scale, based upon the district upon which the mining price is based."

In accordance therewith, the representatives of the various competitive districts met at the Chittenden Hotel, and agreed upon the following scale of wages and conditions to govern all inside day labor for the year beginning April 1, next, and ending April 1, 1899:

Inside Day Scale.

Track layers	$1 90
Track layers' helpers	1 75
Trappers	75
Bottom cagers	1 75

Drivers	$1 75
Trip riders	1 75
Water haulers	1 75
Timber men, where such are employed	1 90
Pipe men for compressed air plates	1 85
Common men in long wall mines in the third vein district in northern Illinois	1 75
All other inside day labor	1 75

The above schedule of day wages only applies to men in the performance of their labor, and does not apply to boys, unless they do and are employed to do a man's work.

That the eight hours a day means eight hours' work in the mine at the usual working places for all classes of inside day labor. This shall be exclusive of the time required in reaching said working places in the morning, and departing from the same at night.

Regarding drivers: They shall take their mules to and from the stables, and the time required in doing so shall not include any part of the day's labor, their work beginning when they reach the parting at which they receive empty cars; but in no case shall the driver's time be docked while he is waiting for said cars at the point named. But when the men go in the mine in the morning they shall be entitled to two hours' pay, whether or not the mine works the full two hours, but after the first two hours the men shall be paid for every hour thereafter by the hour, or for each hour's work, or fractional part thereof.

If for any reason the regular routine of work cannot be furnished inside labor for a portion of the first two hours, the operators may furnish other than the regular labor for the unexpired time.

This contract is entered into in good faith by both parties, and there is to be no deviation from it by the operators, miners or day laborers.

W. H. Zimmerman,
W. W. Risher,
M. H. Johnson,
Wm. H. Zeller,
Jas. H. McClelland,
Committee on behalf of Operators for the Block Coal District.

Samuel Anderson,
Barney Navin,
William Thompson,
Peter Fleming,
William Wilson,
Executive Committee District No. 8, United Mine Workers of America, for the Block Coal Miners.

It will be seen from this that the cost of mining lump coal, where paid for by the ton, is practically fixed. Where it is paid for by the ton, run of mine, the price varies according to the proportion of screened coal produced. Thus, where the lump coal amounts to 66 per cent. the price paid is 40 cents a ton. With the soft coals of Pike county and other places where the lump coal amounts to less than half of the coal mined, 30 to 33 cents is paid.

Where machines are used, payment is made in various ways. As given in the agreement, the price per ton is three-quarters that of picked mine coal. In some cases the digging is paid for by the cut and the loading by the ton. Thus, in a mine using electric machines, the machine runner receives 8 19-27 cents and the helper 7 22-27 cents per cut, or a total of $1.15 7-27 for seven cuts, yielding in this case 25 tons, making the cost per ton 4 62-100 cents for the undercutting. Loaders in this case receive 21 72-100 cents per ton, to be divided among them. This makes the total cost of labor for mining and loading coal 26 34-100 cents a ton. In some mines they pay by the foot for cutting, by the day for shooting and by the car for loading, and still other methods are adopted.

2237. (d) Removal of Coal from the Mine, Screening, Weighing and Loading.—The men necessary for this part of the work are paid by the day, with but few exceptions. This part of the subject can be best studied by taking actual lists of day men for different kinds of mines and different outputs.

Thus, for a small new mine with an output of 200 tons a day, short haulage:

Day Men at .... Mine.

Men.	*Number.*	*Daily Wage.*	*Total.*
Drivers	2	$1 75	$3 50
Roadmen	1	1 90	1 90
Mine boss	1	2 40	2 40
Engineer	1	2 40	2 40
Dumpers	2	$1 75 and 1 50	3 25
Trimmer	1	$1 75	1 75
Total			$15 20
Average of 200 tons			076

An expense of 7.6 cents on this score. (Cars here hold 3,000 lbs.) This perhaps is the lowest extreme. Next let us take a typical pick mine, with a capacity of 400 tons a day. The figures for such work from an actual case are as follows:

Day Men at.................. Mine.

Men.	*Number.*	*Daily Wage.*	*Total.*
Drivers	8	$1 75	$14 00
Road men	2	1 90	3 80
Trapper	1	1 00	1 00

Men.	Number.	Daily Wage.	Total.
Trapper	1	75	75
Cager	1	1 96	1 96
Load dropper	1	1 75	1 75
Driver, boss	1	1 90	1 90
Mine boss	1	2 60	2 60
Engineer	1	2 12	2 12
Fireman	1	1 70	1 70
Blacksmith	1	2 00	2 00
Weigh boss	1	1 60	1 60
Flat dropper	1	1 10	1 10
Dumper	1	1 75	1 75
Trimmer	1	1 50	1 50
Stableman	1	1 62½	1 62½
Night watch	1	1 62½	1 62½
Total			$42 78
Average of 400			106

This item in this case increases the cost of the coal by 10.6 cents a ton.

A third example may be taken of a pick mine whose output comes between the other two. (Capacity, 300 tons daily.)

Day Men at.................Mine.

Men.	Number.	Daily Wage.	Total.
Drivers	12	$1 75	$21 00
Timbermen	2	1 90	3 80
Road men	3	1 90	5 70
Bottom lifters	2	1 75	3 50
Cager	1	1 75	1 75
Greaser	1	1 00	1 00
Mine boss	1	3 00	3 00
Engineer	1	2 00	2 00
Night men	2	1 60	3 20
Firemen	2	1 60	3 20
Weigh boss	1	2 00	2 00
Blacksmith	1	2 00	2 00
Leveler	1	1 50	1 50
Pumper	1	1 50	1 50
Total			$55 15
Average of 300 tons			15

In this case men cost about 15 cents a ton. Compared with the first case, it shows somewhat the difference between a new mine with short hauls and an old mine with long hauls. In the first case the drivers haul 100 tons apiece, and one road man can take care of the entries. In the latter case each driver only hauls 25 tons a day, and there is required extra a cager and greaser, and for the entries, five men instead of one.

Still another case of a mine with an output of 250 tons gave as follows:

Day Men at.................Mine.

Men.	*Number.*	*Daily Wage.*	*Total.*
Drivers	6	$1 25	$7 50
Road layers	2	$1 50 and $1 25	2 75
Pit man	1	1 25	1 25
Trappers	3	50	1 50
Mine boss	1	2 00	2 00
Engineer	1	1 60	1 60
Fireman	1	1 00	1 00
Weigh boss	1	1 35	1 35
Dumper	1	1 25	1 25
Trimmer	1	1 25	1 25
Stableman	1	50	50
Total			$21 95
Average of 250 tons			087

A cost in this case of 8.7 cents per ton. This, as might be judged, is a southern mine, where wages are lower than farther north.

Turning to machine mines, the following figures are for an electric mine, having at the time an output of 550 (?) tons a day.

Day Men at.................Mine.

Men.	*Number.*	*Daily Wage.*	*Total.*
Mine boss	1	$2 60	$2 60
Drivers	9	1 75	15 75
Motormen	2	1 75	3 50
Wireman	1	1 75	1 75
Roadmen	2	1 90	3 80
Timbermen	2	1 90	3 80
Cagers	3	1 75	5 25
Trappers	6	75	4 50
Pumpers	3	$1 00 to $1 80	4 55
Hoisting engineer	1	2 00	2 00

Men.	*Number.*	*Daily Wage.*	*Total.*
Night engineer	1	1 75	1 75
Firemen	2	$1 75 and $1 50	3 25
Weigh boss	1	1 75	1 75
Blacksmith	1	2 00	2 00
Flat trimmers	4	1 50	6 00
Dumper	1	1 25	1 25
Carpenter	1	1 75	1 75
Rouster	1	1 50	1 50
Stableman	1	1 60	1 60
Total			$68 35
Average of 550 tons			.123

This gives a total of 12.3 cents a ton as the cost of day labor at mine.

In a mine using air machines to mine and rope haulage, the figures will be somewhat different, and may be given for a mine delivering 1,000 tons a day:

Day Men at.................Mine.

Men.	*Number.*	*Daily Wage.*	*Total.*
Drivers	17	$1 75	$29 75
Roadmen	3	1 90	5 70
Bratticeman	1	1 90	1 90
Jerrys or roustabouts	2	1 90	3 80
Trappers	5	75	3 75
Pumper	1	1 75	1 75
Pipeman	1	1 85	1 85
Water hauler	1	1 75	1 75
Cagers	2	1 96⅞	3 93⅔
Assistants	2	1 75	3 50
Rope riders	2	1 90	3 80
Bottom engineer	1	1 53	1 53
Driver boss	1	1 73	1 73
Mine boss	1	2 60	2 60
Engineer	1	2 10	2 10
Night watch	1	1 33⅓	1 33⅓
Firemen	2	1 53⅓	3 06⅔
Assistant fireman	1	1 25	1 25
Blacksmiths	2	2 00	4 00
Trimmers	4	1 45	5 80
Rousters	2	1 10	2 20
Dumper	1	2 00	2 00
Dumper	1	1 76	1 76
Weigh boss	2	2 10	4 20

Men.	*Number.*	*Daily Wage.*	*Total.*
Empty runners	2	1 45	2 90
Top stableman	1	1 15	1 15
Top boss	1	1 73	1 73
Machine boss	1	2 25	2 25
Total			$103 08⅔
Average of 1,000 tons...			.103

In this case day labor amounts to 10 cents a ton. Adding these costs to the costs of labor for mining and yardage, there is obtained as the labor cost of the coal mine run:

	Cost of Mining.	*Day Labor.*	*Yardage.*	*Total.*
First case	$0 40	$0 07	$0 02	$0 49
Second case	40	10	02	52
Third case	57 (?)	15	02	74
Fourth case	30	08	02	40+
Fifth case	26	12	02	40+
Sixth case	30?	10	02	42+

Due to omissions and other causes, it is probable costs are 5 to 10 cents above these figures. In one machine mine the amount paid for a certain period ran in the following ratio:

Wages paid machine men and helpers.......	$207 62	
Loaders	874 97	
		$1,082 59
Inside men	$596 38	
Top men and monthly men	389 40	
		985 78
		$2,068 37

During this time the proportional output was 4,374 tons, run of mine, or 47 cents a ton for labor. It will be noticed that the cost of yardage, getting coal out of mine, screening, weighing and loading on flats is almost as much as the digging and loading on mine cars. That is where the machine mine loses much of the advantage it gains in reduced cost of mining coal.

In the State Statistician's report for 1895-96, he gives reports from eighty-six mines, in which 2,737,686 tons of coal were mined and $2,196,868 paid for wages in mining it. This gives a total of 80.2 cents a ton as the labor cost of the coal.

IV. Operating Materials.

2238. (a) Rails and Ties.—In one of the mines these were estimated at 18 yds. a day of 16 lb. iron rail, costing $6.33. About twenty-seven ties 3 in. by 5 in. by 5 ft. at 5 cents each, $1.35, or 1.4 cents a ton of output. Tracking and rooms, 6.25 cents for 25 tons of coal, or .25 cents a ton, making 1.65 cents a ton for the mine. At other mines estimates run down to .25 cents per ton.

2239. (b) Timber.—This item is largely influenced by the character of the roof, and will run from a small fraction of a cent per ton for some mines with good roof (.2 cents in one mine) to 2 cents a ton, and probably will average not far from 1 cent a ton. Posts cost from $15 to $30 a thousand. In some of the mines the entries require almost no timbering, while in others, after a few years, the entries require not only considerable timbering, but a good deal of lagging. This would add slightly to the above amount, so that 1 cent a ton for the average is probably none too high.

2240. (c) Oil, Feed for Mules, Coal for Boilers, Etc.—From figures obtained, the oil for cars and engines will cost about $\frac{1}{8}$ of a cent a ton. Feed for mules will run about 15 to 20 cents each day, or from .25 to 1 cent per ton, depending on whether mechanical haulage is used and upon the length of haul. Probably .25 cent per ton for mines using mechanical haulage and .5 cent for those using only mule haulage.

2241. (d) Other Items.—It is probable that other expenses, brattices, repairs to roofs and to machinery, deterioration of cars, cables, cages and machinery, judging from such figures as are at hand, will cost not less on an average than 3 cents a ton.

Summing up these items it seems probable that cost of operating materials will average not far from 5 cents a ton.

V. Office Expenses, etc.

2242. These will include books, stationery, stamps, advertising, mine maps and surveying, book-keepers, superintendent, rent, taxes, insurance and many other items. Upon this we have so little data that our estimates are little more than guesses. However, it is probable that few companies run under 1 cent a ton, and it is easy to figure up expenses that would run up to several cents a ton. Some of the operators say that 5 cents a ton is not too high.

VI. Summary of Cost of Coal on Car.

2243. The following table gives a summary of the cost of coal on the car in cents:

	A.	*B.*	*C.*	*D.*	*E.*
Royalty	3.3	5.0	10.0	5.0	5.0
Interest on equipment	2.0	2.0	2.0	4.0	4.0
Cost of labor	40.0	50.0	74.0	47.0	45.0
Operating materials	5.0	5.0	5.0	5.0	5.0
Office expenses	1.0	5.0	5.0	5.0	5.0
Total	51.3	67.0	96.0	66.0	64.0

A is supposed to represent conditions in the southern part of the State for a pick mine; in other words, minimum cost (at schedule preceding strike of 1899). B, pick mine in northern part of field, bituminous coal. C, pick mine on block field, representing greatest cost. D and E, different types of machine mines.

As we had not all the data for any single mine, the above figures are only approximate, but suggest that a ton of run of mine coal can hardly be placed on a flat under fairly average conditions for less than 50 cents, or 2 cents a bushel, while it may run up in the block field to close to $1, or 4 cents a bushel. The average for the field will probably be between 60 and 70 cents, and I am not sure that it would be far out of the way to say that a ton of run of mine coal will cost not far from the schedule price paid for pick mining of lump coal, except in the block field, where it would seem to run considerably over.

In practice it is the custom of many operators to charge all the expenses of the mine to the lump coal, letting any sale of small coal go to profit and loss. On this basis a ton of lump coal will cost more nearly the same over the field. Thus, the most of the southern coal is rather soft, many of the mines yielding only 45 per cent. of lump, which would make the lump coal cost $1.10 a ton when run of mine costs $0.50. Where run of mine costs $0.60 a ton and 66 per cent. is lump, the lump coal would cost on this basis $0.90 a ton. Where run of mine coal costs $0.90 and 75 per cent. is lump, the lump costs $1.20. On this basis it is evident that lump coal is often sold for less than it costs, and it is also evident that the method does not give a fair idea of the cost of the lump coal except on the basis of the small coal being so much waste. The method is used because of the uncertainty attending the sale of the small coal. At times this brings a good price, and again is almost given away. Formerly there was small demand for the small coal, but the introduction of fire grates adapted for its burning and better screening are creating a larger and steadier demand for it.

Another way to look at it is to consider a ton of lump coal as costing the same percentage of the total cost of the coal that it bears to the total amount of coal mined. Some operators follow this method, and one of the largest operators remarked that it was only a question of time, with improved methods of cleaning and sizing coal, and improvements in grates, when all sizes of coal would sell at the same price. This practically makes the cost of a ton of lump coal, a ton of screening or a ton of mine run coal the same. Thus, if run of mine costs 60 cents a ton to place on flats, and is 66 per cent. lump, three tons will cost $1.98 and yield two tons of lump, which cost $1.32, or 66 cents a ton, and one ton of screening, costing 66 cents. If the lump coal sells for 90 cents, it sells for a profit of 24 cents a ton, and if the screenings sell for 30 cents a ton, they sell for a loss of 36 cents a ton, the net profit in this case being 4 cents a ton, or equivalent to selling run of mine at 70 cents a ton.

On this basis it would seem as though the mining and handling of the small coals was being carried on at a direct loss, and the question would arise, Why not leave the small coal in the mine and make a profit of 24 cents a ton on the output instead of 4 cents? The answer is that the small coal has been considered only a by-product in the mining and removing of the lump coal; that the lump can not be mined without the production of small coal, and that the small coal having been produced, it is more economic to remove it and to sell it than to leave it in the mine.

A third method of looking at the subject would throw all the expense on the lump coal, except the labor cost of removing and preparing the small coal. Without knowing what per cent. of the small coal resulted from the handling of the lump coal after it is loaded into the mine cars, it would be difficult to estimate the costs on this basis. A rough estimate, based on the assumption that one-quarter of every ton of small coal was produced by the abrasion of the lump coal while it is being removed and screened, and so falls on the lump side of the expense account, gave, for a case like that given just above, cost of run of mine coal 60 cents—two-thirds lump.

Equivalent cost of lump coal	$0 86
Equivalent cost of screenings	25

This is, of course, only suggestive. On this basis it is evident that the screenings must sell for the 25 cents, or whatever the actual cost is, or else the profit on the lump coal will have to cover the deficiency.

VII. Selling Price at Mines.

2244. Average prices for Indiana coal since 1889 in counties averaging 10,000 tons or over:*

County.	*1889.*	*1890.*	*1891.*	*1892.*	*1893.*	*1894.*	*1895.*	*1896.*
Clay......	$1.14	$1.01	$1.15	$1.25	$1.29	$1.13	$1.07	$0.96
Daviess...	1.02	1.04	1.12	1.11	.97	1.03	.94	.87
Fountain..	1.29	1.00	.99	.89	1.00	1.08	....	.80
Gibson....	....	....	....	....	....	.78	....	.75
Greene....	.91	.94	.91	.84	.83	.96	.69	.77
Knox.....	....	....	....	.84	1.10	.84	.98	.78
Parke.....	1.05	1.09	1.13	1.09	1.16	1.07	.98	.87
Perry.....	1.18	1.05	1.10	.86	1.13	1.12½	1.12	1.12
Pike......	.83	.98	.90	.87	.76	.77	.77	.69
Spencer...	1.15	.96	.88	.80	.84	1.03	1.01	1.34
Sullivan...	.94	.94	1.01	.89	.88	.82	.84	.67
Vand'b'gh.	1.16	1.02	1.09	1.06	1.08	.96	1.03	1.03
Vermillion	.89	1.17	.98	.96	.96	.82	.81	.75
Vigo......	.88	.80	.80	1.14	.95	.95	.78	.70
Warrick...	....	....	.77	.81	.89	.72	.72	.66
State...	$1.02	$0.99	$1.03	$1.08	$1.07	$0.96	$0.91	$0.84

If anything like these figures hold in 1898, it shows a profit over the cost of coal of from 1 cent to 50 cents, though most of them range from 5 to 15 cents.

VIII. Cost of Transportation.

2245. In the following table is given the railway tariff from some of the principal mining centers to some of the main selling centers:

Parke county to Chicago..............................	
Parke county to South Bend..........................	
Parke county to Indianapolis.........................	
Brazil to Chicago.....................................	
Brazil to South Bend..................................	
Brazil to Indianapolis................................	$0 50
Linton to Chicago.....................................	
Linton to Indianapolis................................	50
Washington to St. Louis...............................	
Pike county to St. Louis..............................	

Through an oversight the figures for this table were not procured.

IX. Wholesale and Retail Selling Price of Indiana Coal at Important Points.

2246. The following table from Mineral Resources for 1896-97 is the most comprehensive table available, and I understand that prices do not differ much from those prevailing at that time:

* Mineral Statistics, U. S., 1896-97, p. 511.

Table of Selling Prices of Coal in Indiana in 1896.

TOWNS.	Steam Coal.				Domestic Coal.				Kind of Coal Used.	
	Wholesale.		Retail.		Wholesale.		Retail.			
	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Steam.	Domestic.
Anderson	....	....	....	....	....	$2 30	....	$3 50	....	
Elkhart	....	....	$3 50	$2 50	....	....	$4 50	4 00	Pocahontas and Hocking	Jackson Hill.
Evansville	....	....	....	75	....	....	....	1 40	....	
Ft. Wayne (?)	$3 00	$2 10	2 10	1 80	$4 50	3 75	2 50	2 10	Ohio and Indiana	Ohio.
Indianapolis	85	45	1 50	1 00	1 75	1 45	3 00	2 50	....	Brazil block.
Indianapolis	85	45	1 50	1 00	1 50	1 35	2 75	2 25	....	Island City.
Indianapolis	85	45	1 50	1 00	2 25	2 05	3 75	3 00	....	Pittsburg.
Jeffersonville	1 50	1 35	2 00	1 40	3 05	2 35	3 05	2 78	Pittsburg	Pittsburg.
Lafayette	1 10	1 00	2 50	2 00	2 90	2 45	4 50	4 50	Slack	Pittsburg.
Logansport	1 75	1 75	....	....	3 10	2 85	4 50	4 00	Indiana	Pittsburg.
Michigan City	2 30	2 25	3 25	3 00	....	....	3 50	3 25	Indiana block	Indiana.
New Albany	....	....	1 50	1 25	....	....	2 75	....	....	
Richmond	2 40	1 90	....	....	2 75	2 20	3 50	3 00	....	
South Bend	....	....	1 80	1 55	....	....	....	2 50	Indiana	Indiana block.
South Bend	....	....	2 00	1 90	....	....	3 00	3 50	Indiana block	Hocking Valley.
South Bend	....	....	....	....	....	....	....	4 00	Indiana block	Cannel.
Terre Haute	55	45	1 00	75	85	80	1 80	1 60	Indiana block	Indiana block.

A comparison of the wholesale and retail prices given here shows from 30 cents to $1.40 as the cost of retailing and delivering. In the latter case it is possible that the wholesale price is the price paid by the wholesale companies for the coal at the mine, and includes transportation.

2247. X. Summary of Cost of One Ton of Coal.

To original owner	$0 03	to	$0 10
To capital invested at 6 per cent	02	to	045
To labor and mine expense	50	to	1 00
To operator	05	to	50
To transportation	..	to	..
To retailing and delivering	30	to	1 40
Cost to retail purchaser	75	to	3 25

Possibly an average of lump coal sold in Indianapolis on the basis of three-fourths lump to the ton of mine run would give:

To original owner	$0 05
To capital invested	03
To labor and mine expense	87
To operator	15
To transportation	50
To retailing and delivering ....$0.50 to	90
	$2 50

As stated before, the conditions vary so from mine to mine that probably at no one mine would just such figures be found correct, and at some of the mines will vary greatly from that. Variations in the price largely affect the operator and retailer, the other items being more or less stable.

XI. Additional Items.

2248. In addition to the above items are many items which indirectly influence the results greatly. Perhaps the greatest is the loss recurring more or less periodically from strikes. This loss falls heavily on both operators and miners. In coal mining, as in most mining, though to a somewhat less degree than in most, there is a certain amount of hazard constantly involving losses. These are due to unforeseen irregularities in the coal, moneys wasted in examining or trying to develop unworkable territory, the flooding of the mine or other accidents often unavoidable, but as often due to poor planning. These things tend to cut down the profits of the operators. On the other side are usually more or less regular items of income not included above. Thus, the miner is required to furnish his own tools, powder, etc., and keep his tools sharpened. The company usually does the last for him at so much a month or week, amounting to about a cent a ton. Powder is usually sold to the men by the company, costing the miner about a cent a ton in ascertained cases and yielding often considerable profit to the operator. Among other items of more or less profit to the operator may be mentioned rents of miners' houses, but most important of all, where it exists, the company store. This is a store furnishing all the necessities of life, and often has all the completeness of stock of a department store, at which the employes may or may not be expected to trade, and which may or may not sell goods at a greater profit than other stores.

XII. Earnings of Miners.

2249. On this question the best information at hand is that obtained by the State Statistician and published in his report for 1895-96. It applies to the conditions existing then. We give it verbatim:

"Employes' Statements.—Of the 6,208 miners employed (according to the reports received by the Bureau), the Bureau has statements from 846, about 10.5 per cent. of all, and bases the facts and conclusions on their statements, believing that they will fairly represent the whole number.

"Nationality—Days Worked.—An analysis of the 846 reports shows that of the 6,208 miners, 3,725 are native and 3,483 foreign born. Number of hours constituting a day's work, 9; number of days worked the past year, 147. [Since strike 8 hours constitute a day's work.—G. H. A.]

"Single and Married.—The number of single men, as shown by these reports, is 932; married, 5,276, with an average to the family of those married of 5.1.

"Wages—Tons Mined Per Day.—It is shown by these reports that the average tons of coal mined per day is 3; average price received per ton, 57.1 cents [1898, 69 cents], making the average daily earnings $1.71, and for the 147 days worked during the year, $251.37. The average cost for powder and sharpening tools [oil, etc.] is 34.3 cents per day; for the 147 days, $50.32, leaving the net earnings for the year $201.05.

"Losses From Screening.—Of the 846 who report, 244 estimate the loss to them from screening at 40 cents per day, or $50.80 each for the year.

"Property Owners—Renters.—Of the 5,276 who are married, 2,076 own their homes and 3,650 pay monthly rental of $4.53; $54.36 per annum, a total for the 3,650 of $198,414.

"Building and Loan Shares.—Nine per cent. of the whole number (578) carry each an average of 3½ shares of building and loan stock, an aggregate of 1,923 shares. Of these, 208 say they have built houses by aid of these associations.

"Are You Compelled to Trade at Company Store?—To this question 558 of the 846 give an answer, 83 per cent saying 'no,' and 17 per cent. saying 'yes.' Many of those who say 'no,' add 'you are expected to.'

"Per Cent. of Earnings Spent in Companies' Stores.—Of the 846 the above question was answered by 468, or 55 per cent., which of the 6,208 would be 3,413, say they spend 74 per cent. of their earnings in the stores of the companies for whom they work. Not a few say 100 per cent.

"Do Companies Charge More than Other Stores?—Five hundred of the 846, 60 per cent., answer this question. Of these, 292, 58 per cent., answer 'no,' while 208, 42 per cent., say 'yes.'"

2250. For the sake of comparison and to show some other facts of interest, some figures are given from a paper by Mr. E. R. S. Gould in the Johns Hopkins University Studies in Historical and Political Science:

Families of which statistics were obtained (American miners)	508	
Average number of persons in family	5.3	
Owning homes	134	
Giving information concerning size of house	335	
Average number of rooms	3.9	
Maintained entirely by husband	294	or 57.9 per cent.
Total earnings of family	$550 30	
Of which husband earns	426 73	or 77.5 per cent.
Expenditures—		
Rent	61 19	or 11.7 per cent.
Food	237 44	or 45.3 per cent.
Clothing	112 10	or 21.4 per cent.
Books and newspapers, 80.3 per cent. buy, and spend	5 30	or 1 per cent.
Alcoholic drinks, 60 per cent. use, and spend	18 09	or 3.4 per cent.
Tobacco, 85.8 per cent. use, and spend	9 30	or 1.8 per cent.
Total	$524 71	
Surplus representing year's saving	$25 59	or 4.7 per cent.

XLIX. UTILIZATION AND AVAILABILITY OF INDIANA COALS.

2251. Uses of Coal.—It is an interesting fact that coal, perhaps the most valuable and useful mineral known to us, is of no direct use to us. We can not eat it, wear it or live in it; in short, with insignificant exception, we make no direct use of coal. Coal is of use to us only as it ceases to be coal. Its value lies in its indirect use through chemical changes it may be made to undergo. That chemical change, for the larger part, is a simple one. It consists, in brief, of the union of the carbon and hydrogen of the coal with the oxygen of the air or of metallic ores, forming the new chemical compounds, oxides of carbon and oxides of hydrogen, or chemically, CO or CO_2 (ultimately always CO_2) carbon monoxide or carbon dioxide, and H_2O hydrogen monoxide or common water. It then becomes an interesting fact that the new substances formed by this chemical action are, commercially speaking, of no value. Its value lies mainly in two results accomplished through the chemical changes it undergoes:

1. The production of energy in the form of heat or light.

2. The reduction of certain chemical compounds, especially iron oxide.

It is not my province to attempt to enumerate the almost innumerable uses of coal under these two heads, or the less important ones that do not fall under these heads, of which, all told, there are not a few; but to briefly touch on the few principal uses which are generally considered as forming the market for coal. These may be conveniently grouped as follows:

I. The production of energy.
  (A) Direct production of direct results.
    (a) Warming and cooking.
  (B) Direct production of indirect results.
    (a) Through steam.
    (b) Through electricity.
  (C) Indirect production of results.
    (a) Conversion into gas.
      1. Illuminating.
      2. Producer gas.
      3. Semi-water gas.
      4. Water gas.

(b) Transportation as gas.
(c) Utilization as gas.

II. Reduction of ores, etc.
(A) Direct.
(B) Indirect.

This classification lays no claim to completeness and may be imperfect in many ways, but will serve the purpose we have in view. Of these topics the ones which do, or are likely in the near future to elicit the most inquiry are probably I (B) (a) and I (C) (a), (b) and (c). Therefore, the most of the attention will be given to these.

I. The Production of Energy.

(A) DIRECT PRODUCTION OF DIRECT RESULTS.

(a) WARMING AND COOKING.

2252. The direct results of the chemical actions referred to above are the withdrawal of oxygen from the air or from some compound and the production of energy in the form of heat, and it may be of light. While the production of light by the direct burning of coal may be a strong factor in the selection of coals for certain purposes, it can hardly be included in the commercial uses of coal.

An examination of the ultimate analyses of coal as given in Part I shows only two oxidizable substances (omitting the sulphur, etc.)—carbon and hydrogen. Where the sulphur is determined, it is a common rule to consider the heat obtained from the burning of half of it. To aid in studying the heat value of coals, the following table has been prepared. It is partly from known determinations, but in the main the figures have been especially calculated from the figures usually given as the "heat of formation" of the resultant compounds or from averages of the figures in the analyses given by Mr. Noyes in the 1896 report. It will be recalled that there are two heat units, the calorie, commonly used in scientific work and used in the tables of analyses given further on, and the *British thermal unit* (B. T. U.), generally used in engineering work. The calorie is the amount of heat required to raise the temperature of 1 gram of pure water from 0° to 1° centigrade. For convenience, a unit 1,000 times as large is sometimes taken, known as the great or large calorie, by making the kilogram instead of the gram the unit of weight. The British thermal unit is the heat required to raise a pound of water 1° Fahrenheit.

Heat of formation of CO (J. Thompson)	28.5 great calories.
Heat of formation of CO_2 (J. Thompson)	96.9 great calories.
Heat of formation of H_2O, liquid (J. Thompson)	68.3 great calories.
Heat of formation of H_2O, vapor (J. Thompson)	58.0 great calories.
One gram of carbon (C) in burning to CO_2 yields	8,080 calories.
One gram of carbon (C) in burning to CO yields	2,380 calories.
One gram of hydrogen (H) in burning to H_2O yields	34,460 calories.
One gram of hydrogen (H) in burning to H_2O (vapor) yields	28,600 calories.
One pound of carbon in burning to CO yields	4,400 B. T. U.
One pound of carbon in burning to CO_2 yields	14,400 B. T. U.
One pound of carbon in burning from CO to CO_2 yields	10,092 B. T. U.
One gram of average (Noyes's analyses) Pittsburg coal yields	7,259 calories.
One gram of average (Noyes's analyses) Indiana coal yields	6,879 calories.
One pound of average (Noyes's analyses) Pittsburg coal yields	13,066 B. T. U.
One pound of average (Noyes's analyses) Indiana coal yields	12,382 B. T. U.
One (long) ton of anthracite yields	29,000,000 B. T. U.
One (short) ton of average Pittsburg coal yields	26,132,200 B. T. U.
One (short) ton of average Indiana coal yields	24,764,000 B. T. U.
The fixed carbon (average) in one ton of Pittsburg coal yields	15,840,000 B. T. U.
The fixed carbon (average) in one ton of Indiana coal yields	13,864,000 B. T. U.
The gas (average) in one ton of Pittsburg coal yields	10,292,000 B. T. U.
The gas (average) in one ton of Indiana coal yields	10,900,080 B. T. U.

The following figures are added for comparison:

One gram of coke yields (Kich. Ginth., Technologisches Wörterbuch, 618)	6,500 calories.
One gram of peat yields (Kich. Ginth., Technologisches Wörterbuch, 618)	4,500 calories.
One gram of turf (air dried) yields (Kich. Ginth., Technologisches Wörterbuch, 618)	3,000 calories.
One gram of wood yields (Kich. Ginth., Technologisches Wörterbuch, 618)	2,800 calories.
One gram of petroleum yields (Kich. Ginth., Technologisches Wörterbuch, 618)	10,000 calories.
One gallon of petroleum (7.1) yields (Kich. Ginth., Technologisches Wörterbuch, 618)	127,800 B. T. U.
One thousand cubic feet of natural gas (Phillips) about	1,164,030 B. T. U.

Theoretically one pound of Pittsburg coal = 11.2 cubic ft. of Pittsburg gas.*

One thousand cubic feet of natural gas will evaporate 1,203 pounds of water.*

*Calculated from figures given above. Mr. Emerson McMillin, in Vol. VI of Geol. Survey of Ohio Reports, pp. 538-540, calculated the heat value of natural gas at 1,103,292 B. T. U. According to Prof. Phillips, one ton of Pittsburg coal is theoretically equivalent to 22,400 cu. ft. of gas. It appears to be commonly stated that one ton of Pittsburg coal is equivalent to from 31,000 cu. ft. to nearly 37,000 cu. ft. of gas. Thus Mr. S. A. Ford calculated natural gas

Practically one pound of Pittsburg coal = 7.5 cubic feet of Pittsburg gas,*
or as more generally accepted = 10 cu. ft. of Pittsburg gas.
Theoretically one ton of Pittsburg coal = 22,400 cu. ft. of Pittsburg gas.
Theoretically one ton of Indiana coal = 21,200 cu. ft. of Indiana gas.
Practically one ton of Indiana coal = 20,000 cu. ft. of Indiana gas.

2253. DESIRABLE QUALITIES FOR HOUSEHOLD COAL.—Coal for domestic purposes is used in an open grate, in closed stoves with ordinary fire bowl and flat grate, or with basket grates in small furnaces for hot air heating, and in cooking stoves. These different uses to a certain extent demand different varieties of coal, yet certain qualities are esteemed for all. Of these may be mentioned, not too rapid or fierce combustion, capacity for remaining ignited at low temperature, with but little draught, freedom from sulphur. In the open grate, cheerfulness is an object sought, and consequently a coal giving much flame is desirable, yet this flame must be as free from smoke as possible, or it will produce an objectionable amount of soot and dirt. As grate fires are apt to be kindled frequently, they, in common with cooking stoves, demand a coal that kindles readily. Self-feeding and base-burning stoves require a dry, non-caking coal, like our block or most of the semi-block coals or anthracite. The rapid-burning steam coals are not usually desirable for household purposes, as they tend to burn out grates, require frequent attention, tending to burn fiercely at times and to die out quickly, and, as they often carry large quantities of sulphur, will in such a case produce stifling gases if the draught be imperfect. Sulphurous coals do not

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to have a heat value of 210,069,604 calories. On this basis 1,000 cu. ft. of gas are equal in heat value to 57.25 lbs. of carbon, 67.97 lbs. of coke, or 54.4 lbs. of bituminous coal or 58.40 lbs. of anthracite coal. Or one ton of Pittsburg coal is theoretically equal to 36,764 cu. ft. of Pittsburg gas. Prof. Howard of Columbus calculated the heat value of gas to be 228,461,113 calories; or one ton of Pittsburg coal equals 31,085 cu. ft. of Findlay gas. (Quoted from Penn. Geol. Rep. in Geol. Surv. of Ohio, Vol. VI, p. 138, and 20th Ann. Rep. Geol. Surv. of Ind., p. 380.) Prof. Orton goes on to say (see same reference) that one lb. of Pittsburg coal is theoretically equal to 18.3 cu. ft. of Pittsburg gas, but practically less than 7 cu. ft. of gas will do the work of one pound of coal. The figures to which I have access do not seem to sustain these results. Thus, reducing the heat values given above to British thermal units, we have in round numbers 833,000 B. T. U. and 903,000 B. T. U., respectively. Dividing the first of these by 967, the latent heat of steam, we have 1,000 cu. ft. of natural gas will evaporate (theoretically) 861 lbs. of water. But in actual tests 1,000 cu. ft. of natural gas have evaporated as high as 978 lbs. or higher (See U.S. Geol. Surv., 18 Ann. Rep., Part V, cont., p. 899), in other words, an efficiency of over 100 per cent.

Or, taken from another standpoint, assuming natural gas to have an efficiency of 80 per cent. in a good boiler, if 18.3 cu. ft. of gas were theoretically equal to one lb. of coal, 22 cu. ft. of gas in practice would be equal to the theoretical value of one lb. of coal; or if 7 cu. ft. of the gas were found to be equal to one lb. of coal in practice, the coal by these figures would have an efficiency of only about 31 per cent. As a matter of fact Pittsburg coal has easily double that efficiency in well-designed boilers, indicating error in the original figures.

*Revised Judgment of Committee of Engineers, Soc. W. Pa. (For test see Scientific American, Supplement No. 520, Dec. 19, 1885.)

usually clinker as badly in household use as in steam use, on account of the lower temperature. A coal with a light pulverulent ash is the best, and, of course, the smaller the quantity of ash the less trouble of its removal.

Here again the value of testing a coal is apparent. Mr. A., after repeated trials, finds that a certain coal gives the best results when fired under the boilers at his factory, and at once concludes that that is the best coal, and proceeds to introduce it at his house for the usual household purposes. The result will often be far from satisfactory, though he may not give the matter close enough attention to be aware of that fact. In reality, it might have been that one of the coals that gave the poorest results at his factory would have been the most economical and efficient at his home.

It is a poor coal, indeed, that will not give good service somewhere, and the practice of condemning a coal because it fails in a certain capacity may be very unfair. There are to-day in Indiana many excellent coals lying unworked because they failed to give satisfactory service under a steam boiler. And conversely many excellent steam coals are lying untouched because when first discovered and tried in a stove by the discoverer they burned the grates out, and, having no other use for them himself, he makes no further effort at their development.

At present in Indiana a large percentage of household fires depend entirely upon natural gas. That this is an ideal fuel for that purpose need not be stated. Its low cost, requiring no handling, making no ash to be removed, neither smoke to darken the sky and render all things smutty and black, and its freedom from sulphur and other impurities make it *the* fuel par excellence. Under proper supervision and care it has proved itself a safe fuel. But there is only a limited quantity, and that is being rapidly exhausted. This fact needs no emphasis after the events of the winter of 1898-99. Under indirect uses of coal will be discussed the question, "Can coal be made to produce a gas to take the place of natural gas upon the exhaustion of the latter?"

(B) DIRECT PRODUCTION OF INDIRECT RESULTS.

(a) Through Steam.

2254. Steam Value of Indiana Coal as Based on Analyses.—For this discussion it will be necessary for us to confine ourselves to the recent analyses, as giving a fairer idea of the commercial value of our coals. (See Appendix A.)

The more direct results under this head might be divided into heating by steam and production of mechanical energy by steam; but for our purpose the two may be considered together. At present the direct use of coal for the production of steam exceeds all the other uses combined. The value of any given coal depends on the quantity of steam a given quantity of coal will evaporate, or the quantity of water a given quantity of coal will raise 1° in temperature.

Examining the table, it will be noted that 1 kilogram of Indiana coal will raise 6,879 kilograms of water 1° C., or 1 ton of Indiana coal will raise 24,764,400 pounds of water 1° F. As to evaporating effect, 1 lb. of Indiana coal will evaporate from about 12 to nearly 13.5 lbs. of water, starting from the boiling point. This, of course, is its theoretical evaporative effect. As compared with Pittsburg coal, the latter runs from 13.5 to 14.6 lbs. of water evaporated per pound of coal. As a matter of practice, probably not much over two-thirds of that effect can be obtained; in other words, a first-class coal in a first-class boiler will seldom evaporate more than 10 lbs. of water per pound of coal.

2255. The following table shows evaporative effect in pounds of water evaporated per pound of coal, of different coals from various tests, most of the table being taken from Mr. Arthur Winslow's report on the coals of Arkansas:

COALS.	[1]Johnson.	[2]Blake.	[3]Potter.	[4]Meigs, Meigs Boiler.	[4a]Meigs, Little Giant Boiler.	[5]Babcock & Wilcox Boilers.	[6]Navy Yard Tests.	[6a]Same, Equivalent Evap. from 212°.
Pittsburg	8.20	....	8.50	8.78	6.74	10.20	....	....
Huntington, Ark	....	....	8.50	....	....	....	....	....
Jenny Lind, Ark	....	....	8.40	....	....	....	....	....
Coal Hill, Ark	....	....	7.50	....	....	....	....	....
Kansas Coals	....	6.50	....	....	....	....	....	....
Leavenworth, Kan	....	....	....	6.49	6.42	....	....	....
Indiana Block, Ind	....	7.21	....	....	....	9.47	....	....
Cannelton, Ind	7.34	....	....	7.32	7.12	....	....	....
Run of Mines, Ill	....	....	....	....	....	9.49	....	....
Staunton, Ill	....	....	....	....	....	5.09	....	....
McAlester, I. T	....	....	....	7.68	6.96	....	....	....
San Antonio, M. Co., Tex	....	....	....	....	4.46	....	....	....
Fair Haven, Washington	....	....	....	....	....	....	6.85	8.05
Pocahontas, Va. and W. Va.	....	....	....	....	....	....	7.95	9.38
Pocahontas, Va. and W. Va.	....	....	....	....	....	....	7.70	9.02
George's Creek, Md	....	....	....	....	....	....	6.21	7.45
Standard Victor	....	....	....	....	....	....	6.59	7.92

[1]Experiments on the evaporative power and other properties of American coal. Report to the Secretary of the Navy, 1844, by Walter R. Johnson.

[2]The evaporative power of Kansas coals, by L. T. Blake, 6th Biennial Report of Kan. State Board of Agri.

[3]Test made for Ark. Geol. Surv., Ann. Rep., 1880, Vol. III, p. 72 et seq.

[4]Report on Fuel for the Army, by Quartermaster-General Meigs, 1882.

[4a]Same.

[5]Evaporative Power of Bituminous Coals, by Wm. Kent, Trans. Amer. Soc. Mech. Engrs., 1883.

[6]Tests made at Navy Yards of U. S., Sen. Ex. Doc. No. 82, 53d Congress, third session.

[6a]Same, giving equivalent evaporation from and at 212° F.

The difference is due to losses in several ways: First, radiation from exterior of furnace and boilers; second, heat carried out by chimney by escaping gases; third, imperfect combustion of combustible materials; fourth, heat used up in evaporating water in coal, etc. The first loss is approximately the same for different coals, provided similar conditions are maintained; and so also the second loss depends, with a given boiler, etc., on the temperature. The third loss may take place in two ways—by the escape of the volatile gases without burning, and by part of the carbon burning to CO instead of CO_2, thereby losing between two-thirds and three-fourths of the heat value of the carbon so burnt. To insure the combustion of all the fixed carbon, it is usual to admit to the fire double the amount of air theoretically necessary, and this large amount of comparatively cool air cools down the volatile gases so that they are only partially consumed. The introduction of a hot air draught in the place of the cool by raising the general temperature will doubtless secure more complete combustion of the gases. Of two coals the loss will be greater for the one having the larger percentage of gas. In this respect Indiana coal is at a disadvantage with many of the eastern coals, as it, in common with most western coals, runs high in gas, from 35 per cent. to 45 per cent., with an average of about 38 per cent. This is sometimes expressed as "fuel ratio"=fixed carbon÷volatile hydro-carbons. This ratio for some of the competing States is as follows:

Indiana, average of twenty analyses	1.26
Belleville coal (Illinois), average of six mines	1.32
Western coal fields, Kentucky	1.49
Rich hill coal, Missouri	1.29
Westmoreland Gas Coal Company, Pennsylvania	1.46
Connellsville coal, Pennsylvania, "standard coking coal"	1.98
Pocahontas coal, Virginia, "semi-bituminous," caking	3.95
Bernice coal, Pennsylvania, semi-anthracite	10.30
Wilkesbarre, Pennsylvania, anthracite	19.33

Due to its low fuel ratio, Indiana coal in present practice falls a little short of the ratio of its total heat units to those of Pittsburg coal, or instead of 93 per cent. it is probable this low fuel ratio will make the Indiana coal not over 90 per cent. as efficient as Pittsburg.

Again, Indiana coal is at a disadvantage on account of the large percentage of water carried. As has been previously stated, the water is a waste product, in that it does not burn, but it absorbs large quantities of heat in being vaporized. Thus, a pound of water at 60° F. will take (212°—60°)+967=1119 B. T. U. One per cent. of water in a ton is 20 lbs., which would absorb 22,380 B. T. U.; 10 per cent. would absorb 223,800 B. T. U. In round numbers it may be said that 10 per cent. of moisture means a loss of about 10 per cent. in the efficiency of the coal. Comparing coals gives for moisture:

Indiana coal, average of twenty analyses	8.45
Iowa coal, average of sixty-four analyses	8.57
Illinois, about like Indiana.	
Ohio coals, average of 149 analyses	4.65
Missouri coals, average of 112 analyses	3.40
Kansas coals, average of thirty-eight analyses	4.79
Pennsylvania coals, average of ninety-seven analyses (bituminous)	1.03
Pennsylvania coals, average of thirty-three analyses (anthracite)	3.35

Looking over the analyses, it is interesting to note that the so-called block coals of Indiana, which from one standpoint, are commonly spoken of as dry coals, are, from the standpoint of moisture, the wet coals, usually running over 8 per cent. of water, while the so-called bituminous or caking coals of the State generally run under 8 per cent. In most of the analyses by Mr. Cox the coals were allowed to dry in the laboratory to a large extent. It is of interest to take one of Mr. Noyes's analyses, and suppose that by drying all but about 1 per cent. of water is removed, and having recalculated the per cent. of the remaining parts, compare it with the original analyses and with an average of the best of the analyses of Pennsylvania and West Virginia coal by Mr. Noyes. Gauged by the heating effect, the Little Redstone coal is nearly an average of the Pittsburg coals, and the Beck's run coal is the best. Of the Indiana coals, that from Brazil Block No. 1 is not far from the average.

	B. B. No. 1 (Wet).	*B. B. No. 1 (Dry).*	*Little Redstone.*	*Beck's Run.*
Total combustible matter	85.12	97.8	91.00	96.06
Volatile combustible matter...	35.16	40.4	35.88	36.01
Fixed carbon	49.96	57.4	55.20	60.05
Moisture	13.82	.9	.98	2.09
Ash	1.06	1.2	7.94	1.85
Sulphur	1.47	1.7	.82	.64
Heating effect	6810.	7755.	7316.	7726.

While the commercial drying of the block coals seems now out of the question, it is of interest to note that could it be done Indiana block coal would be able to show a theoretic heating effect as good or better than any bituminous coal in the country.

The ash detracts from the value of a coal largely in the expense of handling. Five per cent. of ash means 100 lbs. to the ton, or 1 ton in every 40 tons flat of coal. It also requires removing from the furnace room, and often to a considerable distance. Indiana coals compare well with other coals in this respect, even when taken under the conditions that these samples were.

Indiana, average of twenty analyses..................	5.61
Illinois, average of six analyses	7.60
Arkansas, average of twenty-four analyses	6.76
Kansas, average of thirty-eight analyses	10.19
Pennsylvania, average of seventy-six analyses (bituminous)	5.35
Maryland (Cumberland)	6.40
Pocahontas, Virginia, average of fifteen analyses.........	5.19
Anthracite, Pennsylvania, average of thirty-three analyses	8.31

In percentage of sulphur the Indiana block coal is as low as the best. The caking coals average about with other western coals and higher than most of the eastern coals. As with the ash, this factor in the analyses is largely affected by the method of sampling.

2256. In comparing Indiana block coal with Illinois coals the following analyses and comparisons are of interest. The letter was written in 1876 and published in 1884.

H. G. Sleight, Indianapolis:

Dear Sir—The following is the result of the analyses, made in the laboratory of the State Geologist, of the three samples of coal which you brought me for that purpose:

No. 1 block coal, taken at random from a car load shipped from Brazil, Clay county, Indiana.

No. 2, from Wilmington, Ill., on the Chicago & Alton Railroad; also taken from the delivery at Chicago.

No. 3, Minonk coal, Ill., on the Illinois Central Railroad; also taken from the delivery at Chicago.

No. 1 is an ordinary sample of block coal. No. 2 is a glossy, jet black caking coal, with specks and scales of pyrites. No. 3 is a very brilliant black caking coal, which, when broken, shows numerous markings of sulphide of iron.

A large lump of each sample was reduced to fine powder and kept, well stoppered, in separate bottles. From these bottles, which contained proper average samples of the coals, the quantities were taken necessary to complete the separate processes to which a coal must be subjected in order to point out its commercial value. For convenience these coals will now be referred to by the numbers given above. The results are given in 100 parts of coal:

No. 1. Indiana Block Coal.

Specific gravity, 1.285. A cubic foot weighs 80.31 lbs.

Ash, white	2.50
Fixed carbon	56.50
Coke	59.00
Volatile matter	32.50
Water	8.50
Total	100.00
Iron	0.82
Alumina	1.20
Silica, lime and magnesia	0.48
Ash	2.50

Total sulphur, 1.43. The iron is combined with 0.947 of sulphur, leaving 0.493 of sulphur combined with the other constituents of the ash and carbon. This coal contains 7.424 calculated heat units, and one pound will convert 11.4 lbs. of water from 0° Cent. (32° Fahr.) into steam at 100° Cent. (212° Fahr.).

No. 2. Wilmington Coal.

Specific gravity, 1.248. A cubic foot weighs 78 lbs.

Ash, red	6.50
Fixed carbon	46.00
Coke	52.50
Volatile matter	37.50
Water	10.00
	100.00

Total amount of sulphur in this coal, 4.74 per cent.; iron, 4.34 per cent.=9.298 of pyrites; this would be in excess of the sulphur, so that all the iron does not exist as sulphide. The ash is composed of iron, 4.34; silica, 2.16.

This coal contains, by calculation, 6,762 units of heat. One pound will convert 10.4 lbs. of water from 0° Cent. (32° Fahr.) into steam at 100° Cent. (212° Fahr.).

No. 3. Minonk Coal.

Specific gravity, 1.232. A cubic foot weighs 77 lbs.

Ash, brown	5.50	
Fixed carbon	48.00	
Coke		53.50
Volatile matter	35.00	
Water	11.50	
		100.00

Total sulphur, 3.63 per cent. Sulphur, combined with iron, 2.719. Sulphur, combined with other mineral matter, 0.911.

Composition of ash—

Iron	2.38
Alumina	0.80
Silica	2.32

This coal contains 6,756 calculated heat units. One pound will convert 10.3 lbs. of water from 0° Cent. (32° Fahr.) into steam at 100° Cent. (212° Fahr.).

From this it will be seen that one ton of the Indiana block coal will convert into steam, from 0° Cent. (32° Fahr.) to 100° Cent. (212° Fahr.), 22,-800 lbs. of water, while the Illinois coals will only convert into steam, under the same conditions, 20,800; a difference of 2,000 pounds in favor of the block coal, or nearly eight barrels.

In addition to its superior heat-producing properties, the Indiana block coal contains a minimum quantity of sulphur and ash, while the other coals contain these injurious diluents in great excess.

I need hardly dwell upon the injurious effect which the sulphur exerts upon grate bars, fire boxes and boilers, where it is used for generating steam, since it is well known to all intelligent engine drivers that when the sulphur is brought in contact with red-hot iron it causes it to fuse or lose its tenacity; thus, the sulphur from coal will destroy grate bars, fire boxes, and, sooner or later, the boilers themselves.

The pyritiferous ash of the Illinois coals will also give great trouble, since it will fuse into clinkers, which, by their rapid accumulation, stop the draft and otherwise derange the perfect combustion of the coal, so that frequent stops must be made, or favorable moments taken, to remove them from the fire chamber. On passenger trains using such coals, much inconvenience is also experienced by the passengers, who are compelled to inhale the sulphurous fumes which escape from the smoke-stack and are wafted back into the coaches by the motion of the train.

No inconsiderable part of the commercial value of a coal depends upon its strength and resistance to atmospheric agencies, which cause it to crumble and waste when stocked. In this respect, again, Indiana coal will endure stocking for years without deterioration or loss from crumbling, while Illinois coals will crumble into dust from the decomposition of sulphide of iron which it contains in such large quantities. It is given in Trautwine's "Engineer's Pocket Book" that 4.47 tons of water will carry a passenger train 20 to 30 mi., or even more if the grades are light. Then, assuming for the sake of comparison, that the evaporation of 4.47 tons of water will run a given train 25 mi., one ton will run it 5.7 mi. Now, a ton of Indiana block coal will convert into steam one ton more water than the Illinois coal; consequently, it will, under like conditions, run a train 5.7 mi. farther than the Wilmington or Minonk coals—a difference of more than 20 per cent. in favor of Indiana coal. Indeed, so different is the Indiana block coal from the Illinois coals here reported on, chemically and physically, that they can not rightly come into competition for steam and house purposes, where a due regard is paid to economy of fuel, safety to machinery, comfort and health.

E. T. COX,
State Geologist.

Indianapolis, March, 1876.

2257. Steam Value of Indiana Coal in Practice.—Believing that the truest test of a coal is its behavior in practical work, considerable correspondence was entered into with leading firms all over the State in a large variety of industries, to ascertain, if possible, how Indiana coal compared with other coals, especially Pittsburg, as that is often taken as a standard—first, in steam producing power per ton of coal; second, in steam-producing power per dollar of fuel cost; third, in production of ash, effect on grate-bar, etc., etc.

Our inquiries were very liberally responded to, though, unfortunately, but a small percentage of those written to have had experience with other than Indiana coal, or in some cases only with some other coal, and still fewer could give definite figures.

In regard to the comparative steam-producing power of Indiana coal as compared with other coals, the replies on the whole indicate a difference in favor of Pittsburg coal about in accord with the conclusions drawn from a comparison of their analyses.

Before giving recent correspondence it may be well to quote a test made some years ago and printed in the report for 1883 (p. 41):

Mr. J. J. Turner, Superintendent of the Indianapolis & Vincennes R. R., made for some weeks a careful test of the comparative merits of Indiana coal (from Greene county) and the celebrated Pittsburg coal, with especial reference to locomotive purposes, with the following results:

	Pittsburg.	*Indiana.*
Wheels hauled one mile per ton of coal..........	.97	.99
Gallons of water evaporated per ton of coal......	.53	.52
Average temperature during test................	39.00	39.90
Total consumption	.40	.35

Turning to the recent correspondence, we find a considerable difference of opinion, as may be judged from the quotations that follow.

In general the users of Indiana coal seem well satisfied. The following extract is a sample of the expressions used by many:

We are buying altogether Indiana coal. This coal we can state we find satisfactory, as far as steam producing per dollar of fuel cost is concerned and as regards production of ash or effect on grate bars.

That in many cases this satisfactoriness is largely due to the financial aspect of the case is evidenced from such letters as the following:

We use Indiana slack coal and have never used much else. We find it satisfactory, price considered, but from what Pittsburg and Ohio coal we have used, we think it will do 25 per cent. more work pound for pound. We have no figures on which to base this assertion, so you may consider it a random statement.

While, without definite knowledge, I judge that the comparison in this case, as in many others, is between Indiana slack and Pittsburg lump. Slack coal, as is very well known, suffers a great loss as compared with lump coal, in transportation, and in burning by dropping through the grate, even where especially designed grates are used.

Perhaps a still greater scurce of loss is from the oxidations of the volatile hydrocarbons, which may be insignificant in lump block coal, but may be very high in a wet slack coal, amounting in some cases to as much as half the heat value of the coal. See paragraphs on weathering of coal, further on. We regret that more emphasis was not laid in our inquiries, that the form of the coals compared be given, as it would seem probable that in such cases as the above and others Indiana slack is compared with eastern lump, or, in other words, low-grade Indiana coal is compared with high-grade eastern coal, though we do not know that such is the case.

Again, in some cases the use to which the coal is put makes a great difference. Thus, from an extensive tool works they write:

> We are consumers of different kinds of coal, but do not use any Pittsburg coal. Our Indiana coal we use only for steam purposes. We use anthracite, Virginia smithing coal and Connelsville coke, and, of course, we find that the last three named items are much superior to the Indiana coal, although for steam purposes our Indiana coal can not be excelled.

A gentleman familiar with the use of Pittsburg and Linton coal at a city water works plant and at a large stone quarry writes:

> We use (at the water works) Pittsburg mine run, as it only takes about half as many cars of coal as Linton coal. * * * Linton coal is a good steam coal, and at the quarry there has not been such a marked difference in cost. We consider the Pittsburg about the same cost as Greene county. (At 50 cents per ton more.) The difference in the two plants, I think, comes from a different demand—one for a slow fire and the other a full fire, the Pittsburg holding the fire better.

We have regretted not being able to give more definite figures, as, after all, they tell the story better than opinions not based on figures. The most definite figures obtained were from a "very careful ten days' test" of "Indiana block coal and Ohio lump" in one of our large water works plants, which gave the following:

	Tons.
Ohio coal used in ten days	75,487
Brazil coal used in ten days	61,600
Difference	13,887
Ohio coal required to pump 1,000,000 gallons of water	6.7
Indiana coal required to pump 1,000,000 gallons of water	6.5
Difference 420 lbs. or	.2
	Lbs.
1 ton of Ohio coal makes ashes	172
1 ton of Brazil coal makes ashes	149

Other figures will be given under the next heading.

2258. As regards the comparative value of block and bituminous slacks, the following letter from a prominent foundry in Brazil is of interest:

Referring to your letter of the 29th ult., will say that Indiana block coal is equal to any coal in its freedom from sulphur, but, in our opinion, does not make as much heat as Pittsburg or West Virginia coal, and is, of course, much cheaper in this locality. In using slack for steam boiler furnaces, we find the bituminous slack of this locality (which is about the same as the Illinois slack) makes greater heat than block coal slack, and is cheaper, but is far more sulphury, and hence more injurious to boilers and grates.

The letters quoted from have been selected as characteristic of those received, and, in connection with others from which we do not feel at liberty to quote, go to show quite conclusively that: First, with present practice, Indiana coal will average from 5 to 15 per cent. lower in heating power than Pittsburg or West Virginia coal. That, without regard to cost, some of the Indiana coals are better than some of the eastern coals shipped into this State. That if Indiana slack or run of mine (which usually contains a larger per cent. of slack than eastern coals) be compared with eastern coals in the same form, the heat value will be still more in favor of the eastern coals. This is probably due, as stated above, to the oxidation of the volatile hydrocarbons in the fine coal by weathering. That Indiana block coal comes nearer Pittsburg coal for most purposes than other western coals.

Among the interesting things brought out in the letters not quoted from is that many firms having experimented with different Indiana coals have selected the coal which gave them the best results, and in these selections a large variety of coals have been picked out, indicating that good coal is not confined to any one district of the State. These results indicate that the conclusions reached by a study of the analyses are very nearly correct.

2259. From the commercial standpoint a more important question than the first is: How do Indiana coals compare with other coals in steam production per dollar of fuel cost? In most cases the question is not: What is the best coal? but, What coal will give the most power per dollar of cost? In this case location plays a most important role, inasmuch as it influences the cost of coal through freight charges. Let us take an example: One pound of Coal A will evaporate 10 lbs. of water; 1 lb. of Coal B will evaporate 9 lbs. of water. Which will be the cheaper coal to use when A costs $2.25 at the engine room, and B $2.00 at the engine room? To evaporate 900,000 lbs. of water will require 45 tons of A or 50 tons of B; 45 tons of A cost $101.25; 50 tons of B cost $100.00; difference, $1.25, apparently in favor of cheaper coal. But when it is considered that 5 tons more of B have to be handled, with a corresponding increase in ashes to be removed, the difference about disappears, and may easily be reversed if the coal requires much handling. If, however, we assume A to cost $2.50 and B $2.00, the difference in evaporating 900,000 lbs. of water is $12.50, a difference that would ordinarily much more than pay the extra cost of handling. From the above example we might formulate a very general rule, as follows: Where the best heating effect of two coals is in the ratio of 9 to 10 (about the ratio between Indiana and Pittsburg coal), it will be more economical to use the better coal if its cost be not more than one-eighth above the cost of the poorer coal. If it be more than that, the poorer coal will yield the better results for the money. This rule makes no account of sulphur, character of ash, of smoke, and numerous other factors that may in practice greatly affect the problem.

Indianapolis is situated about 70 mi. from the Brazil block field and 90 mi. from the Linton field, and the conditions there may be taken for most of the towns within 100 mi. of the Indiana coal field. On December 9, 1898, the retail price of domestic coals in Indianapolis was as follows:

Indiana coal from Linton	$2 75
Indiana block coal	3 00
Pittsburg, Pocahontas, etc.	4 00
Slack coal on switch, to large consumers	75

Cost of Pittsburg over Brazil block, one-third. Cost of Pittsburg over Linton coal, five-elevenths. Under the rule given above, Pittsburg coal could not compete in this market with Indiana coal.

In 1896 steam coal (Indiana) and domestic coals ranged in Indianapolis as follows:*

	Domestic Coals.				Steam Coal.			
	Wholesale.		Retail.		Wholesale.		Retail.	
	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.
Brazil block	$1 75	$1 45	$3 00	$2 50	....	....	....	....
Linton	1 50	1 35	2 75	2 25	$0 85	$0 45	$1 50	$1 00
Pittsburg	2 25	2 05	2 75	3 00	....	....	....	....

* Mineral Resources of U. S. for 1896, p. 386.

No quotations were given for foreign steam coals. That Pittsburg coal can not compete in Indianapolis is evident from the letters received from Indianapolis firms, of which it is only necessary to quote from one or two of the largest concerns here:

> The Indiana coal can be laid down at Indianapolis at so much less than Pittsburg, that Pittsburg coal is hardly considered available in this district for fuel purposes for large plants.
>
> We have not used Pittsburg coal. It is too expensive for our use. We burn mixed nut and slack under our boilers, and get such coal here in Indiana.

South Bend is about 200 mi. from Brazil, only places in the extreme northeastern corner of the State exceeding it in distance. It may therefore be taken as representing the extreme of unfavorable conditions for Indiana coal on account of the long haul for Indiana coal. It will therefore be interesting to know how Indiana coal competes with outside coals there. Here, again, results differ. The fact that, as might be expected, South Bend is on the border of the Indiana market has led many of the large firms there to make more or less extensive tests.

Reference has already been made to tests by the City Water Works Department. From the financial standpoint these gave the following results:

Ohio coal used in ten days..	75.487 tons, at $2.82 per ton.	$212 97
Brazil coal used in ten days.	61.600 tons, at $2.44 per ton.	150 30
Difference	13.887	$62 67
Cost of pumping 1,000,000 gallons of water with Ohio coal		$18 80
Cost of pumping 1,000,000 gallons of water with Indiana coal		15 98
Amount saved per 1,000,000 gallons pumped with Brazil coal........		$2 82

We have already quoted from a firm there who prefer Indiana coal, on account of the price, even though in their opinion Pittsburg coal will do 25 per cent. more work. One of the largest plants in the State, situated there, writes:

> We have made very exhaustive tests on this question. * * * In a general way, the Indiana coal does not compare with the Ohio coal as to quality. Taking into consideration the freight, we are using Indiana coal.

On the other hand, some of the tests seemed to give the opposite result. Thus, another of the large plants there writes:

Can only say that our experiments have not been as thorough as they should have been to give you the data you desire. * * * We are now using, and have been for some months, a Youghiogheny coal from the Pittsburg district. This is a better coal for steam purposes, as well as for use in annealing ovens, and, while the cost per ton is slightly higher, delivered in our yards, the quality is much superior, and the actual saving on a financial basis is 7.2 per cent. Aside from this, there is a saving in the handling, as a less quantity is burned, and the cost of truckage and of unloading is also materially decreased, owing to a considerably less quantity having to be handled per day.

Another large firm writes:

We have made some experiments with Indiana block coal and also with Pennsylvania coal. The crude results, without any corrections, are as follows: With Pennsylvania coal at 25 cents per ton above Indiana block, we found a difference of about 15 per cent in favor of Pennsylvania coal.

These and other letters from South Bend indicate that its distance from the Indiana field is so great that the freight charges on Indiana coal make it cost almost if not quite as much as Pittsburg, from the standpoint of steam produced per dollar of fuel cost. The balance of evidence in this case seems to be a little in favor of the Indiana coal. Now, an examination of the State map will show at once that there are only a few towns in the northeastern corner of the State that are farther from the Indiana coal field than South Bend. And, while, in going east instead of northeast of the Indiana coal field, the same conditions as at South Bend will be found at a less distance from Brazil (on account of the reduced haul for Pittsburg or Ohio coals), still it is believed that, except the limited areas that get water transportation from the east, over the greater part of the State, Indiana coal will do more work than outside coals per dollar of fuel cost. Of course, local conditions, as long haul by wagon, etc., will materially modify these conclusions. We are led to this conclusion, not alone from the arguments given above, but because they seem to be backed by the experience of our correspondents at numerous places. Thus, Laporte is but a little within the limits given, but the two following quotations are samples of the letters from there:

We do not use any Ohio, Pennsylvania or Virginia coals; freight charges on this stock are against us, and we are buying altogether Indiana coal.

Last year the strike was prolonged and we used Pittsburg and West Virginia coals, and, while they burn and make steam satisfactorily, yet they are so dear that we were glad to get a supply of Island coal again.

In general, therefore, we are led to conclude that, for a steam coal to be used in Indiana, Indiana coal gives the best results for the money.

In comparing different coals, different results are often the result of different adaptability of the furnace to the fuel used. The best furnace and best method of firing is the one which gets the highest value out of the coal, and these differ greatly for different coals. Thus certain coals require a special form of grate, a certain thickness of fire and a certain amount of draft to yield good results. Another coal which, under proper conditions, will yield as good or better results, may, if burned under the conditions favorable to the first coal, appear to be of very inferior quality. Thus in an actual test of a certain coal it evaporated 6.32 lbs. of water per pound of coal, but, deducting what fell through the grate (for it was a very friable coal), it was found to have evaporated 10.5 lbs. of water per pound of combustible. Pittsburg coal, in the same furnace, under a similar test, showed 8.41 and 9.10 lbs. of water evaporated per pound of coal and per pound of combustible, respectively. In this case the character of the furnace made the Pittsburg coal seem much the stronger, while actually the two coals had the comparative strength of 100 to 115.

(b) Through Electricity.

2260. At the present time an electric current is obtained from coal by first burning the coal to produce steam, expanding the steam to produce mechanical motion, using the mechanical motion to drive a dynamo. At each step of the process much energy is lost, so that the energy of the electric current finally obtained amounts to only one-tenth to one-hundredth of the energy possessed by the coal. The high efficiency of electric dynamos and the facility with which energy can be transmitted for short distances by an electric current has led to much thought and time being given to the problem of obtaining an electric current directly from the combustion of the coal. While much progress has been made, the matter must still be considered in the experimental stage, and therefore will receive only this passing notice here.

Suffice to say that the most successful work has been done by Dr. W. W. Jacques and by Dr. Alfred Cochn. The Jacques process consists in brief in blowing air through a bath of fused caustic soda with a carbon anode and an iron cathode, by which is obtained a large current with a small voltage. The work of these investigators is discussed quite fully in the technical magazines of the past few years.

(B) INDIRECT PRODUCTION OF DIRECT RESULTS.

(a) CONVERSION OF COAL INTO GAS.

2261. This phase of the subject has for us in Indiana the widest interest, for several reasons. Primarily the widespread and continued use of natural gas has made our people appreciate the advantages of gas as a fuel, with the consequent great reluctance to returning to the use of coal again. Second, much of our State is threaded with pipe lines, and many of our cities are thoroughly equipped for distributing fuel in the form of gas. Third, there has arisen out of the necessities of the case a class of men trained in all the practical phases of gas transportation and distribution. Fourth, Indiana coal is high in gas or the volatile hydrocarbons, and if the coal can be burned in the form of gas it will yield a much higher efficiency as compared with other coals than at present. Fifth, while at present large consumers of coal for power purposes are using slack, formerly a waste product, and obtaining it often at a price below all competition, yet it seems evident that it is only a question of time, and that not long, when this increasing demand for cheap coals will raise the price, until, in the words of one of the largest shippers of coal in the State, the size of the coal will have nothing to do with its selling price, but lump and slack will sell for the same or at prices proportional to their heating value. Sixth, the gradual improvement of the gas engine with efficiencies of 20 per cent. or more from the gas or 15 to 20 per cent. from the coal, and of the new heat motors recently introduced in Europe, with an efficiency of over 34 per cent. as against 4 to 14 per cent. for steam engines, is likely in the future to create a constantly increasing demand for gaseous fuels.

Accordingly, the question is a common one with thinking men all over the State: "Can we not utilize our coal fields in the production of a gas that shall take the place of the natural gas when that gives out?" Realizing the importance of this subject, the writer had hoped to give the matter considerable study, but there proved not to be time, and the best he is able to do is to present a sort of summary of a few of the well-known processes and such scattered facts as could be picked up in a few hours' reconnoissance in this field. It is hoped they may be suggestive and may interest competent persons sufficiently to induce them to go deeper into the subject, with the result of the final practical solution of the problems presented.

Coal is a solid, yet it requires but a small amount of heat to drive off a large volume of gaseous matter, and there is left a light porous solid known as coke. The larger part of this gas is combustible, and, what is more, a pound of it when burned will yield a larger amount of heat than a pound of the carbon which is left, and which, in the present method of burning coal, is mainly depended upon for the production of heat. Further, if the carbon remaining be burned with an insufficient supply of air or oxygen, there is formed carbon monoxide, CO, which is a combustible gas, and still has a large part of the heating power of the carbon. This suggests very briefly how the solid fuel coal may be converted into a gaseous fuel. In practice, quite varying processes are used, yielding quite different results.

The different results obtained may be tabulated as follows:

Illuminating gas or coal gas.
Producer gas.
Water gas.
Dowson or semi-water gas.
Rose-Hastings and other modifications of above.
Acetylene gas.

The principles underlying and main operations in the production of the above gases may be briefly stated:

2262. ILLUMINATING GAS.—This gas is simply the volatile hydrocarbons of the coal which are driven off by heat. In practice it is made in two ways—in a closed retort when the gas is the object sought, and in a modified retort, the coke oven, in which the coke is the product desired and the gas is too often wasted.

In the first case the coal is placed in a series of clay retorts to which air has not access and heated in furnaces until the volatile matter is driven off. After coming off from the retort, it, the gas, is carried through a series of purifiers which remove the tar, ammonia, sulphur and other impurities. This, the ordinary process of making "artificial gas," is too well known to need lengthy description.

The second case is only a modification of the first, although a different object is in view. The ordinary bee-hive coke oven is like a gas retort in principle, except that the heat necessary to produce the coke is obtained by the combustion of part of the charge of coal. In the more modern coke oven, however, the principle of the gas retort is more closely followed, and the heat is derived by the burning of part of the gas in flues in the side walls of the oven. In this case the two processes are quite similar, except that the coke retort is five or six times as large in each dimension, and in the first case the heat is supplied by part of the coke, which is there a by-product, while in the other case the heat is supplied by part of the gas. In the latter case the gas deprived of its tar, ammonia and benzole before being burned in the oven flues. In the first case all the gas is obtained, in the latter not much more than half. Whether tried or not, the suggestion has been made that the heat necessary for the coking might be supplied by producer gas, which is much poorer and cheaper.

2263. PRODUCER GAS.—This gas is made by forcing air into an incandescent mass of coke. In principle, the air, as it enters the combustion chamber, supplies oxygen to the carbon of the coal and there is formed CO_2 as in most cases of the combustion of the coal; but as it passes upward through the mass, this CO_2 meets large quantities of uncombined carbon, and this unites with part of the oxygen of the CO_2, leaving CO and forming large additional quantities of CO. So that the gas that passes off is composed mainly of CO and the inert nitrogen (N) of the air. The gas which passes off from a blast furnace is largely of this nature, and early forms of retorts for making producer gas were modeled after the blast furnace, a type that is being returned to. As just stated, producer gas contains a large percentage of nitrogen. This formed four-fifths of the air driven into the furnace, and necessarily passed on and became part of the gas resulting from the process. As it will not burn nor support combustion, it becomes that much dead matter in the gas. Various attempts have been made to find a process of cheaply withdrawing the nitrogen, but, as it does not combine actively, these efforts have as yet met with small success. Better success has been met with by substituting a gas for the air that, while supplying the oxygen, contained no inert gas. The substance used is water in the form of steam, and the product is called water gas.

2264. WATER GAS is made by forcing a current of superheated steam through a mass of incandescent carbon in the form of coal or coke. In this case, instead of the nitrogen associated with the oxygen, as in the air, we have hydrogen (H) united with the oxygen, but in the presence of the highly heated carbon the union is broken up and the oxygen unites with the carbon, as before passing out as CO, but in this case associated with hydrogen, a highly combustible gas, instead of nitrogen. In this case the associated gas, hydrogen, is of small volume and consequently the quantity of gas produced per ton of coal is much smaller than in the manufacture of producer gas, but makes up by being much richer. Unfortunately the process is not continuous, as the heat required to disassociate the steam tends to cool the mass of carbon below the point where the desired changes will take place. It is therefore necessary to first drive air through the mass until its temperature is sufficiently high, when the air is turned off and steam is driven through. The plant required may be described as an upright retort or generator, a boiler for generating steam, a superheater, and a fan for drawing the gases through the retorts. Frequently two or more retorts are used, alternating in their action. As the gas produced is nonluminous it is usual to add to the gas as it passes through the top of the generator a small quantity of some form of petroleum, and as the gas is drawn through the superheater this petroleum is broken up into the lighter fixed gases, thereby greatly enriching the water gas; when thus enriched water gas is known as carburetted water gas. It is not necessary here to go into the details of the process, and it will of course be understood that as little heat as possible is wasted, the superheaters and boilers being heated from the heat carried out by the gases.

2265. Dowson, or Semi-Water Gas is a result of a combination of the principles of the manufacture of water gas and producer gas, as in it a combined current of air and steam is driven into the retort or generator, the air being in sufficient amount to keep the mass of carbon at the high temperature necessary. This gas, as might be expected, contains a large mixture of nitrogen, but it contains a higher percentage of combustible gases than the producer gas.

2266. Modifications of the Above Processes.—A difficulty encountered with much of Indiana's coal in the manufacture of these gases is its caking property, a property that would seriously interfere with drawing a current of air or steam through any considerable mass of it. The suggestion is made that the gas could be successfully made by first driving off the volatile hydrocarbons in a coking retort and then transferring the coke so produced to retorts or generators without cooling. It would seem as though such an apparatus could be devised, by which the coking and generating could be carried on simultaneously, the coking retorts perhaps being placed above the generators so that the waste heat of the generators would do the coking while the coke could be transferred without cooling to the generators below. The gas from the coking retorts, ordinary coal gas, would then be mixed with the gas produced in the generator, whether that be producer, water or Dowson gas.

Other processes for utilizing bituminous coals are already in the market. As an illustration of these may be described the Rose-Hastings process, which is being tried with success at Louisville, Ky. The following brief description of this process is given by Mr. Joseph D. Weeks in the 16th Ann. Rep. Geol. Surv. U. S., Part IV, Mineral Resources, p. 419: "This process * * * uses soft coal and what are known as cumulative generators. The plant in operation at Louisville can be described as having four upright retorts or generators and one superheater, all set in a circle. Soft coal is charged into three of these retorts and coke into the fourth. Air is driven through the three coal chambers, burning a portion of the coal and heating them to a high temperature, the resulting hot gases being meanwhile carried down through the coke, in this way heating it up without burning it. The heat necessary to start the blast and also that required to bring the coke to the finishing temperature is gained by a short blast upward through the coke. When the machine has been brought to the right heat and before the blast is stopped, a charge of soft coal is dumped into each one of the coal chambers. The blast is then stopped and steam turned under each of the coal chambers, and, mingling with the coal gas distilled off from the fresh charge of soft coal, passes over to the coke chamber, down through the red-hot coke, where it has the vapors of oil changed into fixed gases, and up through the superheater, where this process is thoroughly completed."

Since writing the above we have received from the Bridgewater Gas Company, of East Liverpool, Ohio, a short description of the process they are using by which they are enabled to produce a gas that competes with natural gas at 20 cents a thousand for domestic use. The main features of the process seem to be that instead of blowing air through the coal, as in making producer gas, the air is first driven through manganate of soda, which absorbs the oxygen. The oxygen is then released with steam and the steam and oxygen driven together through the generator. This surplus of oxygen is sufficient to keep the temperature of the mass up to the point where the steam is dis-associated and so the process becomes continuous. The bituminous coal found in that section is used. The result is a gas of about 500 heat units.

At an experimental plant erected at Scranton, Pa., by Mr. J. Gardner Sanderson, he claims that by actual measurement they were able to produce and store from 120,000 to 188,000 cu. ft. of gas with one ton of fine waste from the washing of anthracite culm. That was from what was left after the marketable sizes had been screened out.

2267. Acetylene Gas.—This gas, which has only recently been introduced commercially, and especially for lighting, is made by quite a different process from the others. The gas has the formula C_2H_2 and is made by the action of CaC_2 or calcium carbide on water. The recent notable extension in the use of this gas is due to improved methods of producing CaC_2 on a commercial scale. At present this is made by the action of a powerful electric arc on a mixture of powdered coal or coke and lime. The two substances are mixed in the proportion of 87½ lbs. of lime to 56¼ lbs. of carbon, which yields theoretically 100 lbs. of CaC_2, the rest passing off as CO. In contact with water this carbide yields acetylene gas C_2H_2 and CaO, H_2O.

2268. COMPOSITION OF THE GASES.—In this connection it will be of interest to add the composition of natural gas.

COMPONENTS.	Natural Gas. (Finley.)		Coal Gas.		Producer Gas.	
	*1	2	3	4	5	6
	Vol.	Wt.	Vol.	Wt.	Vol.	Wt.
Hydrogen....H	2.18	.268	46.00	8.21	6.00	.458
Marsh gas....CH_4	92.60	90.383	40.00	57.20	3.00	1.831
Carbonic oxide....CO	.50	.857	6.00	15.02	23.50	25.095
Olefiant gas....C_2H_4	.31	.531	4.00	10.01	....	....
Carbonic acid....CO_2	.26	.700	.50	1.97	1.50	2.517
Nitrogen....N	3.61	6.178	1.50	3.75	65.00	69.413
Oxygen....O	.34	.666	.50	1.43	....	....
Hydrogen sulphide....H_2S	.20	.417	....	....	....	....
Water vapor....H_2O	....	....	1.50	2.41	1 00	.686

COMPONENTS.	Water Gas.		Producer Gas.	Dowson Gas.	Sanderson Gas.	Taylor Gas.
	7	8	9	10	11	12
	Vol.	Wt.	Vol.	Wt.		
Hydrogen....H	45.00	5.431	2.80	14.00	19.85	4.51
Marsh gas....CH_4	2.00	1.931	....	....	0.66	1.79
Carbonic oxide....CO	45.00	76.041	33.30	27.20	28.80	25.38
Olefiant gas....C_2H_4	....	....	....	....	....	....
Carbonic acid....CO_2	4.00	10.622	.50	5.2	3.80	4.02
Nitrogen....N	2.00	3.380	63.40	53.3	46.46	64.04
Oxygen....O	.50	.965	....	....	0.40	0.26
Hydrogen sulphide....H_2S	....	....	....	....	....	....
Water vapor....H_2O	1.50	1.630	....	....	....	....

*Nos. 1-8 by Emerson McMillin, Geological Surv. of Ohio, VI, pp. 538-543; Nos. 9-10 by Arthur Kitson, Jour. Franklin Inst., Dec., 1890, p. 321; No. 11 by J. Gardner Sanderson, from anthracite culm at Scranton; No. 12 by H. W. Spangler, of gas made by Taylor process at Otto Gas Engine Works at Philadelphia.

It will be seen from the above that natural gas is principally marsh gas; coal gas is likewise largely marsh gas, but with considerable quantities of hydrogen, carbonic oxide and olefiant gas; producer gas is principally carbonic oxide and nitrogen, water gas principally carbonic oxide, with some carbonic acid and hydrogen. Dowson gas is principally hydrogen, carbonic oxide and nitrogen. Acetylene gas is not a mixed gas like the others. Mr. Edward H. Earnshaw gives the following analyses of coal gas and carburetted water gas:*

	Coal Gas.	*Water Gas.*
Benzene vapor	.50	.6
Heavy hydrocarbons	4.25	12.8
Carbonic acid	8.04	30.7
Hydrogen	47.04	32.4
Marsh gas	36.02	13.9
Higher paraffins	0.00	2.4
Carbonic acid	1.60	2.7
Oxygen	.39	.7
Nitrogen	2.16	3.8

2269. Weight of Gases.—These gases have the following specific gravities:†

Natural gas (Finley)	.570
Coal gas	.450
Water gas	.570
Producer gas	1.000
Air	1.000

1,000 ft. of of air will weigh at 40° F	80.0 lbs.
1,000 ft. of natural gas will weigh at 40° F	45.6 lbs.
1,000 ft. of coal gas will weigh at 40° F	32.0 lbs.
1,000 ft. of water gas will weigh at 40° F	45.6 lbs.
1,000 ft. of producer gas will weigh at 40° F	80.0 lbs.

2270. Caloric Value of Gases.—As taken from different sources, the gases mentioned yield about the following heat units in burning:

One foot of natural gas yields (about)	1,100	B. T. U.
One foot of coal gas yields (about)	730	B. T. U.
One foot of water gas yields (about)	320	B. T. U.
One foot of water gas (enriched) yields (about)	680	B. T. U.
One foot of producer gas yields (about)	150	B. T. U.

*Chemical Composition and Technical Analysis of Water Gas, Edw. H. Earnshaw, Jour. Franklin Inst., 146, p. 161, Sept., 1898.

†McMillin, Geol. Surv. of Ohio, VI, 537.

One foot of Dowson gas yields (about)	180 B. T. U.
One foot of Rose-Hastings gas yields (about)	410 B. T. U.
One foot of Rose-Hastings gas (enriched) yields (about)	650 B. T. U.
One foot of acetylene gas yields (about)	1,476.7 B. T. U.
One foot of East Liverpool gas yields (about)	500 B. T. U.

From these figures it will be seen that coal gas yields only about three-fourths as much heat as natural gas for equal volumes; water gas, unenriched, less than one-third; enriched, over one-half; producer gas, one-seventh or less, etc.

By the pound the difference is still more marked. Mr. McMillin gives the following figures:

One pound of natural gas yields	24,195 B. T. U.
One pound of coal gas yields	22,968 B. T. U.
One pound of water gas (unenriched) yields	7,069 B. T. U.
One pound of producer gas yields	1,957 B. T. U.

The difference in amount of water evaporated from a temperature of 60° F., when the resulting gases are escaping at 500° F., and when there is 20 per cent. excess of air introduced with all the gases (and in all cases ignoring radiation), has been figured out by Mr. McMillin as follows:

1,000 ft. of natural gas will evaporate 893 lbs. of water.
1,000 ft. of coal gas will evaporate 590 lbs. of water.
1,000 ft. of water gas will evaporate 262 lbs. of water.
1,000 ft. of producer gas will evaporate 115 lbs. of water.

We are now ready to proceed to the most important item:

2271. Total Heating Power of Gases from One Ton of Coal, and Cost of Same.—In the preceding paragraph it would seem that the advantage was all on the side of coal gas, or, to a less extent, of water gas. But in that it is forgotten that one ton of coal will yield much less coal gas or water gas than of producer gas or Dowson gas, and that when that factor is taken into account the difference largely disappears.

Youghiogheny gas coal yields 4.34 cu. ft. of gas to the pound of coal at the Indianapolis gas works, according to Mr. Cox, while he gives for Indiana cannel coal about 5 cu. ft. and Indiana caking coal about 4 cu. ft. According to these figures, one ton of Indiana coal would yield about 8,000 cu. ft. of coal gas. One ton of coal (anthracite) converted into CO with air gives 60,000 cu. ft., and, adding the 110,000 cu. ft. of nitrogen that enters with the air, we have one ton of coal yielding 170,000 cu. ft. of producer gas.

Mr. Kitson, from his experience,* estimates that in making semi-water or Dowson gas under the best conditions, with the steam furnished at a temperature of 500° F. from a separate boiler, 1 ton of coal will decompose 1,500 pounds of steam, yielding:

H	166 lbs. or	29,800 cu. ft.
CO	4,194 lbs. or	53,700 cu. ft.
N	5,179 lbs. or	63,500 cu. ft.
CO_2	733 lbs. or	6,000 cu. ft.
	10,072	153,000

But, deducting $\frac{1}{8}$ to $\frac{1}{4}$ of a ton for the heat necessary to raise the temperature of the steam, the results are reduced to 130,000 cu. ft. of gas, or, if the heat of the cooling gas be utilized, say 150,000 cu. ft.

Water gas, unenriched, under the best conditions yields about 40,000 cu. ft. of gas to the ton of coal.

Rose-Hastings gas, enriched, yields about 64,000 cu. ft. to the ton of coal, though in this case it should be noted that the oil and coke that enter into the process will often cost more than double what the coal costs.

In the manufacture of acetylene gas one ton of coal is used in making 214 lbs. of calcium carbide, and as one pound of the latter yields from 5.5 to 5.75 cu. ft. of gas, a ton of coal will yield over 13,310 cu. ft. of gas. Here, again, there are other items that very materially affect the result from the standpoint of cost.

Combining the figures of this paragraph with those of the last, there results as the product of one ton of coal:

Coal gas	8,000 cu. ft.×	730 B. T. U.=	5,840,000
Producer gas	170,000 cu. ft.×	150 B. T. U.=	25,500,000
Dowson gas	150,000 cu. ft.×	180 B. T. U.=	27,000,000
Water gas (not enriched)	40,000 cu. ft.×	330 B. T. U.=	12,800,000
Rose-Hastings gas (enriched)	64,000 cu. ft.×	650 B. T. U.=	41,600,000
Acetylene gas	13,300 cu. ft.×	1,476 B. T. U.=	19,630,800

Here again the figures tell only a partial story, as the desideratum is the number of heat units for a given cost, and in the different processes the initial cost of the ton of coal may be the most important item or it may be a very small item. Thus in the Rose-Hastings

*Jour. Frank. Inst., XXXVIII, 321.

process the coal in the generator represents only a little over one-fourth the cost of the materials used. Lack of time has prevented getting figures that may be used for comparison. Such figures, however, as are at hand may be suggestive.

As to the cost of making coal gas, I can do little better than to quote from an article by Mr. Edw. W. Bemis on "Recent Results of Municipal Gas Making in the United States," in Vol. VII of the Review of Reviews (American magazine). He gives the figures for ten cities which he had studied. Of these all made coal gas at the time except Philadelphia, which was using 40 per cent. of water gas (doubtless carburetted). Bellefontaine and Hamilton, Ohio, had just introduced improved processes by which the cost was much reduced. Thus at Bellefontaine, using an Askins gas plant with a capacity of 126,000 cu. ft. a day, of 22 candle power, the cost of 1,000 ft. in the holder (not counting interest or taxes) was 20 cents. Adding 10 cents for interest, etc., makes cost of making gas 30 cents per 1,000 ft. The distribution will cost from 10 to 30 cents extra.

At the cities to be mentioned coal ranges in price from $1.64 at Wheeling, W. Va., to $4.39 at Danville, Va. Of the by-products the coke sells at these cities for from 3.5 cents at Wheeling to 10 cents at several of the cities; tar, per barrel of 50 gallons, sells at from $1.32 at Richmond, Va., to $3.90 at Hamilton, Ohio.

The desired figures are included in the following table:

CITY.	Cost in Holder, in Cents.	Cost at Point of Consumption, in Cents.	Interest at 5 Per Cent. and Taxes at 2 Per Cent., in Cents.	Total Cost per 1,000 Feet, in Cents.
Philadelphia	48	85.5	20.6	106.1
Richmond, Va	Others not determined.	84.3	23.1	107.4
Alexandria, Va		94.3	29.3	125.6
Henderson, Ky		58.1	32.3	80.4
Wheeling, W. Va		35.4	20.4	55.8
Bellefontaine, Ohio		63.7	30.8	94.5
Danville, Va		107.7	32.7	140.4
Charlottesville, Va		46.5	38.8	85.3
Hamilton, Ohio	42.2	52.4	43.3	95.7
Fredericksburg, Va	......	127.1	47.0	174.1

In many of the above cases local causes serve to account for the difference exhibited.

It is quite probable that since that article was written (1893), advanced methods have very materially lowered the figures given. The utilizing of the coke to make water gas to be enriched and mixed with the coal gas is making considerable saving.

For comparison, the cost of 1,000 cu. ft. of illuminating gas as made in Indianapolis in 1896-97 is given. (From detailed report made June 18, 1899, of an examination of the books of the Indianapolis Gas Company for the mayor and board of public works.)

Coal	$0.206
Cannel coal	.017
Lime	.011
Naphtha for Lowe gas process	.027
Other materials	.077
Cost of materials	$0.338
Labor at works	$0.180
Superintendence	.028
Taking meter statements	.036
Clerk hire	.029
General office salaries	.050
Main items of labor, etc	$0.323
Repairs at works and residual expense (freight, etc.)	$0.133
Repairs, lines, etc	.055
Operating pipe lines	.043
Repairs, etc	$0.231
Taxes	$0.065
Other items	.054
Total	$1.011
Less receipts from residuals	.326
Net cost of 1,000 cu. ft. (not including interest on investment)	$0.685

From this it would seem that the cost of the gas in the holder was:

Materials	$0.338
Labor and superintendence	.208
Repairs and residual expense	.133
	$0.679
Less receipts from residuals	.326
	$0.343

While the cost of distribution, etc., is practically an equal amount.

These figures are for a yearly output of practically 200,000,000 cu. ft. From statements of the officers of the company, it was evident that by more than doubling the output the cost per 1,000 ft. would be materially decreased, possibly one-fourth; that is, on a basis of an output of 500,000,000 cu. ft. a year, the costs would be nearer:

Cost in holder	$0 28
Distribution, etc.	22
Selling price	75

The gas produced is a mixture of coal gas and carburetted water gas, no natural gas being used, according to the statement of the company.

The figures for from February 1, 1898, to February 1, 1899, gave a net cost of 69.81 cents per 1,000 cu. ft. The same week this report was made the local gas company of Cincinnati made a proposition to the Board of Public Works for a 20-year franchise on the basis of selling illuminating gas for 75 cents per 1,000 cu. ft. and fuel gas at 50 cents per 1,000 cu. ft. This is mentioned as showing the downward tendency in the cost and selling price of coal gas.

Mr. Weeks gives the following figures of materials used and cost at assumed prices of these materials in the manufacture of Rose-Hastings gas, having been favored with a statement as to the actual amount used in making over 10,000,000 cu. ft. of 20 candle power gas at the Louisville works.

Materials used to make 10,596,000 ft. of Rose-Hastings gas—

Oil	gallons	21,325,000
Soft coal slack	lbs.	328,503,900
Coke	lbs.	60,932,175
Boiler coal	lbs.	87,954,270

Average per 1,000 cu. ft.—

Oil	gallons	2.01
Coal	lbs.	31.00
Coke	lbs.	5.75
Boiler coal	lbs.	8.30

By taking a location where oil is 1.5 a gallon, coal $1.20 a ton, coke $2.40 a ton, which approximate the conditions at Indianapolis, the cost of materials per 1,000 cu. ft. would be:

	Cents.
Oil, 2.01 gallons, at 1.5 cents	3.02
Coal, 31 lbs., at $1.20 a ton	1.86
Coke, 5.75 lbs., at $2.40 a ton	.67
Boiler coal, 8.3 lbs., at $1.20 a ton	.38
Total	5.93
Add for labor	1.60
	7.53

This of course does not include interest or taxes, etc. Distribution would amount to, as before, 10 to 30 cents per 1,000 ft.

This plant is used to augment the supply of natural gas on cold days, etc.

Mr. Kitson estimates that with coal at $3 a ton it should not cost over 2.5 cents per 1,000 ft. to make Dowson or semi-water gas. I judge that would not include labor, interest, taxes, etc.

I have not at hand figures giving cost or estimates of cost of water gas.

In a paper in the Journal of Franklin Institute, No. 139, p. 321, Mr. J. J. Suckert expresses his belief that calcium carbide can be obtained at a cost of $5 a ton. He gives tables showing the debit and credit sides of the account of a firm who are making it as a by-product in the manufacture of fire and dry-pressed brick, in which the calcium carbide is credited as selling at $7 a ton. In other articles describing its manufacture, the cost of manufacture is placed variously at from $20 to $40 a ton. If it can be made for $5 a ton, the cost of materials for 1,000 cu. ft. of acetylene gas would not be far from 50 cents.

From the above figures we may derive the following:

Cost of 1,000 cu. ft. of coal gas (material and labor only), say	33.33	cents.
Cost of 1,000 cu. ft. of Askins gas (material and labor only), say	20.00	cents.
Cost of 1,000 cu. ft. of Rose-Hastings gas (material and labor only), say	7.53	cents.
Cost of 1,000 cu. ft. of Dowson gas (material and labor only), say	2.50	cents(?)
Cost of 1,000 cu. ft. of acetylene gas (material and labor only), say	50 00+	cents.
Cost of 3,000 cu. ft. of coal gas (material and labor only), say	$1.00.	
Cost of 5,000 cu. ft. of Askins gas (material and labor only), say	1.00.	
Cost of 13,200 cu. ft. of Rose-Hastings gas (material and labor only), say	1.00.	
Cost of 40,000 cu. ft. of Dowson gas (material and labor only), say	1.00.	
Cost of 2,000 cu. ft. of acetylene gas (material and labor only), say	1.00+.	

$1.00 worth (per cost) of coal gas yields	3,000 × 730 = 2,190,000	B. T. U.
$1.00 worth (per cost) of Rose-Hastings gas yields	13,200 × 650 = 7,580,000	B. T. U.
$1.00 worth (per cost) of Dowson gas yields	40,000 × 180 = 7,200,000	B. T. U.
$1.00 worth (per cost) of acetylene gas yields	2,000 × 1,476 = 2,952,000—	B. T. U.

As stated above, these figures must not be considered as representing with any accuracy the comparative value of the different gases, but may be considered as showing that, as far as our data goes, carburetted water gas, semi-water gas and modifications of these yield many times as much heat per dollar of cost as the common illuminating or coal gas.

Mr. F. C. Phillips, of Western University, Alleghany, Pa., has calculated the calorific power of natural gas,* and his figures show for 1,000 cu. ft.:

Available heat units: 261,190 to 324,210.
Pounds of water (previously heated to 100° C.) evaporated: 1073.8 to 1333.
Pounds of pure charcoal equal in heating power: 71.26 to 88.45.

But it is found that in practical use the natural gas has an efficiency much greater than that of the coal, so that practically one ton of Pittsburg coal is equivalent to less than 22,400 cu. ft. of natural gas, or it may be safe to say that one ton of Indiana coal is equivalent to 20,000 cu. ft. of Indiana gas.

In the 18th Ann. Rep. of the U. S. Geol. Surv., Mineral Resources, except coal, p. 897, Mr. F. H. Oliphant gives the following equivalents:

Twenty cubic feet or 1 lb. of natural gas will evaporate 20 lbs. of water at 212°.

Sixteen cubic feet of natural gas or 1 lb. of oil will evaporate 16 lbs. of water at 212°.

Ten cubic feet of natural gas or 1 lb. of coal will evaporate 10 lbs. of water at 212°.

Ten cubic feet of natural gas, therefore, equals 1 lb. of coal, or 20,000 cu. ft. of natural gas equals 2,000 lbs. or one short ton of coal; 4,800 cu. ft. of natural gas equals 300 lbs. of oil (1 barrel 34° B.); 4⅙ barrels of oil equals 1 ton of coal.

Mr. Leach, State Supervisor of Gas, reports tests made at Kokomo, Ind., in which the results gave:

One ton of Indiana coal did same work as 20,000 cu. ft. of natural gas.

One ton of anthracite coal did same work as 29,527 cu. ft. of natural gas.

Boiler required 1 cu. ft. per minute per horse power, or 60 cu. ft. per horse power hour.

The Standard Oil Company, according to "Steam" (published by Babcock & Wilcox Company), estimate that 173 gallons are equal to a gross ton of coal, allowing for incidental savings, as in grate-bars,

*Am. Chem. Jour., XVI, 406-429.

carting ashes, attendance, etc. This is but a trifle below the other estimate, as it makes 4.11 barrels of oil equivalent to 1 ton of coal.

Taking the general figures that, bulk for bulk, coal gas will evaporate two-thirds as much, and enriched water gas one half as much as natural gas, we obtain the following costs of the different fuels necessary to evaporate 10 tons of water:

Fuel.	*Amount required.*	*Cost.*	*Total.*
Coal	1 ton,*	$1.00 to $4.00 per ton (delivered)	=$1.00 to $4.00
Natural gas	20,000 cu. ft.,	05 to 20 per 1,000 (delivered)	= 1.00 to 4.00
Oil (crude)	173 gal.,	015 to 03 per gal. (delivered)	= 2.59 to 5.19
Coal gas	30,000 cu. ft.,	25 to 35 per 1,000 + $0.25 to $0 35	=15.00 to 21.00
Water gas	40,000 cu. ft.,	08 to 18 per 1,000 + 15 to 30	= 9.20 to 16 80
Rose Hasting	40,000 cu. ft.,	08 to 12 per 1,000 + 15 to 30	= 9.20 to 16.80
E. Liverpool, etc	40,000 cu. ft.,	08 to 12 per 1,000 + 15 to 30	= 9.20 to 16.80
Dowson or semi-water gas	120,000 cu. ft.,	025 to 05 per 1,000 + .05 to .10 for delivery.	9.00 to 15.00

These figures must not be considered as more than suggestive of comparative results. They indicate, first, that with gas at the present price in Indianapolis ($0.06 to $0.10 a thousand cu. ft.), coal can not compete for domestic use nor can any artificial gas be made to successfully compete with it, nor would it be feasible for the present natural gas companies to supplement their natural gas supplies with an artificial gas during times of excessive demands, as during extreme cold weather. Second, that with present prices, or probable future prices with present methods, artificial gases can not be made to compete with coal from the financial standpoint, though there would be some competition due to natural advantages of a gaseous fuel over a solid fuel. Third, they indicate that for fuel purposes coal gas can not compete with strictly fuel gases. Fourth, that as between the different fuel gases the margin of favor is not strongly on the side of any one gas or process, as far as the information we were able to obtain goes. In general, that with present methods the advantage will all be on the side of coal.

If, for a moment, we consider present tendencies, it will be evident that the tendency will be for the gaseous fuels to gain in advantage over coal, and, in view of the failure of natural gas, for artificial gases to gain over natural gas. For, while coal has shown a slight downward tendency in price, artificial gases for fuel purposes have shown a marked decrease in cost of production. Further, coal mining has reached a stage where improvements will lower the price but small fractions at a time, while fuel gas engineering is still in a somewhat primitive stage. Again, mechanical engineering appears to be having

*Say 1.3 tons Indiana slack.

much greater success in raising the efficiency of gas engines than in increasing the efficiency of the steam engine. And still further is the constant gain in the efficiency of transporting potential energy in a gaseous form rather than in the solid form. These and other factors seem to show the tendency to be in favor of artificial fuel gases. Thus I would make the suggestion that to secure the highest efficiency, other things being equal, a gas made mainly from coal should be made in the mine. That is, having prepared a point in the mine by replacing the pillars of coal with stone or masonry and secured the necessary height of rooms by taking down roof or taking up the floor, set up the plant for the manufacture of gas at that point. By this plan the principal raw material would be obtained at a minimum, nor does it appear that in most cases this advantage would be offset by other disadvantages.

Considering these tendencies, it seems safe to predict that within a very few years it may be possible, by using the best processes under the best conditions, to sell a fuel gas in cities not over 100 miles from the coal field that will be little, if any, more expensive than coal for household purposes, and which by the use of gas engines may successfully compete with coal for steam production.

2272. Transportation of Energy.—Energy is transported in one of two forms, kenetic or potential. An electric current is an example of the first, a car load of coal is an example of the second. The one is active energy, the other is stored energy. The one is subject to loss through everything that can absorb energy with which it may come in contact. For this reason it can be transmitted only limited distances, depending on the ability to insulate it from those substances which will absorb its energy. For this reason it is generally conceded that where energy is to be transmitted long distances it should be in the potential form. Electricity has taken a prominent place in recent years in the transmission of power, but experience seems to show that where the power is to be transmitted over 30 mi. it is cheaper to ship the coal than to send the same power by electricity. Mr. N. W. Perry* cites the case of the New York Edison Illuminating Station, where it is found cheaper to haul coal two miles by cart at a cost of 45 cents a ton to their plant in the heart of the city, with the enormous rents there, than to locate on the water front, where rents are cheap and the coal can be taken directly from the boat, and to transmit their electricity by wire the additional two miles. The suggestion is often made that with the high efficiency now attained by the electric dynamo

* Engineering Magazine, XII, 49.

and motor, it would be cheaper to convert the energy of the coal into electric energy at or in the mine and transmit it by large copper cables to the points at which it is to be used. The plan is attractive and it is possible may be rendered feasible by future inventions in electricity. Probably the greatest distance that electricity has been transmitted in quantity is from the River Neckar, at Lauffen, Germany, to Frankfort, a distance of 109 mi. Fresno, California, receives power 35 mi., using a triphase alternating current and pressure of 11,200 volts. Sacramento, Cal., receives 3,000 H. P. from Folsom, 24 mi. away, using the same system and a pressure of 11,500 volts. Perhaps the most notable example is the system in operation between Niagara Falls and Buffalo, with a capacity of between 50,000 and 100,000 H. P. President A. E. Kennelly, in his inaugural address before the American Institute of Electrical Engineers, says that a copper rope one-half inch in diameter will carry 2,500 kilowatts (equals about 3,350 H. P.), by maintaining an effective potential of 10,000 volts, with a loss of energy of two-thirds of 1 per cent. per mile. One suggestion that has been made in this connection is the conversion of the coal into gas at or in the mine and its immediate use without loss of heat in a gas engine or heat motor coupled directly to the dynamo. In fact, at the time of writing, investigations being carried out along the line of the transmission of electric energy without wires suggest that the near future may entirely revolutionize the utilization and transmission of the energy of coal, and suggest that we may soon have the energy of the coal transformed into electric energy in the mine and from thence distributed without wires to whatsoever points it may be desired. Turning from this to accomplished facts, it is found that, taking into consideration the losses in transit and the great first cost of conductors, the electric current can not compete with the coal car over any considerable distance.

The cost of railroad transportation of coal is generally estimated at .5 or ½ cent per ton per mile. At $1 a ton, 200 tons can be carried at a cost of 1 ton, or 200 horse power requires 1 horse power to transmit it one mile. With coal at $3, one horse power will serve to transmit 600 horse power. Mr. Perry estimates that to transmit every one mile by electricity costs 145 times as much as to transport the equivalent coal 1 mi. by rail. As compared with these, Mr. Denny Lane has estimated that with ordinary 16 candle power coal gas 3,000 horse power could be sent a distance of 1 mi. for 1 horse power, or being 1-30 of 1 per cent. of the power transmitted. I do not know whether this includes that most important item, interest on investment, or not.

If cast-iron piping is used, its weight per mile as given by Mr. McMillin,* may be used to calculate its cost per mile on a basis of $20 a ton.

Pipe 6 in. in diameter 7-16 in. thick, will weigh 158,400 lbs., cost $1,584.

Pipe 12 in. in diameter ⅝ in. thick, will weigh 440,000 lbs., cost $4,400.

Pipe 24 in. in diameter ⅞ in. thick, will weigh 1,188,000 lbs., cost $11,880.

Pipe 30 in. in diameter 1 in. thick, will weigh 1,737,000 lbs., cost $17,370.

Wrought iron, according to the same authority, gives:

Pipe 3 in. in diameter will cost, at	$0 20	a foot,	$1,056.
Pipe 6 in. in diameter will cost, at	55	a foot,	2,904.
Pipe 12 in. in diameter will cost, at	2 40	a foot,	12,672.
Pipe 15 in. in diameter will cost, at	3 70	a foot,	19,536.

The comparative carrying capacity of the different-sized pipe is indicated in the following table, where for comparison the pressure in each case is 2 in. and the length of pipe 1,000 yds.:

	Cu. ft. per hour.
A 3 in. pipe 1,000 yd. long with pressure 2 in. will discharge	1,482
A 6 in. pipe 1,000 yd. long with pressure 2 in. will discharge	8,408
A 12 in. pipe 1,000 yd. long with pressure 2 in. will discharge	47,433
A 24 in. pipe 1,000 yd. long with pressure 2 in. will discharge	377,770
A 36 in. pipe 1,000 yd. long with pressure 2 in. will discharge	741,830

Mr. McMillin gives the cost of laying pipe less than 10 in. in diameter 4 ft. deep at from 10 to 15 cents per lineal foot. In cities and towns, of course, that would be much increased. Wrought-iron pipes, which are always used where the pressure is high, are screwed together by steam engines at small cost. The cost of joints for cast-iron pipe is considerable, estimated at from $100.00 for 3-in. pipe to $1,500.00 for 30-in. pipe, per mile.

These figures show that the cost of a plant, piping, pumping stations, etc., to supply a city like Indianapolis from the coal field would probably cost not less than $2,000,000, upon which the interest at 5 per cent. would be $100,000 a year. That factor alone would pay the freight on 200,000 tons of coal, and must be carefully considered in discussing the feasibility of piping gas from the coal field. But when it comes to making the gas at points already supplied with pipe lines

* Geol. Surv. of Ohio, VI, 528.

and distributing pipes, there comes in the factor of the loss of such lines if they are to be abandoned on the exhaustion of the gas fields.

One of the best suggestions yet made in this connection is that, since upon the exhaustion of the gas the pipe lines now running from the gas field to such cities as Indianapolis will be of no value in their present position, and since the pipe is the main item of expense, these lines of pipe may be taken up and relaid so as to connect those cities with the coal field. This can be done at a comparatively small expense.

Friction in pipe lines is estimated to reduce the pressure at about the rate of 7 lbs. per mile, thus requiring a pressure of 200 lbs. to drive the gas 30 mi.*

Mr. Leach reports the following figures for the Logansport line:

Length of line, 45 miles. Crooked line, supplies several towns and many farmers en route.

Pressure at supply end	295 lbs.
Pressure at receiving end	60 lbs.
Loss in transit	235 lbs.

Or 5.2 lbs. per mile.

Considering the tendency of some of the gases to condense when sent under high pressure, it would seem advisable to draw the gas through the pipes, by frequent pump stations, until the distributing point is reached.

For piping long distances, producer gas is out of the question and Dowson or semi-water gas is at a serious disadvantage, because to get the same power as by coal gas requires the piping of three times the quantity of gas, or in other words the cost of transmitting a given quantity of energy by Dowson gas will cost three times as much as to transmit the same energy by coal gas or enriched water gas. These facts suggest that the most efficient gas to pipe long distances will be a gas which is a combination of coal gas and enriched water gas. If the gas is to be made at the point of distribution, Dowson or semi-water gas may prove the cheaper.

2273. This leads to a few words about the advantages of the gas engine. Mr. F. H. Oliphant gives the following table,† showing the efficiency of different types of engines:

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* Rep. Cham. Comm., Pitts., p. 35.

† Mineral Resources of U. S., 1896, p. 897.

Fuel per Indicated Horse Power per Hour.

TYPE OF ENGINE.	EQUIVALENT OF GAS AND COAL.	
	Gas.	Coal.
	Cu. Ft.	*Lbs.*
Gas Engine	13	1.3
Triple expansion condensing	16	1.6
Double expansion condensing	20	2.0
Single cylinder and cut-off	40	4.0
Ordinary high pressure without cut-off	75	7.5

It will thus be seen that the gas engine has a higher efficiency than the highest type of steam engine. The ordinary type of engine will use from 4 to 5 lbs. of coal to produce a horse power for an hour. Assuming 5 lbs., 1 ton of coal would furnish, through such an engine, $33{,}000 \times 60 \times 2{,}000 \div 5 = 872{,}000{,}000$ units of work. Theoretically, 1 ton of Pittsburg coal will furnish $26{,}000{,}000 \times 772 = 20{,}072{,}000{,}000$ units of work, so that such an engine does not utilize more than 1-25 or 4 per cent. of the actual energy of the coal.

In a paper read by Mr. J. Gardner Sanderson before the Scranton Board of Trade in 1877, he says: "I found at the Otto gas engine works, West Philadelphia, where they employ gas engine power, the gas being produced with Buckwheat coal, costing $2.65 per ton in their bins, that their weekly cost per horse power fuel was 6 cents and under, and that 1 lb. of coal furnishes 1 horse power per hour. The Otto company guarantees 1 horse power per hour for 1¼ lbs. of anthracite pea coal, with producers and engines of their own construction."

"At Danbury, Conn., gas and electricity are furnished by the same company. They have three 100 horse power Otto gas engines, run with producer gas, made with anthracite egg coal, costing at the time of my visit $5 per ton. They are satisfied they have a very economical plant, and say they get 1 horse power per hour with 1 lb. of coal."

More satisfactory still are actual figures from actual tests, and through the kindness of Mr. Piper I am enabled to give some of the results of tests made of the White and Middleton gas engines in use at the Soldiers' and Sailors' Monument in Indianapolis. Only two of the tests are given. At another test, the figures for which were not at hand, still better results were obtained:

Number of test	4	7
Duration in minutes	20	20
Gas in cubic feet (10 minutes)	38	79

Air: holes open in air drum................	9	9
Air: Suction (inches of water).............	1	13/16
Air in cubic feet (10 minutes)..............	975.6	879.66
Ratio of air to gas........................	14.89	11.13
Water in pounds (5 minutes)...............	138	124
Temperature of water (Cent.): Entering	13.5	13.5
Temperature of water (Cent.): Leaving.....	45.0	49.0
Revolutions per minute	200	200
Explosions per minute.....................	58	100
Ratio of explosions to double revolutions....	.58	1
Weight on brake in pounds.................	27⅝	67.5
Brake, H. P..............................	13.47	28.66
Horse power lost in jacket................	36.5	39.6
Horse power in gas burned................	89.3	185.7
Gas per eff. H. P. hour....................	16.9	16.34
Reading spring balance....................	11	38
Temperature of air and gas................	18.5	19.0
Practical efficiency	15.0	15.4
Distribution of heat—		
Effective work done on brake, in H. P...	13.47	28.66
Effective work done on brake, in per cent.	15.1	15.6
Work wasted in water jacket, in H. P....	36.50	39.6
Work wasted in water jacket, in per cent.	40.8	21.3
Work lost in exhaust, radiation, etc., in H. P.............................	39.33	117.44
Work lost in exhaust, radiation, etc., in per cent.	44.1	63.1
Total work given to engine, in H. P......	89.3	185.7
Total work given to engine, in per cent...	100.0	100.0

Mr. N. W. Perry cites* the case of a gas engine at the Pantin flour mills, which, by using Dowson gas, developed an indicated horse power of 280 (220 b. h. p.) by the consumption of the equivalent of 1.03 lbs. of coal per brake horse power, equal to an efficiency of about 20 per cent.; and even higher efficiencies are reported. That, on the basis of the above table, would be nearly equivalent to getting one horse power per hour from 10 cu. ft. of natural gas. On that estimate, that would be equivalent to 15 ft. of coal gas, 20 ft. of carburetted water gas or 60 ft. of semi-water gas; or 1 ton of coal would yield, in an ordinary engine, 400 horse power.

4,000 cu. ft. of natural gas in gas engine will yield...	400 H. P.
6,000 cu. ft. of coal gas in gas engine will yield......	400 H. P.
8,000 cu. ft. of water gas in gas engine will yield.....	400 H. P.
24,000 cu. ft. of Dowson gas in gas engine will yield...	400 H. P.

* Engineering Magazine, XII, 49 et seq.

If these figures are correct, then, to equal the cost of coal per horse power per hour for different costs of coal (of Pittsburg quality), these gases should cost as follows:

COST OF COAL.	EQUIVALENT COSTS OF GASES PER 1,000 FEET.		
	Coal Gas.	Water Gas.	Dowson Gas.
$1.00	$0 25	$0 16	$0 04
2.00	0 50	0 32	0 08
3.00	0 75	0 48	0 12

In other words, carburetted water gas at 50 cents, used in a gas engine, would by these figures be as economical as $3 coal used under an ordinary boiler with an ordinary engine. To compete with double or triple expansion engines it would have to sell at as low as 20 to 25 cents. These figures are only intended to be suggestive, and may not be fully realized in practice.

This subject should not be passed without a mention of recent results in the production of high efficiency motors, like the Diesel heat motor, recently introduced in Europe, in which the gas or oil is ignited by the heat of compressed air and burns steadily as it enters the cylinder. A single cylinder engine of this type is reported to have given an efficiency of 34.7 per cent., and later forms of up to three cylinders, at present operating, are claimed to do even better. It would seem as though an engine built on this principle would also be more free from the liability to disarrangement and break-down than the gas engine, on account of the absence of explosive action and probably lower temperature of combustion.

But little has been said in the above about producer gas, and the impression may have been left that it was an early product of experimentation in the manufacture of fuel gases, and that its low heat value had caused it to be cast aside. On the contrary, it has to-day a very extended and successful use. A large per cent. of the operations in metallurgy are now conducted by the aid of producer gas generated in Siemens and other producer furnaces. And it is found to yield a great saving over the direct utilization of coal. But in these cases the gas is used close to the point at which it is made, so that a large part of what would be waste heat is utilized in the regenerative chambers. Dowson gas is also being used to some extent in the same way, the gases being burned without cooling, the generator being placed close to the furnace. As an instance of this, Mr. Sanderson, in the paper quoted above, says that "at Oxford, N. J., gaseous fuel from anthracite, Buckwheat, was used in the furnaces at the nail works, and Mr. Lukins informed me that about 600 lbs. of Buckwheat coal converted into gas did the work of 1,000 lbs. of egg coal used direct. Besides the convenience of handling and certainty of the heat, was freedom from dust and sulphur."

Producer gas, however, can not be conducted long distances, except at an expense out of proportion to its value as a heat producer, and we have been interested in this inquiry principally in a fuel that could take the place of natural gas, not alone as a heat producer, but in the facility with which it could be distributed and handled.

2274. A word may well be added concerning the value of the different gases for illuminating purposes. The illuminating power of the gases may be stated thus:

Natural gas burning 5 ft. per hour in ordinary tip, furnishes about 6 candle power.

Natural gas burning 5 ft. per hour in argand burner furnishes about 12 candle power.

Natural gas burning 5½ ft. per hour with mantel (thoria, etc.) furnishes about 70 candle power.

Coal gas burning 5 ft. per hour in ordinary tip furnishes from 16 to 22 candle power.*

Coal gas burning 5 ft. per hour in Welsbach burner furnishes about 70 candle power.

Acetylene gas burning 5 ft. per hour in Welsbach burner furnishes about 250 candle power.

Carburetted water gas and gases like the Rose-Hastings run about the same as coal gas. It is seen from this that acetylene gas, which was not considered as an available source of heat for steam and heating purposes, is to be a close competitor of coal gas for lighting purposes, if indeed it is not bound to supersede it. As between coal gas burned in the ordinary tip and acetylene gas burned in the same way, there can be little doubt as to which will survive. Whether it can overcome the competition of the future cheap combined coal and water gas burned in Welshbach and other improved burners will be decided in the future.

Mr. Cox, in his third and fourth annual reports (1872), gives the result of a study of some of the Indiana coals in regard to their production of gas, as compared with standard Youghiogheny gas coal.

*Improved tips are now made somewhat on the principle of the Bunsen burner, in which by securing a more perfect combustion it is claimed the same quantity of light is obtained by the use of but a fraction of the gas ordinarily required.

Without going into details, his results may be tabulated as follows (Youghiogheny considered 100):

	Gas Yield.	*Illuminating Power.*	*Coke.*
Cannelsburg cannel, Coal II............	1.20	1.50	.58
Standard shaft, Coal VII..............	.90	.88	.90
Wilson shaft, Coal VI..................	.98	.88	.97

In quality, Indiana coke is not of a high grade, not being strong, and generally filled with large cells that give it a honey-comb appearance. The best coke seen by the writer in this State is some recently made from the Princeton coal.

II. Use of Coal in Metallurgical Processes.

(A.) DIRECT USE.

2275. Indiana has long been famous for its possession of a coal suitable for direct use in the reduction of ores and other metallurgical processes. A caking coal cannot be used direct in the blast furnace, as its caking property causes it to run together and prevent the passage of the blast. A non-caking coal, to be successfully used, must also possess the other qualities; it must be extremely free from sulphur and it must be strong enough to bear the burden placed upon it in the furnace. Indiana block coal meets these requirements in a remarkable degree. As a matter of fact, the block coal, as with any non-caking coal used in the furnace, is coked in the upper part of the furnace at a cost of considerable heat, and whether the presence of volatile hydrocarbons thus driven off in the top of the furnace compensates for the loss of heat, I can not say. Considering that these gases are combustible as they come from the furnaces, and that they are not all required for heating the air blast, it would seem as though an establishment where the heat value of these gases was fully utilized could run more economically using coal as a fuel than by using coke. It is also evident that to succeed with the use of coal direct the furnace must be designed with that in view. Whether through lack of proper design in the blast furnace, or a failure to utilize the heat of the gases distilled from the coal, or, as suggested elsewhere, through a failure of Indiana iron ores to realize expectations, the fact remains that there are to-day no blast furnaces in Indiana using block coal. That due, perhaps, to one of the first causes mentioned, block coal did not give entire satisfaction in the furnaces of this State, may be judged from a paragraph by Mr. Cox in his report for 1873, p. 113:

"INDIANA BLOCK COAL is of itself very strong and able to bear up as much burden as coke, but it is, by the heat in the upper part of the furnace, converted into a dense coke before it meets the blast, where it enters into perfect combustion. That my readers may comprehend the important part performed by the blast, I will state that more than five tons of air are required for every ton of pig iron smelted. From the fact that the raw coal is changed to coke before it is burned, the effect produced by the two materials, coke and raw coal, are the same in the zone of fusion, and it is only in the upper part of the furnace that we must look for dissimilar effects. Here the raw coal is gradually heated, and the hydrogen and hydrocarbons, which form about forty parts of its substance, are distilled off, and the gaseous contents of the shaft are, consequently, about 37 per cent. greater than when coke is the fuel; it follows, therefore, that, if the size of the throat and gas flues are properly adjusted for coke, they must be made at least one-third larger for raw coal. If this point is not attended to, the furnace must lose heat, through want of perfect combustion, run irregular, and consume vastly more fuel per ton of pig iron made.

"Mr. I. Lothian Bell, in his valuable work on the Chemical Phenomena of the Blast Furnace, says that 'raw coal in the blast furnace requires the extra heat produced by 15 lbs. of coke for every 100 lbs. of coal to expel the volatile matter, or in other words, to coke it, and its reducing powers are diminished, consequently, in that proportion.' Mr. Bell arrives at this conclusion by ascertaining that 15 lbs. of coke are burned under the retorts, at the gas works, for expelling the gas from 100 lbs. of coal, and he estimates the calories of coal and coke to be about the same. A similar showing is made if we reason from the process of making coke in ovens. Here the heat necessary for distillation is derived from the expelled gas, and of that one-third only is required for the operation, and the other two-thirds are wasted for want of means to utilize it.

"Under the most favorable management at Cleveland, in the north of England, twenty-two and one-half hundred weight of coke will smelt one ton of pig iron from Cleveland ironstone. This stone is a lean carbonate of iron, very similar in composition to the Clarke county (Indiana) ore. Twenty-two and five-tenths hundred weight, or 2,520 lbs. of coke, will correspond to 3,360 lbs. of block coal, and I have no doubt but that, when we have discovered the proper form of furnace and the best mode of preparing the stock at our command, less than two tons of block coal will be required to make a ton of pig iron.

"The loss of heat by absorption, when raw coal is used in the blast furnace, is more than compensated for by the highly deoxidizing action of the hydrogen and hydrocarbons in which the ore is so completely bathed. The amount of oxygen absorbed from the ore by carbonic oxide, when the fuel is coke, reaches, under favorable conditions, about 30 per cent. of the entire oxygen which it contains. Now, there is no reason why this reducing action of carbonic oxide should not proceed to completion if those acids which facilitate the reduction are present in sufficient quantity.

"It has been proven by investigation that moisture must be present to promote this favorable action of carbonic oxide, and indeed it is mentioned by some that the process of deoxidation cannot take place in the furnace without it. Raw coal supplies this essential constituent (H_2O), together with hydrogen (H), in far greater abundance than coke; and since hydrogen is a much better deoxidizer than carbonic oxide, and the hydrocarbons themselves being almost as good absorbents for oxygen as the latter gas, I have every reason to believe that, when used under the most favorable conditions, we will obtain as large yield of iron with the Indiana block coal fuel as can be obtained from the same ores with coke, and the quality of the iron will be superior to that made with the latter fuel.

"I am satisfied that most, if not all, of the difficulties experienced by the cooling and irregular working of the raw coal furnaces in this State come from a want of sufficient sized outlet at the throat for the waste gases, for it must be borne in mind that the heat of the furnace, within certain bounds, depends upon a good upward draft."

In his report for the preceding year he gives 4,250 lbs. as the amount of coal required in Clay county to make a ton of iron. It would seem as though the key to the successful use of block coal in the blast furnace was, first, proper design of furnace, and, second, complete utilization of the gases that escape.

As yet, gaseous fuels have not proved successful in the reduction of ore, apparently because the ore needs the separating influence of the coal or coke to prevent its forming an agglutinated mass, through which the blast can not be driven until it has reached the stage of a melted metal.

2276. Coking.—In certain metallurgical processes, as the obtaining of iron from its ore, certain qualities are required of the fuel. Two of these are purity and a lack of cohesiveness when burning. The caking coal of the State, from its property of running together when burning, and from its usual lack of purity, lacks both of the qualities mentioned. Block coal has those qualities, but is limited in quantity. However, if a caking coal be heated out of contact with air, or with a very limited supply, the volatile gas is driven off, leaving a hard gray mass of nearly pure carbon, that has the property of not running together when burning and of being somewhat freer of sulphur than the coal of which it was made, and may be very free of sulphur where the coal used is first crushed and then washed.

Fig. 985. Slack pile at Ehrlich mine at Seeleyville, Vigo county. Extends back to tipple, of which the top just shows in distance on left side. Showing enormous volume of waste (fine coal, etc.) by former methods of mining and preparing coal for market.

In many mines the coal is soft, and the proportion of small coal to lump is so great that it is difficult or impossible to find sale for much of this fine coal, which thus becomes a waste product. (See Fig. 985.)

If it be found that it is suitable for the making of coke, a saving may be made by the erection of a coking plant.

In this State the bee-hive oven is used exclusively. Fig. 986 shows the exterior appearance of a row of ovens. The single ovens are dome or bee-hive shaped, 10 to 12 ft. in diameter and 6 or 8 ft. high. They are built of fire brick encased in an outer wall of stone. Along the top of the row of ovens runs a track, and under this is a hole in the top of each oven. The washed coal is charged to the ovens through the hole in the top from cars on the track just mentioned. The coal is spread evenly on the floor until the oven is full. In front of each oven will be noticed a hole, which is closed with an iron door. The oven being full, the coal is ignited. Air is admitted at the bottom, while the gases pass off through the hole in the top. These gases, at first pale, gradually become darker and stronger. After twenty-four hours the air holes are closed, but the gases are allowed to escape for another twelve hours. Then the upper hole being closed, the coke is

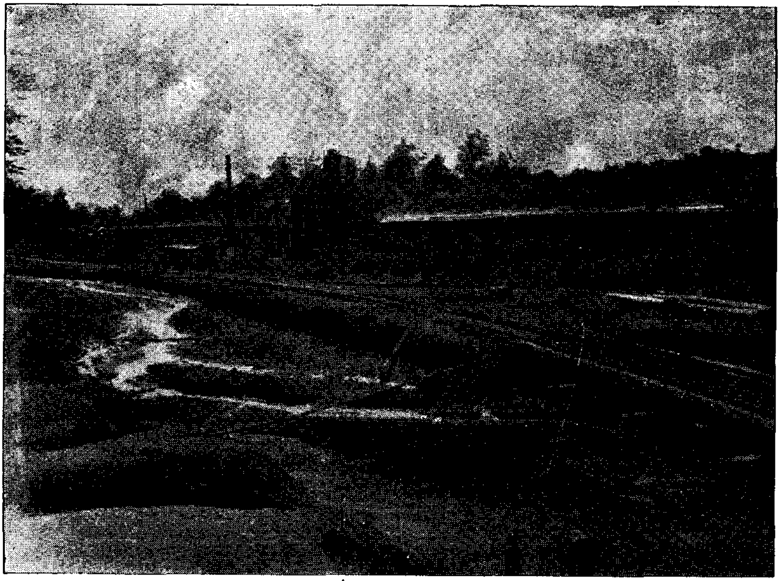

Fig. 986. Coke ovens at Alum Cave, Sullivan county. Type of those used in Indiana.

allowed to cool for twelve hours. Then the coke is drawn, being first drenched with water. Except for the first charging, the oven walls retain sufficient heat from one charge to the next to ignite the last charge.

Remembering that the coke is composed of the fixed carbon plus the ash, an examination of the analyses of the Indiana coals as given beyond, especially the more recent analyses by Mr. Noyes, will show the theoretic per cent. of coke from these coals is little if any over 55 per cent., against about 75 per cent. for the well known coking coals of Pennsylvania. That is, theoretically, two tons of Indiana coal are required to produce one ton of coke. In practice the actual percentage of coke will be probably a little less than the theoretic per cent. This loss is largely due to the coke consumed in the coking process. In 1896, 8,956 tons of coal in Indiana produced 4,353 tons of coke, a yield of 49 per cent. This coke sold for $1.99.

Numerous ovens are now made to in part remedy that loss by supplying part of the heat by the combustion of the gases in flues around and under the oven; these are known as short retort ovens. These are broadly of two classes—the regenerative oven, which uses vertical flues and a high heat, and the recuperative ovens, using horizontal flues and a comparatively low heat, the latter seeming to be preferable. These reduce the time and labor required, thus making a saving in that way as well as in the amount of coke per ton of coal used.

A still further saving is effected in the use of by-product ovens, which are planned not only to save in labor, but to save the ammonia and tar. Thus, it is estimated that, with a fairly efficient condensing plant, one ton of coal will on the average yield 25 lbs. of sulphate of ammonia and 60 lbs. of tar, which would yield a handsome return.

Again, certain recent forms of ovens are found to yield combustible gases equal to as high as eight or nine horse power a year per oven for an oven averaging 520 tons a year.

With the style of oven at present in use in this State, and the much smaller coke per cent. of our coals as compared with Pennsylvania, it must be conceded that we can not compete with them in outside trade, but must be limited to local trade; but with such by-product ovens as may now be had, we see no reason why Indiana coke should not become a profitable article of manufacture.

L. APPENDICES.

Appendix A. Coal Analyses.

As first handed in, the manuscript contained a chapter giving all the analyses of Indiana coal known to have been made. But after the report was well in press, it was found that it was going to make a much larger volume than was anticipated, and in order to reduce its volume somewhat, it was decided to omit all of the analyses numbering between 400 and 500, except the few made recently upon which reliance could be placed as giving quite closely the relative commercial values of the coals concerned. No small number of such omitted analyses had been given, in part, in the descriptive matter of Part III, though the tables omitted showed, in each case, physical appearance and quality, specific gravity, color of ash, percentage of coke, appearance of coke, heating effect and evaporating effect, in addition to what is given in Part III.

The adaptability of any coal is determined in two ways: (1) By a chemical analysis; (2) by actual tests.

Several hundred analyses of Indiana coals have been made, though a large proportion of these have only a limited value, for three reasons: (1) Inadequate method of sampling; (2) loss of moisture before analysis; (3) lack of sulphur determinations. Recently a number of analyses have been made by Mr. W. A. Noyes, part of which were published in the 21st Ann. Rep. of this department. A few other analyses have been obtained.

METHOD OF ANALYSIS.—As the bulk of the analyses given in the report were made by Mr. Cox or his assistants, it may not be out of place to give his own description of his manner of conducting a coal analysis:*

"It is a matter of no little difficulty to select from a mine a proper sample for analysis, at least such a sample as will represent the average commercial value of the seam. The best way, therefore, is to take samples from the top, middle and bottom parts of the seam. These should be carefully labeled, wrapped in paper and sent to the laboratory as soon thereafter as practicable. On arriving at the laboratory they should be taken in hand at once.

"About a pound of each sample should be pulverized fine enough to be passed through a porcelain colendar with one-tenth inch perforations, then transferred to bottles with good cork stoppers. Each bottle should be labeled, showing the date of mining, when bottled, name of mine, etc. These bottles serve as stocks from which the different quantities are to be taken that serve for analysis. It is not a good plan to mix the portions taken from different parts of the seam and consider the mixture an average sample, so that one set of analyses may serve; for, though it might furnish a fair statement of the commercial value of the seam, it would leave us in ignorance of much useful information in regard to the true character of the seam.

"PROXIMATE ANALYSIS.—One gram is charred in a covered platinum crucible of about one fluid ounce capacity. The heat is derived from a three-jet Bunsen gas burner, and the crucible is kept at a bright-red heat until the escaping gas ceases to burn and the condensed carbon disappears from the cover. The weight of the charred

* Geol. Surv. of Ind., 7th Ann. Rep., 1875, pp. 34-36.

mass gives the coke, and the volatile matter is estimated by the loss. To determine the hygroscopic water, one decigram of pulverized coal is weighed in a small, shallow platinum capsule and placed in a hot air bath, where it remains at a temperature of 100° to 105° C. for one hour; the loss gives the water. The capsule, with the dry coal, is then placed over the strong flame of a Bunsen burner until it is consumed to ash.

"The weight of the ash is deducted from the coke to find the fixed carbon, and the weight of the water is deducted from the total volatile matter to find the per cent. of combustible gas.

"All this appears very simple, but it requires great care and attention in order to obtain reliable results. The temperature of 100° C. (212° F.) is recommended, since it is believed that a higher temperature is no more effective and is more liable to produce decomposition of the volatile constituents."

As shown in this description, and as shown by his analyses as given in Part III, Mr. Cox did not separate the sulphur in his analyses. In his analyses the sulphur in part remained in the ash and in part was driven off with the gases.

Recent Analyses.—A few analyses recently made by Mr. W. A. Noyes, or under his direction, will also be given. The method of analysis used was the same in principle as that used by Mr. Cox, and is described in detail by Mr. Noyes in the 21st Annual Report of the State Geologist, p. 99. The main difference lay in the manner of procuring the material analyzed. The more recent method of the first analyses, as described by Mr. Noyes, is: "The samples, with one exception were taken in the mines at the face of the vein, beginning at the top and cutting down at several places in such manner as to procure an average sample of the coal. These large samples were then broken into small pieces and 'quartered' down to secure the smaller sample, which was submitted to analysis. These samples were taken in the mines by Mr. Robert Fisher, State Inspector of Mines, and Mr. James Epperson, Assistant Mine Inspector, and not by owners of the mines." As regards reliability and the analysis showing the average quality of any coal, there can be no question of the superiority of the latter method of obtaining samples over the earlier of picking out hand specimens for testing. Where analyses of the same coal were made by both methods, Mr. Noyes's results will be adopted, as tending to give more nearly the commercial value of the coal. For the analyses made in 1898 a somewhat different method of sampling was adopted, in the endeavor to obtain more nearly the commercial product. The method as given by Mr. Noyes is as follows:

"SAMPLING COAL FROM CAR.—Start near one corner of the car and drive a scoop shovel down into the coal as far as it will reach. Bring it up with all the coal it will carry and throw into a wheelbarrow or box. In this manner take six shovelfuls from each side of the car at equal distances apart, and six through the center of the car—eighteen shovelfuls in all. If the coal is mostly in large blocks, take pieces of the same weight as the shovelful, but take also some of the finer or slack coal, if there is any in the car, taking it in such proportion that the proportion of slack in the sample will be as nearly as possible the same as in the car.

"Break the coal of the sample so that no pieces are larger than an orange. Mix and pile in a regular heap, sweeping the dust into the heap. Cut twice across the center, and take all of two opposite quarters. Make a heap of the part taken or of the part remaining, and repeat. When the amount of coal has been reduced somewhat, break what remains finer and quarter down again till a sample is obtained which will fill a pint or a quart fruit jar. Put in the jar at once and screw the cap on tight.

"If the sampling is done at the mines, shovelfuls may be taken at regular intervals as the car is filled, or at longer regular intervals as several cars are filled."

In 1883 Mr. G. M. Lavette prepared a table of all the coal analyses made of Indiana coal up to that time. This is now out of print.

By calculation from the percentage of carbon and hydrogen contained, there can be determined the number of units of weight of water one unit of weight of the coal will raise 1° C. This is called the heating effect of the coal. If this number be divided by 536.5, the latent heat of steam, there will be obtained a number representing the units of weight of water at the boiling point which will be converted into steam by one unit of coal. Thus, it may represent the number of pounds of water evaporated by one pound of coal or the number of kilograms or number of tons of water evaporated by one kilogram or one ton of coal. This number shows the evaporative effect of the coal. A comparison of the numbers in these two columns for different coals is supposed to show the relative heating or evaporative effect of the two coals. In actual present practice, one pound of good coal will evaporate in a good boiler about ten pounds of steam.

The first group of analyses was made by Mr. Noyes for the 21st Ann. Rep. (1896), and include for comparison seven coals from Pennsylvania and West Virginia. The averages of this table were used in the chapter on availability of Indiana coals.

Number.	COUNTY.	NAME OF COAL AND OWNERS.	Total Combustible Matter.	Volatile Combustible Matter.	Fixed Carbon.	Moisture.	Ash.	Sulphur.	Heating Effect—Calories per Kilogram, Calculated.	Heating Effect—Calories per Kilogram, Berthier's Test.	Evaporative Effect—Pounds of Water per Pound of Coal.
1	Vanderburgh	Sunnyside Coal and Coke Company, Evansville	86 73	38 59	48.14	6 44	6 83	1.85	6,924	6,759	12.9
2	Warrick	Deforest mine	84.16	39.09	45.07	6.08	9.76	2.14	6,705	6,339	12.5
3	Knox	Edwardsport coal mine, Edwardsport Coal and Mining Co.	82 03	36.00	46.03	8.75	9.22	3.08	6,495	6,345	12.1
4	Knox	Bicknel mine, Bicknel Coal Company	83.76	35.22	48.54	7.61	8.63	1.67	6,692	6,489	12.5
5	Daviess	Cabel and Kauffmann	87.15	37.99	49.16	6.50	6.35	1.85	6,958	6,981	13.0
6	Sullivan	Star City	87 30	38.53	48.77	9.40	3.30	1.23	6,995	7,002	13.0
7	Sullivan	Alum Cave	84.77	42.60	42,17	6.49	8.74	3 18	6,712	6,894	12.5
8	Greene	Buckeye or Fluhart, Linton Coal and Mining Company	86.79	35.69	51.10	7.81	5.40	0.72	6,974	6,618	13.0
9	Greene	Summit mine, Dugger and Neil Coal Company	87.54	35.30	52.24	7.44	5.02	0.61	7,041	6,852	13.1
10	Greene	Island City mine No. 1, Island City Coal Company	86.47	35.97	50.50	7.12	6.41	0.84	6,944	6,819	13.0
11	Vigo	Ray mine, Seeleyville, Vigo County Coal Company	84.46	40.25	44.21	7.57	7.97	4.01	6,656	6,762	12.4
12	Clay	Gart No. 5 shaft, Brazil Block Coal Company	85.27	36.11	49.16	11.20	3 53	0.62	6,856	6,774	12.8
13	Clay	Brazil Block No. 1 shaft, Brazil Block Coal Company	85.12	45.16	49.96	13.82	1.06	1.47	6,810	6,[illegible]88	12.9
14	Clay	Eureka Mine No. 1, Carbon, Eureka Block Coal Company.	86.74	36.32	50.42	9.80	3.46	0 34	6,985	7,050	13.1
15	Clay	Crawford No. 3 mine, Crawford Coal Co.	84.58	36.34	48.23	11.26	4.16	0.56	6,803	6,858	12.7
16	Clay	Columbia No. 2 mine, Teller, McLelland & Co.	89.52	36.75	52.77	7.47	3.01	0.57	7,202	7,344	13.4
17	Owen	Lancaster No. 4 mine	83.85	36.45	47.40	12.73	3 42	0.55	6,744	6,636	12.6
18	Parke	McIntosh No. 1 mine, near Diamond, I. McIntosh & Co	87.70	36.69	51.01	8.21	4.09	0.95	7,039	7,008	13.1
19	Parke	Cox No. 3 shaft, "bituminous," Brazil Block Coal Co.	88.33	41.88	46.45	6.49	5.18	2.93	7,009	6,897	13.1
20	Pittsburg coals	Beck's Run, first pool, Hays Coal Company	96.06	36.01	60.05	2.09	1.85	0.64	7,726	....	14.6
21	Pittsburg coals	Anchor, fourth pool, Beaumont Coal Company	89.84	35.30	54.54	1.30	8.86	0.45	7,230	....	13.5
22	Pittsburg coals	Caledonia, fourth pool, T. J. Wood	90.26	35.22	55.04	1.35	8.39	0.69	7,256	....	13.5
23	Pittsburg coals	Stony Hill, fourth pool, John D. Nixon	92.74	35.46	57.28	1.11	6.15	0.56	7,462	....	13.9
24	Pittsburg coals	Little Redstone, fourth pool, Little Redstone Coal Co.	91.08	35.88	55.20	0.98	7.94	0.82	7,316	....	13.7
25	West Virginia coals	Raymond, Marmet Smith Coal and Mining Company	91.16	40.14	51.02	3.20	5.64	2.25	7,266	....	13.6
26	West Virginia coals	Belmont, Belmont Coal Company, Belmont, W. Va.	90.04	37.84	52.20	1.45	8.51	0.46	7,248	....	13.5
		Average of Indiana coals	86.36	38.22	48.14	8.45	5.61	1.52	6,879	....	12.7

The same report also contains the following analyses by Mr. J. R. McTaggart and Mr. H. W. Carver, first published in the Journal of the American Chemical Society, Vol. 17, p. 843. These, Mr. Noyes tells me, were properly sampled from the cars at Terre Haute, and so should be of va˜ue:

COMPONENT.	New Pittsburg A.	New Pittsburg B.	Lancaster.	Brazil.	Shelburn.	Shop.
Moisture	6.83	5.89	12.66	8.98	8.63	2.36
Volatile combustible matter	39.92	42.23	34.44	34.49	38.82	31.11
Fixed carbon	39.93	40.40	47.22	50.30	43.45	42.44
Ash	13.31	11.48	2.68	6.22	9.05	24.09
Carbon	62.88	65.26	71.40	70.50	66.86	57.32
Hydrogen	5.07	5.17	5.56	4.76	5.30	4.56
Nitrogen	1.01	1.17	1.54	1.36	1.50	1.44
Oxygen	13.06	13.25	18.42	16.29	15.69	9.93
Ash (corrected)	17.98	15.15	3.07	7.09	10.65	26.75
Sulphur	7.46	5.88	0.62	1.39	2.57	4.25
Iron, calculated	6.53	5.14	0.54	1.22	2.25	3.72

The following additional analyses were made for this department under the direction of Mr. Noyes:

MINE.	Total Combustible Matter.	Volatile Combustible Matter.	Fixed Carbon.	Moisture.	Ash.	Sulphur.	Heating Effect, Calories per Kilogram—Calculated.	Evaporative Effect—Pounds of Water per pound of Coal.
Ayrshire mine, Pike county	82.47	41.32	41.15	10.75	6.78	0.81	6,622.24	12.36
Pleasantville, Sullivan county	81.28	37.61	43.67	11.30	7.42	3.13	6,433.40	12.0
Cannelburg (cannel coal)*	75.43	49.08	26.35	1.47	23.10	1.48	6,027.48	11.25
Blackburn, Pike county	87.33	43.38	43.95	7.47	5.20	5.21	6,918.41	12.9
Oswald mine, Gibson county	83.02	37.72	45.30	7.88	9.10	2.71	6,590.76	12.29
Farnsworth, Coal VII	78.29	34.40	43.89	12.07	9.64	1.03	6,276.84	11.71
Coke from coal, Oswold mine, Princeton	88.34	0.20	88.14	0.14	11.52	1.89	7,053.18	13.16
Coal from Gifford mine, by T. H. Watson	77.15	37.67	39.48	13.12	9.73	2.95	6,107.37	11.4

* The coke from the "cannel coal" was pulverulent.

Appendix B. Mines, Etc.

As originally handed in, this appendix formed Division LI of the report, and consisted in the main of tables, in which were gathered all the data obtained about the small mines of the State. To reduce the volume of the present report, these tables are omitted here, but may be given in connection with some future report of the Mine Inspector.

For obtaining data at the small mines, the following outline was worked out as a basis for inquiry:

1. Mine—
    - (a) Name.
    - (b) Owner or owners.
    - (c) When opened, and history.
    - (d) Miles to railroad.
    - (e) Present condition.
2. Coal—
    - (a) What seam.
    - (b) Greatest thickness.
    - (c) Least thickness.
    - (d) Average thickness.
    - (e) Quality, appearance, etc., used successfully for what purposes.
    - (f) Dip, structure, cleavage, faults, etc.
3. Roof—
    - (a) Material.
    - (b) Thickness.
    - (c) Character.
    - (d) Draw slate.
4. Floor—
    - (a) Material.
    - (b) Thickness.
    - (c) Character.
5. Entrance—
    - (a) Drift, slope or shaft.
    - (b) Depth.
    - (c) Equipment.
6. Power used—
    - (a) For hauling.
    - (b) For hoisting, etc.
7. Mining methods—
    - (a) Method of mining.
    - (b) Width of room.
    - (c) Width of pillar.
    - (d) Timbering, etc.
8. Ventilation.
9. Number of men employed and for how long.
10. Annual yield in bushels or tons.
11. Area worked out.

The omitted tables contained the data gathered on the basis of the above outline. In lieu of these, we will simply give a table which summarizes the portion of the county summaries pertaining to mines, etc.:

COUNTY.	Number of mines working 10 men or over.	Number of mines working less than 10 men.	Total number of mines in operation.	Large mines abandoned.	Small mines not working.	Strippings, outcrops, etc.	Total number of opening to coal.
Warren	....	16	16	....	41	40	97
Fountain	2	26	28	16	37	95	176
Montgomery	....	....	....	....	....	7	7
Putnam	....	9	9	....	....	113	112
Parke	13	? 53	? 66	22	....	210	231
Vermillion	5	47	52	3	140	65	260
Owen	1	27	28	3	....	....	200
Clay	30	18	48	91	100	511	750
Vigo	15	25	40	15	75	125	255
Greene	6	89	95	3	....	462	560
Sullivan	12	43	55	6	....	233	294
Martin	1	37	38	....	100	112	250
Daviess	12	40	52	22	50	150	274
Knox	3	9	12	5	14	66	97
Orange	....	1	1	....	2	13	16
Crawford	....	....	....	....	4	9	13
Dubois	1	35	36	3	39	194	233
Pike	6	125	131	3	150	267	450
Gibson	1	4	5	....	6	45	56
Perry	2	38	40	....	67	56	163
Spencer	....	36	36	....	37+	100	298
Warrick	7	93	100	8	....	255	363
Vanderburgh	6	0 ?	6	....	....	10	16
Posey	....	....	....	....	....	12	12
Total	123	731	852	200	862	3,150	5,183

From the above table it would appear that over 5,000 coal openings or exposures had been visited or located in our work. Of these three-fifths, or over 3,000, were small strippings or outcrops, or wells or drillings, the small strippings largely predominating. The other two-fifths, or 2,000, were classible as mines, of which number over one-half have been abandoned or have not been worked of late years, leaving about 850 mines which are or may be open part or all of the year; of this number, 123 are large mines visited by the Inspector.

The classification of the small mines, strippings, etc., has been a difficult problem. As a matter of fact, with few exceptions all outcrops have been stripped from some. In many cases this has only amounted to a bushel or two. In more cases the man upon whose farm the coal outcrops has obtained his winter's supply of coal from such outcrops, sometimes for a single year, sometimes year after year. In many cases such outcrops are only depended upon to get coal for thrashing or some similar purpose. It hardly seems proper to call these mines, though often in the course of time thousands of bushels may be taken in this way. Most of the strippings of the above table are of this character. Next there comes the stripping from which a man may sell some coal to his neighbors; in this way these strippings grade up until strippings were met in which in midsummer were working as high as fourteen men. The same thing is true where the outcrop occurs in a steep hillside, so that mines of this character run all the way from those which have had a total output of a bushel or two to well equipped drifts or shafts, like those illustrated in Plate LXXXIX, which run the whole year and usually keep just below the ten-men limit, while the output may run from five to ten tons a day for six months in the summer, and from 40 to 50 tons a day for the other six months.

Again, to determine whether to call a mine a working mine or not, is often a difficult problem. Some of the small mines work the year round; some will get out coal in the summer only, when it is called for, but the majority are practically abandoned from planting time or earlier until October, so that their opening up the following fall is often governed by the condition they may be in at that time. Thus, they may be opened regularly for several falls and then abandoned for several years, then opened up again for a year or two or more. In general, the small mines, when visited in the summer, were neither working nor in a condition to be examined. In the second column of the table, therefore, are included all the small mines which were worked the preceding winter or which are generally worked winters, though possibly not the winter or two preceding our examination.