

(*Paper No. 3136.*)

## “Coal-Mining by Mechanical Appliances.”

By JAMES WARNE CHENHALL, M. Inst. C.E.

“THE Cambria coalfields” are situated in Weston County, Wyoming, about 65 miles south-west from Deadwood, South Dakota. They were discovered in 1887, and were thoroughly proved by drifts at various points within the area, and by diamond-drill borings during 1888 and 1889. The coal underlies a slightly undulating tableland about 6 miles broad, at the base of the “Black Hills,” on the south-west side.

To the north-east the surface of the country rises and the coal measures cease. To the south-west the tableland ceases, and the coal seam suddenly changes from a nearly level position to a very steep dip and passes beneath the surface to such a depth as to be out of the reach of the miner. The tableland is intersected by cañons, or narrow valleys, between 300 feet and 500 feet deep, which have cut down through the sandstone that lies over the coal seam, through the coal and into the formation below it. The coal seam, where it can be worked, lies in a compact body under the tableland referred to, and between two cañons called “Salt Creek” and “Oil Creek.”

It is believed that the workable coal underlying this tableland covers an area of not more than 25 square miles, and not less than 15 square miles. The coalfield is compact and is not badly cut by denudation, although several cañons or gulches do cut through it and expose the seam outcropping on the steep hill-sides. One of these cañons, about 7 or 8 miles long, leads from the plain through the tableland to the very heart of the coalfield, and through this a branch line of the Burlington Railway system communicates with the mines. The main and back entries of the two mines which have been opened (*viz.*, the “Antelope” and the “Jumbo” mines), and the town of Cambria, are situated at the head of this cañon. The coal seam at this point outcrops between 50 and 60 feet above the bottom of the cañon, thus giving an abundance of fall for the tipples, through the coal breakers, and over the screens to the railway-cars below.

The seam throughout the productive area lies practically flat and has few faults or disturbances. There is no vertical hoisting of coal or pumping of water, the coal being worked by drifts, or tunnels driven in from the sides of the cañon. The thickness of the seam varies between 5 feet 6 inches and 7 feet 6 inches, being greatest in the "Jumbo" mine. The roof is of sandstone, solid, sound and good, that stands exceptionally well, needs little timbering, and is not subject to dangerous caves, as in many mines. The floor is also sandstone with sometimes a few inches of clay between it and the coal. So far there has been no trouble from gas given off by the coal, and fire-damp is as yet unknown in the two mines opened. The coal in these mines is entirely cut by machinery, as it is much too hard to be cut by hand labour.

*Nature and Character of the Coal.*—The coal from the fields is uncommon in its physical character, being very hard and partaking of the character of a bituminous shale, black in colour, bright in fracture, and when touched not soiling the hands. When ground into a fine powder it develops a brown shade much like lignite. Its line of cleavage is in the direction of its natural bedding in the seam, and it breaks up into slabs; it is, however, easily broken across the grain. Although it has so much in common with bituminous shale, it is, in the Author's judgment, a true coal, bordering on what is known in Great Britain as cannel coal, but during its combustion it behaves in most respects like an ordinary bituminous coking coal, with the exception that when it is thrown on a very hot fire it decrepitates, and the surface breaks off; this, however, is no drawback to it as a fuel, since, on account of its bituminous nature, the small pieces soon become agglomerated into coke. Like cannel coal, it ignites very readily, burning with a long hot flame. To utilise its heating power to the full as a steam-producing fuel, the flues or tubes of the boilers should be made much larger than is usual in boilers constructed for the consumption of ordinary steam coals. The same may be said in reference to its use as a smelting fuel for reverberatory furnaces. Furnaces built for the use of this coal should be at least one-third longer than those built for smelting with South Wales or English coal. Some portions of the coal are much duller in colour than others, and from appearance one would at once conclude that these were layers of shale; such, however, is not the case. These streaks or layers in the coal are almost cannel coal, but with a percentage of ash one and a half times that of the average of the other portions of the coal, and

this is the only drawback it has in relation to the other portions of the coal in the seam.

*Specific Gravity.*—The mean specific gravity, as obtained by a series of experiments on a number of samples of coal, was 1·322, the highest being 1·398, and the lowest 1·28. For the purpose of comparison the following are average specific gravities of British coals :—

Anthracite, Welsh . . . . .	1·530
Glasgow . . . . .	1·290
Cannel coal . . . . .	1·272
Newcastle (bituminous) . . . . .	1·269

The Author tested (in duplicate) forty-five samples of this coal for ash, the average given being 12·49 per cent., the lowest of the series 5·32 per cent., and the highest (a sample of the shale portion of the seam) 33·07 per cent. There is no difficulty in selecting this coal so as to give an average of 7 per cent. to 8 per cent. of ash. The ash produced is very dry and infusible, does not clinker readily, and is therefore easily removed from the fire-grate. A sample tested gave: silica 60·65 per cent., alumina 38·00 per cent., lime and iron 0·20 per cent. The following analysis may be taken as an average, representative of a series of forty-five samples :—

	Per cent.	Per cent.
Combustible volatile matter . . . . .	34·13	
Moisture . . . . .	3·42	
	—	37·55 volatile matter.
Combustible fixed carbon . . . . .	49·92	
Ash . . . . .	12·50	
	—	62·42 coke.
Total . . . . .	99·97	

Sulphur and iron are present in some portions of the coal in the form of pyrites. Sometimes as high as 2 per cent. to 3 per cent. of sulphur is found; the pyrites is very unevenly distributed throughout the seam. A selected sample of the coal is represented by the following analysis :—

	Per cent.	Per cent.
Combustible volatile matter . . . . .	33·29	
Moisture . . . . .	3·50	
	—	36·79 volatile matter.
Combustible fixed carbon . . . . .	56·96	
Ash . . . . .	6·25	
	—	63·21 coke.
Total . . . . .	100·00	

This coal emits large volumes of dense black smoke due to the readiness with which, when heated, it parts with its large percentage of volatile bituminous matter. Notwithstanding the high percentage of volatile matter and ash, it is a good steam-generating and smelting fuel, and with specially designed furnaces for its combustion very good results can be obtained. (1,500 tons per day are being used as locomotive fuel on the Burlington Railway.) It also produces a good hard compact coke, bright and metallic in colour, in every way suitable for metallurgical purposes, and capable of bearing a heavy crushing load, being therefore suitable for blast-furnace fuel, and the smelting of copper, lead, silver and gold in blast furnaces. Its only drawback is a high percentage of ash; but compensation is made in the case of smelting the precious metals by the fact of this coal and coke containing a small quantity of gold and silver. Some samples have given as high as 3 dwts. of gold to the ton of coke, but the average is between 1 dwt. and 2 dwts. of gold to the ton. This is the first time that the Author has found gold and silver in the ash of coal. Coke from these mines is almost exclusively used in the gold-smelting works (blast furnace smelting) at Deadwood in the "Black Hills," South Dakota, U.S.A.

A series of experiments gave an average of 10,472 cubic feet of gas per ton of coal, its illuminating power being such as to make it suitable as an illuminating gas. The production of tar during the manufacture of coke from the coal averaged 21·00 gallons to the ton of 2,240 lbs., and 71·46 gallons of ammonia liquor to the ton was obtained, or 92·46 gallons of tar and ammonia liquor to the ton of coal distilled. The ammonia liquors are weak in ammonia, due to the large quantity condensed, but the yield of ammonia gives a fair average, being equal to 14·24 lbs. of sulphate of ammonia to the ton.

#### GENERAL DESCRIPTION OF THE CAMBRIA MINING COMPANY'S PLANT AT CAMBRIA, WYOMING.

*Power.*—The power for operating the Cambria plant is obtained from a battery of fourteen boilers, consisting of the following:—Eight two-return flue boilers of 40 HP. each; one Heine water-tube boiler of 350 HP.; three 72-inch return tubular boilers of 150 HP. each; seventy 4-inch flues; two 48-inch return tubular boilers of 60 HP. each; twelve 6-inch flues. Steam is generated with the use of fine slack and unmerchantable coal obtained by

cleanings around the tippie. From this plant the steam is conducted by underground insulated pipes to the several haulage engines, tippie engine and compressors.

Three air compressors, two of 215 HP. each, and one of 125 HP., of the Norfolk type, are in constant use for supplying power to coal cutters and drilling machines operated in both mines. This compressed-air system includes the usual air receivers placed at advantageous points along the distributing pipes, outside the power house and inside the mines. The large compressors have cylinders 26 inches by 30 inches, and the small one has cylinders 22 inches by 24 inches. The steam pressure is 100 lbs. per square inch.

The coal is hauled from both the "Antelope" and "Jumbo" mines by the tail-rope system, and is undercut with Jeffrey's mining machines and Ingersoll coal-cutters, operated by compressed air delivered to them at a pressure of 65 lbs. to 85 lbs. per square inch. Rails weighing 25 lbs. to the yard are used in the main entry track, and 16-lb. rails are used for side entries and in rooms. There are now about 25 miles of 42-inch gauge track in the two mines. The "room and pillar" system of mining is used in both mines, although in a few districts of the "Antelope" mine the "long wall" system is found to be more economical.

"*Jumbo Mine.*"—The haulage engine for this mine is located about 300 feet from the entrance. It was built by the Nelsonville Foundry and Machine Co., of Nelsonville, Ohio. It is a double-drum engine, geared five to one, with two cylinders 16 inches by 24 inches, the drums being 6 feet in diameter and 2 feet 6 inches wide between the flanges, the latter being 12 inches deep, with capacity for holding about  $1\frac{1}{2}$  mile of 1-inch wire rope on each drum. The average trip consists of twenty pit cars, each weighing about 1,800 lbs., and containing about 4,000 lbs. of coal, hauled by a steel-wire rope 1 inch in diameter, of six nine-wire strands. A rope of this diameter, with nine wires to the strand and the Lang lay, has been found to give longer service than one with seven wires and the regular lay. The main line takes the tip in to a distance of 3,000 feet, the rope passing around the bull-wheel, 6 feet in diameter, placed under the track. The two ropes are then separated and connected with others of a branch line and the cars moved to the south district by the same engine. The trips are landed by the rope at the beginning of the trestle and let down by gravity to the tippie. After being dumped, the cars run by gravity to the foot of the incline, from which point they are taken by the rope.

In 1897 a new opening was made about 1 mile south of the tippie, and a railroad of 42 inches gauge, with maximum gradients of 2 per cent. in favour of loads and  $\frac{1}{2}$  per cent. against loads, was constructed along the side of the hill to the tippie. A 15-ton Baldwin locomotive handles the coal on this line and is able to deliver fifty loaded cars per trip. The entire mine is ventilated by a fan 25 feet in diameter, located near the main entrance, which operates by exhausting the vitiated air.

*"Antelope Mine."*—The entrance to the Antelope mine is on the west side of Coal Cañon, and when first opened in 1889 and 1890 the vein was found to be thinner than in the Jumbo mine, and it was deemed advisable to use smaller cars, weighing about 1,500 lbs. and containing about 2,400 lbs. of coal. As the workings progressed, the vein thickened and the largest cars can now be used in the mine, if desired. The main work in the Antelope mine is being done on the west side of Camp Cañon. The main entry between Coal Cañon and Camp Cañon is 3,200 feet long, from portal to portal, and the track reaches the portal on the west side of the cañon, a further distance of 400 feet, crossing on a trestle bridge 85 feet high.

The haulage engine at this mine is of the first motion pattern, the cylinders being 24 inches by 34 inches, and the drum 5 feet in diameter and 5 feet wide between the flanges, which are 6 feet 6 inches in diameter. The capacity of the drums is  $2\frac{1}{4}$  miles of  $\frac{3}{4}$ -inch wire rope. The trips from this mine consist of forty pit cars, each containing about 2,400 lbs. of coal.

The mine is ventilated by two fans, each 20 feet in diameter, one being located in Coal Cañon, near the haulage engine, and the other near the portal on the west side of Camp Cañon.

*Tippie.*—In the tippie building the coal from both mines, after being dumped by Mitchell tipples, is crushed by modern anthracite crushers and thoroughly cleaned by plate and revolving screens. The fine dust passing through screens of  $\frac{3}{8}$ -inch mesh is transferred by conveyors to large bins to the west of the building and drawn from the bottom of these into a wagon for transfer to coke ovens. Impurities in the coal are picked out by men and boys stationed along the conveyors that take the coal from the crushers, and removed by other conveyors. The coal is loaded into open railroad cars on three tracks and into box cars, with box-car loaders, on two others, there being five loading tracks in constant use.

*"Coke-Ovens."*—The coke-ovens are located about  $\frac{1}{2}$  mile south of the tippie. They are seventy-four in number and of beehive pattern, capable of producing 75 tons of coke per day. The entire

output of these ovens is used by the Deadwood and Delaware Smelting Co., Deadwood, South Dakota. To meet the demand of other smelting furnaces that will be erected in the near future, plans for a new battery of ovens are now under consideration; these will be of the by-product saving type, the Cambria coal being known to contain a large percentage of tar and ammonia. The coal is delivered to the ovens by a bottom-dump wagon holding about  $5\frac{1}{2}$  tons of slack, let down on a standard-gauge track by gravity from the tippie.

*Workshops.*—The plant is provided with complete machine, blacksmith-, carpenter- and pipe-shops, equipped with appliances adequate for making current repairs of all kinds and constructing new machinery when desired.

*Buildings.*—The mine-owners operate the only stores in Cambria, selling merchandise of all kinds, drugs, meat, etc., to the employees and people in the vicinity; as well as to a large hotel for the accommodation of those who do not prefer private boarding-houses. They also own 146 dwellings of various kinds, which are occupied by the miners and other employees, besides a large office building and warehouses.

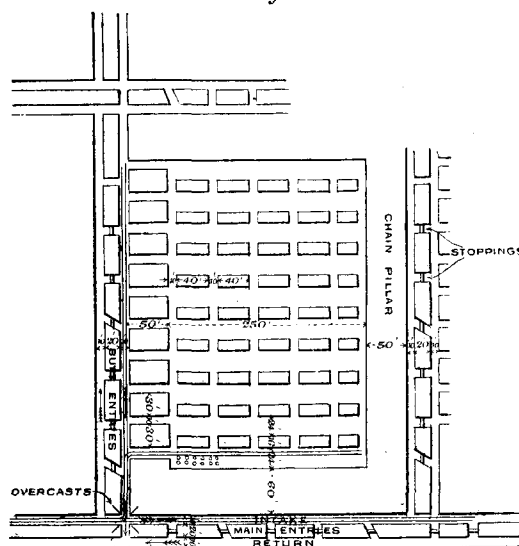
*Electric Lights and Signals.*—The tippie, workshops, engine-houses, and all parts of the plant are equipped with electric glow-lights, as are also the dwellings, the lamps in the cottages being of 16 and 32 candle-power each. The electricity is supplied by two dynamos located in the compressor building, as follows:—one dynamo giving 250 amperes at 110 volts, and one dynamo giving 150 amperes at 110 volts. Both are driven by an 80 HP. compound engine. For signalling in the mines a small dynamo is operated during the day, providing current to parallel wires running to all parts of the workings. The trip riders can signal from any point by completing the circuit with a copper rod laid across the wires.

*Water-Supply and Fire-Protection.*—The water-supply is derived from springs located about 5 miles north of Cambria, and brought to the mines by gravity in iron pipes 8 inches and 4 inches in diameter, furnishing excellent natural pressure for fire protection when taken from hydrants placed at favourable points. The tippie building is provided with a standpipe having outlets at different heights, with hose attachments ready for service. Two hose carts, filled with hose  $2\frac{1}{2}$  inches in diameter, are also stationed at points where they can be quickly obtained when needed. In addition there are six dozen portable chemical fire-extinguishers distributed in the care of employees and at convenient places in the mines and shops.

*Methods Employed in Working the Coal.*—The method employed in working the coal is that known in America as the “room and pillar,” which is the same as the “pillar and stall” in Great Britain. The illustration, *Fig. 1*, shows dimensions of entries, rooms, pillars, etc., which fairly represent the average conditions. It will be understood that the arrangements are sometimes modified in minor details to suit changing conditions in the texture and strength of the roof as well as in the solidity of the coal.

In driving the entries, cross-cuts are made about every 50 feet

*Fig. 1.*



ROOM-AND-PILLAR SYSTEM, CAMBRIA COAL-MINES.

for ventilation purposes, and as soon as a new one has been opened the preceding cut is tightly closed. The illustration shows a series of ten rooms, the minimum used in a sub-district, but local conditions sometimes warrant increasing the number to fifteen before the cross entry is driven, without danger of a squeeze resulting during the process of drawing the pillars. *Fig. 1* also represents the average length of rooms when they are going to the rise.

In some districts of the mine, where the seam lies horizontally for a considerable area, and consequently favours haulage in any



direction, the butt or working entries are driven about 200 yards apart, and rooms are turned from both and driven so as to leave a chain pillar about 50 feet thick. After all the rooms in the sub-district are worked out the inside pillars are drawn, leaving the chain pillars to protect entries. Practically all the coal in the seam is obtained, with the exception of losses due to unavoidable squeezes, that rarely occur. When drawing pillars they are worked out on lines parallel to the face rooms, when the sustaining power of the roof is uniform throughout the area, but if weak portions are developed the lines of cutting are varied to suit conditions and to sustain the roof in the best way for saving the coal. During the course of the earliest experience in these mines the rooms were opened 40 feet wide, but this was found to be too great for safe working, and a width of 24 feet was adopted as giving the best results. The single-entry system is never used in these mines. At present the coal is undercut with cutter-bar machines, supplied by the Jeffrey Manufacturing Company, Columbus, Ohio, and coal cutters manufactured by the Ingersoll-Sergeant Drill Company, New York, the machines of both companies being worked by compressed air.

Some mines using the air-chain machines are said to have attained results superior in economy and cost of maintenance to those by the cutter-bar machine, but the experience with them, under the conditions at the Cambria Mines, does not justify making the change, especially as the Ingersoll machine makes a better average record than either of the Jeffrey machines. Shearing machines are not used and no side cutting is required. Much of the drilling is done with the "Giant" drill manufactured by the Jeffrey Manufacturing Company and operated by compressed air, although many of the miners do their drilling with the McNelly-Hardscog hand drills owned by themselves. Nearly all the underground work is done on the contract system in these mines, the men being paid a certain price per car, varied to suit the conditions of the work at each place, to give the miners an equal rate of wage. The prices generally paid in the Jumbo mine, reduced to the tonnage basis, are as follows (the loading being done entirely by hand):—In rooms: cutting, 14 cents, drilling, 5 cents, loading, 2 cents. In entries: cutting, 17·5 cents, drilling, 5 cents, loading, 25 cents, drawing pillars, 35 cents. With the Ingersoll coal-cutter the average work done in ten hours in the Jumbo mine is to undercut a length of 48 feet, 4 feet deep, or 192 square feet. With this machine the cut is from 12 inches to 14 inches high at the start, tapering to a few inches in height

at a depth of 4 feet, but the cuttings contain a large proportion of coarse pieces suitable for the smaller sizes of merchantable coal and a minimum amount of fine slack; some of the best miners will at times largely exceed the above results. With the Jeffrey machine the average work in ten hours is to undercut a length of 32 feet to a depth of 5 feet 6 inches, or 176 square feet. This cut is only from 6 inches to 8 inches high, and the cuttings contain a very large percentage of slack, suitable only for coke making. The "long wall" system is used in a few districts of the Antelope mine, where the coal is thinner, and it is more economical than the "room and pillar" or "pillar and stall." Where necessary, in both mines, on account of heavy gradients, auxiliary engines are operated by compressed air to assemble the cars from rooms and make up the trip within reach of the main haulage ropes.

The absence of water in any considerable quantity, most of the workings being quite dry, and the entire absence of coal gases, are marked features in connection with these mines. Upwards of 2,000 tons of coal per day is now being cut in these mines by machinery worked by compressed air, and the property is one of the finest and most completely mechanical-equipped coal mines in the United States.

The output from these mines up to 1st January, 1898, has been as follows:—

	Net Tons of 2,000 lbs.
1889 . . . . .	2,985
1890 . . . . .	203,024
1891 . . . . .	354,106
1892 . . . . .	344,291
1893 . . . . .	310,907
1894 . . . . .	341,828
1895 . . . . .	348,611
1896 . . . . .	371,528
1897 . . . . .	498,997
Total . . . . .	<u>2,776,277</u>

The rate of wages for labour ranges per hour as follows:—

	Cents per Hour.
Surface labour . . . . .	15·0 to 17·5
Masons . . . . .	35·0 „ 45 0
Masons' labourers . . . . .	17·5 „ 20·0
Carpenters . . . . .	22·5 „ 27·5
Firemen . . . . .	17·5 „ 20·0
Teamsters . . . . .	17·5
Drivers underground . . . . .	23·5
Trackmen underground . . . . .	25·0
Timber men . . . . .	25·0 „ 26·0
Trappers . . . . .	11·0

The owners of these mines being a private corporation object to furnish data in regard to the cost of their coal f.o.b. railway cars, therefore the cost of production is not set forth in this Paper. Among the unique features of this plant is the fact that, on account of the large area of land owned, the sale of intoxicating liquors is prevented within a radius of about 8 miles from Cambria, a fact that contributes largely to the success, and may, in part, explain the absence of labour unions and strikes, which is a very unusual experience in coal-mining operations in America. No labour troubles of any kind have ever been encountered at Cambria, and the operators hold the confidence of their employees by fair treatment.

In closing, the Author desires to express his best thanks to the proprietors of the Cambria Mines for the great courtesy and attention shown to him during his visit to the mines, and for the information and photographs since supplied to enable him to complete this Paper.

The Paper is accompanied by nineteen photographs and two tracings, from one of the latter of which Figure 1 has been prepared.

---