Common Commodities of Commerce

COAL

F. H. Wilson

COAL

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EXAMINATION FOR GAS BEFORE FIRING
A RIPPING SHOT

PITMAN'S COMMON COMMODITIES
OF COMMERCE

COAL

ITS ORIGIN, METHOD OF WORKING, AND PREPARATION FOR MARKET

BY

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INTRODUCTORY

GREAT Britain undoubtedly owes her wonderful position among the great nations of the world to her vast store of that natural source of energy—Coal. Without a cheap and plentiful supply of the mineral the industries of this country could never have attained their present prosperous condition and importance, and as a substitute equal in every respect to coal has not yet been discovered it can truthfully be said that the maintenance of the commercial supremacy of Great Britain depends on her coal-mines.

Nature has certainly been kind in endowing this country with large areas containing many valuable coal seams; still it must be borne in mind that the supply is not inexhaustible, and that the quantity required each year is very great indeed. The problem as to the duration of our coal supply is a very difficult and complex one, and has been deemed of sufficient national importance to warrant the holding of two Royal Commissions on the subject during the last forty years.

With the great improvements that have taken place in mining methods of recent years, and the opening out of new coal-fields, there is every likelihood that the supply of coal will last much longer than was thought probable a few years ago. In the author's opinion, however, it is quite time that the question of economising the resources of the country was seriously considered by those in charge of the nation's affairs with a view to prolonging as far as possible the time when our coal supply will be completely exhausted.

The author has endeavoured in the space at his disposal to give the reader an intelligent insight into the many branches of this great industry, which finds employment in Great Britain alone for over one million persons. The majority of the statistics given in the book are taken from the Report of the Royal Commission on Coal Supplies, 1903–05, and other Government publications relating to coal-mining. In conclusion, he begs to acknowledge the kindness of several firms who have supplied information, and in some instances, blocks of illustrations. To Mr. S. Marsden he tenders his best thanks for assistance in the correction of proofs.

LEIGH, LANCS.,
December, 1912.

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CHAPTER I

FORMATION OF COAL SEAMS

It is now universally accepted that coal is the mineralised remains of decayed vegetation which grew in profusion over large areas ages and ages ago. A thin slice of a sample of coal examined under a powerful microscope will often reveal distinct traces of woody tissue and bark. Coal is usually found in more or less parallel layers known as beds or seams, separated from each other by other beds of clay, shale, sandstone, and sometimes limestone. The bed of hard clay on which a coal seam nearly always rests is termed the "underclay," and very often contains numerous fossiliferous remains of roots, helping to substantiate the theory as to the origin of coal.

There are two theories advanced as to the formation of coal seams, known respectively as the "in situ" and "drift" theory. Geologists who advocate the first-named theory maintain that coal beds are the remains of plants, etc., which long ago flourished on the exact site now occupied by the coal itself. It is assumed that the vegetation at that period was of a most luxuriant character, covering immense tracts of flat, marshy ground lying almost at water level. Plant life flourished and died in rapid succession, aided no doubt by a warm, moist atmosphere. In the course of time the low lying land, covered by a more or less thick bed of dead and decaying vegetable matter, became covered with water due to movements of the earth's surface, and formed a large inland sea or lagoon. Mud and sand carried in suspension in the water gradually settled down and covered the vegetation lying at the bottom. In time the sea or lagoon became silted up with beds of sand and mud, thus forming a fresh surface for the growth of other plant life. In this manner layer upon layer of vegetable matter would be formed, separated by layers of mud and sand, and these would be gradually changed into beds of coal, shale, and sandstone. This theory is generally accepted when the " underclay " of a seam contains fossil remains of roots, bark, etc. ; but seams are found, the " underclay " of which contains no such remains, and is not strictly speaking a clay at all. In such cases the " drift " theory is put forward. It is argued that the vegetation in the swamps and marshes lying close to the banks of rivers was carried down by the current and deposited at the river mouth where, in the course of time, it would accumulate into huge masses and eventually sink beneath the water and become covered with sand and mud.

The " in situ " theory seems to be correct as regards the formation of seams deposited on a proper underclay, whilst the " drift " theory explains the origin of seams having no proper underclay. In both theories it is agreed that the vegetable matter was gradually covered by beds of mud and sand. This covering would protect the vegetation from the air, besides subjecting it to the action of heat and pressure. The combined action of time, heat, and pressure would gradually produce a change in its physical appearance and chemical composition, and slowly convert it into some variety of coal.

CHAPTER II

VARIETIES OF COAL

THERE are many varieties of coal, though all are composed of carbon, hydrogen, oxygen and nitrogen, together with a varying amount of incombustible matter called ash. The constituents occur in different proportions in the several varieties of coal; in fact, the amounts differ in any one variety. As carbon is the principal constituent from a heating point of view, it naturally follows that the variety containing the highest percentage is the best. Coal with a high proportion of "disposable" hydrogen is valuable for gas-making purposes. Sulphur, usually in the form of iron pyrites occurs in some seams, and phosphorus in slight quantities is sometimes found. A light grey ash results from the burning of some coals, whilst others leave behind a heavy brown ash. The former is objectionable in coal for household purposes, as it very easily blows about. On the other hand, brown ash generally points to the presence of iron pyrites, and is unsuitable for steam purposes. Coal containing over 1 per cent. of sulphur cannot be used for iron making, as it causes a kind of brittleness known as "red-shortness" in the iron; and even if used for steam raising it often clinkers very badly. Coal may be classified according to chemical composition, heating value, or physical characteristics. The first classification is the one which is perhaps the most satisfactory, but the one generally used is that according to the physical appearance of the coal. Under this heading the different varieties are divided into Peat, Brown coal or Lignite, Bituminous coal (many varieties of which are found), Cannel, and Anthracite.

Peat is supposed to be the first stage in the conversion of vegetable matter into coal. It is of a brown, fibrous character, and generally burns with little heat and a great amount of smoke. It is found in thick beds in many parts of the world; notably in Canada, Russia, Germany, Norway and Ireland. It is only used to a comparatively small extent as a fuel, though the manufacture of peat briquettes in the United States and on the Continent has recently met with some success. The utilisation of peat for lighting purposes has been attempted for many years in Germany, but as yet there has been no satisfactory solution of the problem of how to produce power gas from peat cheaper than coal. It is used as a fuel in the central industrial districts of Russia on account of the high price of liquid fuel. The subject of Canada's resources in peat bogs has been given much attention recently by the Mines Department. It is estimated that there are in that country about 36,000 square miles of peat bogs capable of yielding about 28,000,000,000 tons of air-dried peat. This would be equal in fuel value to about 14,000,000,000 tons of coal.

The average chemical composition of Peat is—

Carbon	from	50	to	65	per cent.
Hydrogen	,,	4	,,	6	,,
Oxygen and Nitrogen	,,	28	,,	35	,,
Ash	,,	10	,,	13	,,

The calorific value of air-dried peat is about 8,000 British Thermal Units[1] (B.Th.U.).

[1] A British Thermal Unit is the amount of heat required to raise 1 lb. of water 1° Fahrenheit.

Brown coal, or Lignite, represents the intermediate stage between peat and true coal. It is of a more or less fibrous nature, brown or black in colour, and burns with a great deal of smoke. With the exception of a small area in Devonshire, brown coal is not found in the United Kingdom, but there are extensive deposits abroad, chiefly in Central Europe, North America and Australasia. It occurs in formations of more recent origin than the Carboniferous in which true coal is found, and the beds are often of very great thickness. Seams have been proved in several parts of the world exceeding 100 feet in thickness, and as the deposits are in many cases quite close to the surface, the mineral is worked quarry fashion.

The average chemical composition of Brown coal is—

Carbon	from	55	to	70	per cent.
Hydrogen	,,	5	,,	7	,,
Oxygen and Nitrogen	,,	26	,,	36	,,
Ash	,,	5	,,	12	,,

The average calorific value is about 11,700 B.Th.U.

Bituminous coal is the name given to true coal other than Anthracite, and is nearly always found in the Carboniferous system. It derives its name from the similarity of its flame to that of bitumen, although it contains no trace of this substance. This variety of coal may be subdivided into caking coals and non-caking or free-burning coals. These, in turn, are still further subdivided according to the use the particular coal is put to, such as house, gas and steam coal. Caking coal is bright and shining in appearance, and when heated, swells into a soft, spongy mass of coke; it is therefore used extensively for coke-making. Non-caking or free-burning coal is usually not quite so bright in appearance as the caking variety. It breaks into cubes and burns with a good deal of flame and little smoke, and does not coke. The world renowned steam coals of South Wales, and Northumberland and Durham are often put in a class by themselves and called semi-bituminous, as they almost approach Anthracite in quality and composition. The great majority of the coal seams found in this country and abroad belong to the bituminous variety.

The average chemical composition of Bituminous coal is—

Carbon	from	84	to	90	per cent.
Hydrogen	,,	5	,,	5·5	,,
Oxygen and Nitrogen	,,	7	,,	11	,,
Ash	,,	2	,,	4	,,

The calorific value varies from 13,500 to 15,000 B.Th.U.

Cannel is a peculiar variety of coal found only in Lancashire and Scotland. It has no cleat or lamination, and when burning gives off a great deal of flame. On account of the crackling noise it makes in the fire it is known as "parrot" coal in Scotland. Cannel is very rich in hydrogen, and on this account was in former times in great demand for gas-making purposes.

The average chemical composition of Cannel is—

Carbon	from	66	to	84	per cent.
Hydrogen	,,	5·5	,,	9	,,
Oxygen and Nitrogen	,,	5	,,	10·5	,,
Ash	,,	2	,,	6	,,

The average calorific value is about 14,000 B.Th.U.

Anthracite is supposed to be the last stage in the formation of coal. It is of an extremely hard nature, has a brilliant black lustre, and does not soil the fingers when handled. It is difficult to ignite, but when once alight, burns with very great heat and practically no flame or smoke.

The change in the composition and appearance of anthracite compared with the other varieties is said to be due to the effect of greater heat and pressure, with the result that most of the volatile matter originally contained has been driven off, leaving a very high percentage of carbon. In the United Kingdom it is only found in South Wales and Ireland. Abroad there are large deposits in the United States, British Columbia, and China.

The average chemical composition of Anthracite is—

Carbon	from	90	to	95	per cent.
Hydrogen	,,	3	,,	4·5	,,
Oxygen and Nitrogen	,,	2	,,	5·5	,,
Ash	,,	1	,,	2	,,

The average calorific value is about 15,250 B.Th.U.

THE WINNING OF COAL SEAMS

CHAPTER III

PROSPECTING AND BORING

A PRELIMINARY examination of the surface rocks is first of all made, when searching for coal in an unknown district or country, to find out what geological formation the rocks belong to, as some idea may then be formed as to whether coal is likely to be present or not. In this country the geological maps issued by the Government are of the greatest service to the mining engineer in proving the existence of seams in new districts. The United States and Australia also publish geological maps periodically, giving a great deal of information to prospectors.

If a surface examination proves the existence of outcrops, trial headings can be driven to ascertain the thickness, inclination and quality of the coal. If, however, outcrops cannot be detected, but other indications point to the possibility of coal being present, some system of boring is tried to prove definitely the existence of coal. By means of boring, information as regards quality, inclination, thickness, and probable cost of sinking may be obtained.

Bore-holes may be put down by two systems—percussive and rotary. In the first named system, which is carried out by hand for depths not exceeding 200 feet, a steel chisel is used which is attached to wrought iron rods about $1\frac{1}{4}$ inches square, and made in 18-feet lengths. The dropping of the chisel gradually cuts away the rock, and a circular hole is made by giving the rods a slight turn after every blow. The nature of the rocks bored through is obtained by examining the debris brought up from the bottom of the hole from time to time. An experienced borer can also tell when a change takes place in the nature of the strata by feeling the rods whilst boring is in operation. When the depth of the borehole exceeds 200 feet, the rods become too heavy to be lifted by hand, and steam power is generally used.

In the early seventies, Captain Beaumont invented the rotary system of boring by means of diamonds, and this system is now generally used when boring for coal, as a section, or "core," as it is called, is obtained of the strata bored through. In the Diamond system inferior diamonds are set in the bottom rim of a wrought-iron crown fixed to the end of hollow rods; as the rods and crown revolve, the diamonds, owing to their hardness, grind the rock away, leaving the "core" in the centre. As the diamonds cut deeper and deeper the "core" gradually rises through the crown into the "core-tube" above, and can be broken off and withdrawn from the hole along with the rods when desired. Whilst boring is in progress, water is pumped down the hollow rods from the surface to the bottom of the hole to remove the debris made by the crown, and to keep the latter cool. The water is forced back to the surface by means of a small pump. The cost of the diamonds is rather high, as they can only be obtained from an unhealthy part of South America.

In the Davis-Calyx system a steel crown (the lower edge of which is formed with long, sharp teeth, set like the teeth of a saw) is used instead of diamonds. Several boreholes were successfully put down by this system in proving the Kent Coal-field.

CHAPTER IV

SINKING SHAFTS

In the early days of coal-mining, only those seams lying close to the surface were worked, and the shafts were of very moderate depth, as the sinking and winding appliances were only of a very primitive nature. At the present time many of the shafts put down in connection with new undertakings have attained depths which were considered impossible not many years ago. Shaft sinking is one of the most expensive items in opening out a colliery even if only ordinary difficulties are met with. Sometimes, however, quicksands or enormous quantities of water are encountered, and sinking is only successfully carried out after a very heavy expenditure; in fact, in several instances sinkings have been abandoned owing to the difficulties met with in the shape of water or loose ground. Up to 1842 it was a common practice to sink only one shaft to work a coal seam, but after the Hartley disaster which occurred in that year it was made compulsory to provide at least two shafts at every colliery.

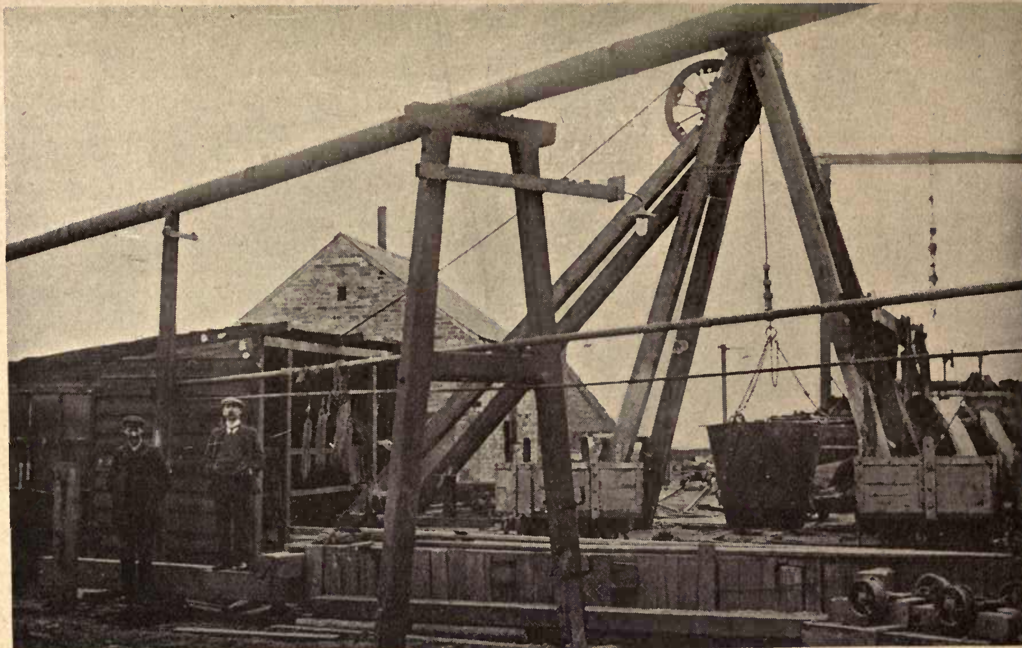
Many points must be carefully considered before the position of the shafts is finally decided upon, as the future success of a colliery undertaking is, to a great extent, dependent on the site selected. If the coal lies at a moderate depth from the surface, and is flat or only moderately inclined, the shafts are usually sunk in the centre of the royalty, so that the underground haulage is equally divided on all sides. On the other hand, if water is likely to be met with in considerable quantities, the shafts may probably be sunk to the lowest point of the royalty, so that any water found in the workings can be drained to the bottom of the shaft and from there pumped to the surface. The shafts should be close to one, or, better still, two railways, as competition enables the colliery to obtain reasonable freight charges; and, if possible, carriage by canal should be provided for. There should be plenty of room close to the shafts for sidings, coke-ovens, washeries, and wasteheaps, also an ample supply of water for steam purposes.

Most shafts are sunk vertically and may be either circular, oval, or rectangular in shape. The circular form is the most common in this country and on the continent. In Scotland and America the rectangular form is favoured, and several oval shafts have been put down in South Wales. The circular is certainly stronger than any of the other forms and is cheaper to sink, and whilst the whole of the space is not utilised as in the rectangular shape, this cannot be considered as waste when the question of ventilation is borne in mind. Circular and oval shafts are lined with brickwork or iron tubbing or a combination of both. The rectangular form is usually supported by a timber framing, though there are several shafts in the United States lined with reinforced concrete.

The size of a winding shaft depends chiefly on the proposed output per day. For an output of 1,000 tons per day of eight hours, a reasonable size would be 18 feet diameter. Many of the new shafts at present being put down or just completed in this country are from 22 to 24 feet in diameter.

The exact size of a shaft having been decided upon, excavation is commenced with pick and spade. For the first 4 or 6 yards the excavated material is raised to the surface in stages by hand. In the meantime a winding engine and headgear are erected and the dirt is afterwards wound up in an iron bucket known as a "hoppet." A temporary engine and headgear may be provided whilst sinking is in progress, or the permanent headgear and engines may be installed at once. If the former plan is adopted, the temporary arrangements are fixed in such a position that the permanent machinery can be erected in the proper place.

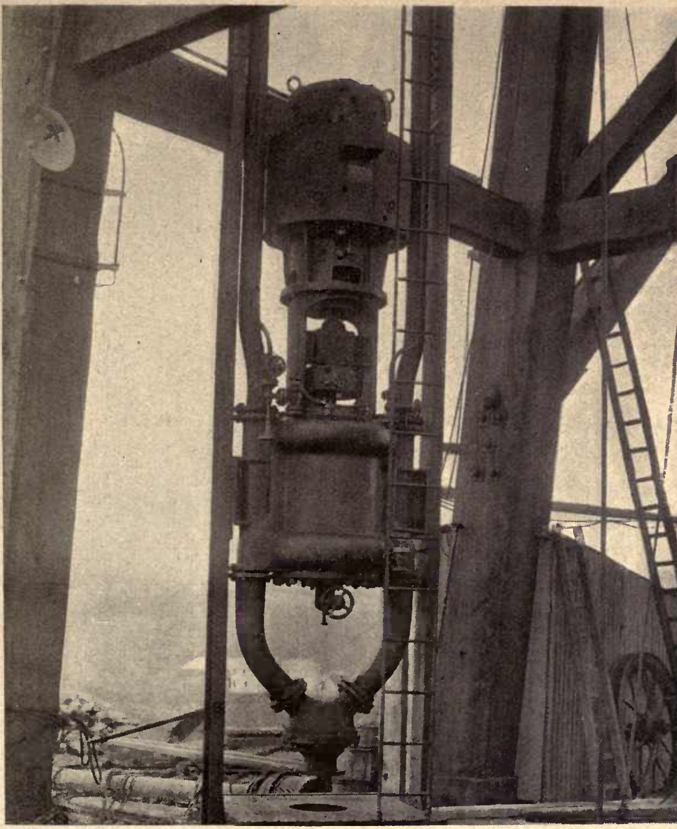
As soon as the soft ground close to the surface is gone through, blasting with some high explosives such as gelignite or blasting gelatine is resorted to. The shot holes are made by hand or some form of hammer drill. With the latter the speed of sinking is considerably increased, and on this account power drills have been used to a considerable extent in recent sinkings. Until the "stone-head"—the first bed of solid rock from the surface—is reached, the shaft sides are temporarily lined with flat steel rings, fixed about three feet apart down the shaft, and kept in place by strong iron hooks. Wooden planks are placed behind the rings and made tight by wedging. As soon as the "stone-head" is reached, a cast-iron bricking ring is carefully laid either in oakum, flannel, or in cement, and the permanent lining of brickwork is carried up from this to the surface. The thickness of the brick lining depends to a great extent on the nature of the ground sunk through, the usual thickness being from 9 in. to 18 in. When the first length of brickwork is finished, sinking is recommenced for a further ten or fifteen yards and the brickwork carried up as before. In this manner sinking and bricking is carried on alternately until the required depth is reached Sinking and bricking simultaneously can be carried out by means of a special form of bricking scaffold designed by Professor Galloway, and used by him at several sinkings in South Wales.



TEMPORARY HEADGEAR FOR A SINKING PIT

Water is nearly always met with in sinking. If the quantity is not large it is dealt with by winding out in water barrels or hoppets. If the amount is at all great special sinking pumps driven by steam or electricity are used. These pumps are slung in the shafts by chains or ropes from a powerful capstan engine on the surface. Electric turbine pumps have been used with great success for dealing with large feeders of water. An illustration of one of these pumps, made by Messrs. Dick, Kerr & Co., Ltd., is shown on the opposite page. The pump is capable of raising 20,000 gallons of water per hour against a head of 800 feet.

Sometimes a lining of cast-iron is used to permanently dam back the water. This lining, which is fitted in segments cast to the circumference of the shaft, is known as "tubbing." One side of the tubbing has a smooth surface, the other is ribbed with horizontal and vertical flanges. The segments are lowered down the shaft and fitted together so as to form complete rings one above the other. In the old system of tubbing the flanges were cast on the convex side of each segment, whereas the latest practice is to have the concave side flanged so that a smooth surface is presented to the natural sides of the shaft. The vertical joints are broken like the joints in brickwork, and between all joints, both horizontal and vertical, thin lead sheeting is placed; the segments are also bolted together along their horizontal and vertical edges.



By permission of Dick, Kerr & Co., Ltd.

ELECTRIC TURBINE PUMP FOR SINKING PURPOSES

CHAPTER V

SPECIAL METHODS OF SINKING

WHILST ordinary water difficulties can generally be dealt with either by the use of powerful pumps or some system of tubbing, excessive quantities are sometimes met with, and the difficulty of sinking becomes considerably increased. A special method of sinking under such circumstances has been devised on the continent known as the Kind-Chaudron system. In this system the shaft is bored out by means of immense boring tools, known as trepans, without any water being raised. A small trepan is first used to bore a hole about half the size of the proposed shaft, a certain distance down. A larger trepan is then used to bore out the shaft to its full size. The boring with the two trepans is carried on alternately until the water-bearing strata is passed. A cast-iron cylinder consisting of rings bolted one upon another with a special water-tight joint at the bottom is then lowered, so that the shaft is lined from top to bottom. Concrete is rammed between the lining and the shaft sides, and when this has set, the water is pumped out of the shaft and sinking is afterwards carried on in the usual manner. This method was successfully used in sinking one of the shafts in Kent some years ago, when, owing to the large quantities of water encountered, it would have been impossible to have succeeded with any ordinary method.

The difficulty of sinking through water-bearing strata is often increased owing to the presence of more or less thick beds of running sand similar to quicksand.

Several systems (all of continental origin) have been used in such circumstances. In Poetsche's system of sinking, the running sand is frozen by first boring a series of holes in the form of a circle round the site of the shaft. The holes are lined with tubes, through which a special freezing mixture is forced, and in time a ring of frozen ground is formed completely enclosing the shaft site. Sinking then proceeds in the ordinary manner as the barrier of frozen ground prevents the watery mass from running into the excavation. This system has been successfully carried out on several occasions in this country, notably at Easington. The cost of freezing is, however, very high. Under ordinary circumstances and conditions it is estimated that to sink two shafts 20 feet diameter the cost would be as follows—

300	feet	deep	£17,500
600	,,	,,	£28,000
1,200	,,	,,	£50,000

Instead of forcing down a freezing mixture, liquid cement has been tried in one or two instances on the continent. The cement is forced down boreholes and works its way into the strata, and when solidified forms a water-tight ring. It is claimed that the cementation process is very much cheaper than any system of freezing, and quite as good.

In the "Haniel and Lueg" drop-shaft system of sinking, a ring of masonry or an iron cylinder with a cutter fitted to its foot, is forced through the loose and water-bearing strata down to the rock free from water. The ground is simultaneously sunk by hand or excavated by a grab. If the shaft cannot be sunk and bricked up in dry work for the first 30 to 50 feet, it is advisable to commence with a masonry drop-shaft which, however, should be sunk only to such a depth as can be reached without applying any additional load. The drop-shaft proper usually consists of cast-iron rings, which are bolted together so as to form a column of tubbing.

The tubbing is forced down through the sand by means of hydraulic jacks erected on the top ring and placed a certain distance apart, their buttress being a pressure ring firmly built in the masonry wall. They are connected to each other by a circular system of tubes, and arranged in such a manner that the rams, after being advanced full length owing to the sinking of the tubbing, can be lifted by hydraulic power to allow further rings to be put on. This system of sinking was successfully applied at Newbiggin Colliery and also at the Astley Green shaft belonging to the Pilkington Colliery Co., Lancashire. At the latter sinking, the "Haniel and Lueg" method of underhanging tubbing was also adopted after the column of tubbing had been pushed through the sand to the stone-head. In this method, the necessity of protecting the shaft sides by temporary supports is done away with, as instead of building up from a curb at the base, the segments are suspended from a crib at the top, thus building downwards. It is claimed that this method not only prevents accidents from falls of ground, but also has the effect of cutting off feeders as they are met with, resulting in a considerable saving of time, pumping charges, etc.

WORKING COAL SEAMS

CHAPTER VI

THE HISTORY OF COAL-MINING

THERE is every reason to believe that the use of coal as a fuel was known to the Ancient Greeks. Theophrastus, a Greek philosopher, more than 2,300 years ago wrote as follows: "These fossil substances that are called coals and are broken for use are earthy. They kindle, however, and burn like wood coals. These are found in Liguria and in Elis, and are utilised by smiths." The Romans, during their occupation of Britain, appear to have established several military stations close to the outcrop of coal seams, and workings and tools found therein have been proved as belonging to the Roman period. In Durham and Lancashire, cinders have been found among the remains of Roman camps.

There does not appear to be any authentic records showing that coal was used to any extent in Great Britain from the time of the Roman occupation until the ninth century. About 852 the Abbot of Peterborough let certain land on condition that, among other items, twelve loads of coal were sent each year to the Monastery. Other records show that coal was used as fuel in Scotland and Durham in the thirteenth century. In 1239 Henry III granted a charter to the Freemen of Newcastle to dig for coal, and about 1269 the monks of Tynemouth were working coal in that locality and shipping it to London, where it was known as sea-coal, and used for manufacturing and household purposes.

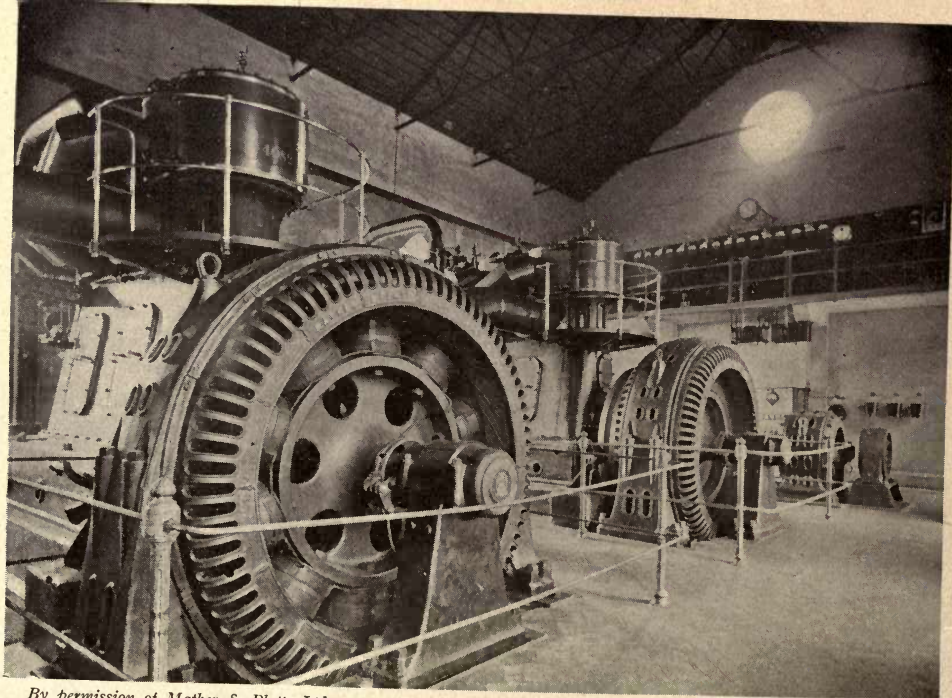
In the Cotton MSS. in the British Museum, mention is made about this time of a grant of sea-coal in the Cannock Chase district in Staffordshire.

Edward I, in 1306, prohibited the burning of coal in London, owing to the bad effects of the smoke on the health of the gentry in the capital, and commanded that fires should be made of wood. This was only a temporary check, however, as mining on an extensive scale, comparatively speaking, was carried on in the north under the direction of the monks of Durham Monastery and Finchdale Abbey, between the twelfth and sixteenth centuries. The monks of Bolton Abbey in Yorkshire purchased coal about the end of the thirteenth century for lime-burning and forge purposes, and were also working coal themselves. Coal was also worked about this time in Lancashire, the Midlands, and South Wales. In the seventeenth century there was a regular shipping trade in coal between Newcastle and Sunderland, to London and various Continental ports. Small quantities were shipped also from the Lancashire and North Wales coal-fields to Ireland.

Up to the beginning of the eighteenth century mining was only carried on in a very primitive manner, as the use of steam was unknown. Coal was obtained by quarrying those seams which ran out at the surface, and by means of shallow shafts or "bell-pits" sunk close to the outcrop. These shafts were of small diameter at the surface, but gradually widened out in the form of a bell until the coal was reached, where as much of it was worked as possible. As the outcrop coal became exhausted, narrow galleries were driven either from the outcrop or from shallow shafts. The galleries were supported by small pillars of coal, though very often the supports became so small owing to "robbing," that they ceased to serve the purpose they were intended for, and the workings had to be abandoned. The coal was conveyed to the shaft bottom or to the mouth of the " day-eye " by manual labour. Natural ventilation was relied on to keep the workings fit to work in, and candles or small lamps were used for lighting.

In 1698 Captain Thomas Savery invented the first practical steam-engine, but it was used solely for pumping water from mines. This was followed, in 1711, by the Newcomen engine, which was used for the same purpose. With the advent of the steam-engine, designed by Watt in 1784, and improved by him from time to time, difficulties which were formerly thought to be insuperable were successfully overcome. It can really be said that from this date coal-mining commenced to rank as one of the greatest industries of the country.

Between 1730 and 1735 Abraham Darby, after many attempts, was successful in the substitution of coke for charcoal in iron smelting, and from this time onwards, as wood became more scarce and the iron industry more prosperous, the demand for coal became greater. It is interesting to note that up to the time of Newcomen the deepest shaft in Great Britain was not more than 120 yards, and the greatest distance of the workings underground from a shaft seldom exceeded 200 yards. The introduction of the steam-engine, however, for haulage, winding and pumping purposes, provided facilities for laying out the workings on a scale heretofore thought impossible. The demand for coal increased considerably when in 1803 coal gas commenced to be used for lighting purposes, and the introduction of the blast furnace in the ironworks of Scotland about 1828 gave a still greater impetus to the industry. This improvement in the smelting of iron ore meant a considerable saving in the amount of fuel required,



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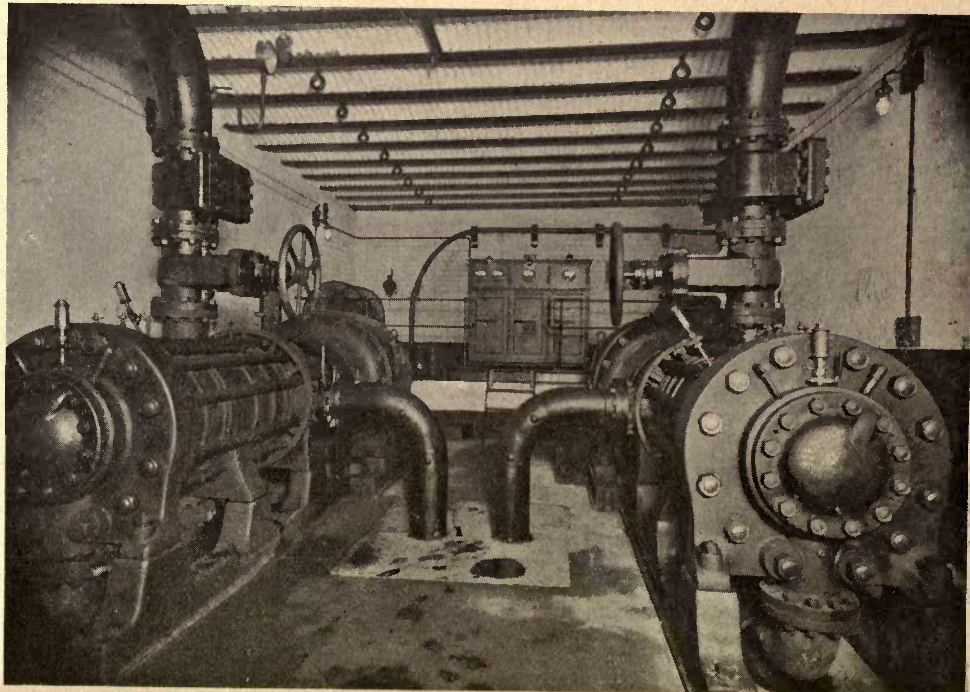
ELECTRICAL GENERATING PLANT AT A COLLIERY but the rapid expansion of the iron trade throughout the country resulted in a greater demand for coal, and this was helped considerably owing to the facilities afforded by railways, steamships, and the increased demand for industrial purposes generally.

Official statistics were obtained for the first time in 1854, the output in that year being put down at 64,660,000 tons. It is not necessary to enumerate the wonderful improvements that have been made, from time to time, in the methods of working and general underground conditions since then; sufficient is it to say that in less than 20 years the output had doubled itself, as in 1873 the output amounted to 126,590,000 tons; in 1880 the output was 146,970,000 tons; in 1890, 181,614,000 tons; in 1900, 225,181,000 tons, and in 1911, 271,891,899 tons.



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CHAPTER VII

METHODS OF WORKING

When coal-mining was in its infancy, the method of extracting the coal was carried out in a very unscientific and wasteful manner. Narrow galleries were driven in the seam in such a manner as to cut it up into a series of blocks known as pillars. The pillars formed a support to the underground roads if left large enough, but in the majority of cases they were "robbed" from time to time and became too small for the purpose they were intended for. The wrongful working of the pillars generally ended in the abandonment of the mine, and much valuable coal was thus lost for ever. As mining became more general, a more efficient system of working was introduced. This was to first cut out the seam into pillars of a fixed size in a systematic manner, and afterwards to extract the pillars and thus lose no coal in the working of the mine. For many years this system, known as the pillar-and-stall method, was the system used, with slight modifications, in every district, and is the method used at the present day in the working of some mines.

Generally speaking, the pillar-and-stall system is used in working seams over seven feet in thickness, or where a seam lies under valuable buildings requiring support or is close to the surface. The modern method of working is to make the pillars either square or rectangular, and as large as possible. The operation of cutting out the pillars is known as "whole" or "strait" working, and the headings are driven from two to five yards in width. The second working, that is, the removal of the pillars, is called the "broken working." Instead of waiting until the whole of the estate is cut up into pillars before the "broken working" is commenced, the mine is divided into districts known as "panels." The panels are separated from each other by a solid barrier of coal, and as soon as a panel is cut out into pillars, these are extracted as quickly as possible. In this manner the cost of the strait working in certain districts of the mine (which in all cases is very heavy) is compensated by the cheaper cost of the broken working in other districts. There are now many modifications of the pillar-and-stall system to suit special conditions, both in this country and abroad.

The Long-wall method of working is now usually adopted when the seam is under seven feet in thickness, though thickness is not the only consideration, as other factors, such as nature of the roof and floor, proximity to the surface, the support of surface property, etc., must also be considered. In this system, the coal is usually extracted in one operation by means of one or more straight "faces," which are started as soon as the pillar for the protection of the shafts is cut out. The haulage and other roads are made as the coal face advances by taking down several feet of the roof and packing the dirt on each side of the roadway. The main haulage roads are laid out so as to divide the seam into districts of equal size, and thus permit of an equal output per day from each district. Branch roads are driven from the main roads at equal distances, the distance apart being regulated to a great extent by the thickness of the seam, and these roads are taken right up to the face of the coal. As the face continues to be worked, further away from the main roads, cross roads are driven cutting the old branch roads off, and from the cross roads new branch roads are started. It often becomes necessary to take down several successive thicknesses of roof in the main haulage roads and airways to maintain a reasonable height owing to the sinking of the roof and superincumbent strata; one operation of roofing down is only necessary, however, in the branch roads if they are cut off by cross roads at proper intervals. The face of the coal may extend in a straight line for hundreds of yards or it may be arranged in a series of steps, by keeping each working place a few yards in advance of the next. The coal is got by first under-cutting or "holing" a length of face. In this operation the seam is cut into, usually at the bottom, for a depth of from four to six feet. If there is a soft clay floor, or a band of clay in the seam, the undercutting is done in the clay instead of in the seam itself, as a considerable saving is effected in the amount of small coal made.

Undercutting by hand is very laborious work, and is, in fact, the most arduous class of labour connected with coal mining, especially in hard or thin seams. On this account undercutting by machinery is becoming more extended year by year. As the undercutting proceeds, sprags or short props are set by the miner to prevent the coal falling on him whilst at work. Some seams, when holed a reasonable depth, can be broken down by driving in steel wedges; others require the use of explosives. When this is necessary shot-holes are drilled in the coal close to the roof, about six inches shorter than the depth of the holing, and the coal is blasted down.

When the mine is over three feet in thickness, the wagon or tub is taken from the end of the branch road right across the face, and filled close to where the coal is lying. In thin mines this is seldom done, as a very small wagon would be necessary, so the coal is thrown by the miner from the face to the road, and there filled out. The roof at the coal-face is supported by props and bars. These may be either of timber or steel; the latter are much more costly, but they last much longer. As well as props, "chocks," consisting of square pieces of timber built up from roof to floor, are used in some mines. Props, bars, and chocks are set at a certain specified distance apart, as laid down by the timbering regulations of the particular mine.

The direction of the long-wall face is generally determined by the "cleat" of the coal, that is, the vertical joints in the coal, and the inclination of the mine. If the coal is of a tender nature, the coal face is laid out at right angles to the cleat, and is termed working "on end." On the other hand, there are seams which could not be worked to a profit if the face were in this direction, owing to the hardness of the coal; when such is the case, the face is laid out parallel to the cleat, and is known as working "on the face." A modification of the two systems is to lay out the face so as to cut the cleat at an angle; this is known as "half-end and face."

A typical method of working long-wall for a seam 4 feet 6 inches thick with an inclination of 1 in 6 to 1 in 8 is as follows:—After the shaft pillar has been cut out, main levels are laid out on either side, and from these at a distance of about 600 yards apart, two main brows are driven to the dip of the seam. At every 200 yards down each brow, levels are driven off on each side, and faces opened out by means of slants and branch levels. The slants are driven up 100 yards apart to cut off the levels before they become too low, and new roads are started off. The cutting off of the branch levels periodically, by the slants, reduces the cost of road maintenance, and also lessens the distance the coal has to be conveyed by hand from the coal face. The levels are provided with mechanical haulage, or horses, to bring the coal from the bottom of the slants to the main brow, where some form of mechanical haulage is used to convey the coal to the pit bottom. The coal on the "rise" side of the shafts can be worked by a similar arrangement of brows and levels. Instead of machine haulage, however, horses or ponies are used on the levels, and the coal is lowered down the brows by gravity.

There are many different systems of working long-wall, as the conditions are never exactly the same in any two mines. Long-wall retreating is the method used in working a mine subject to spontaneous combustion. In this system the seam is cut out into pillars by means of narrow roads until the boundary of the district is reached, and the pillars are then worked back to the shaft in the form of a long-wall face. It is really a combination of pillar and stall and long-wall. The advantage, as compared with the ordinary long-wall advancing system, is that the goaf or waste, in which spontaneous combustion usually takes place, is left behind, and as no roads have to be kept open therein, it soon squeezes up, and becomes practically solid, thus obviating entirely the danger of a fire.

In South Wales, a system of working the anthracite mines, known as "Single and Double Stall" is in vogue. It is a method which has met with great success in working mines with bad roofs and in close proximity to one another.

The well-known South Staffordshire thick seam (which varies from 24 to 30 feet in thickness) is worked on a system known as "Square Work." The seam is cut out into sides of work, about 38 yards by 46 yards, in the bottom 7 feet of the coal, and afterwards worked in such a manner that only six small pillars in each side of work are left in, the full thickness of coal in the remaining portion being extracted. This is a mine liable to spontaneous combustion, and each side of work is so arranged that only two entrances are made to it from the main roads. As soon as a side is worked out, the two openings are securely dammed off by strong brick and sand stoppings. The majority of thick seams are, however, divided into a number of separate seams of normal thickness by dirt bands, varying in thickness from a few inches to several feet, and these are often worked in stages by the ordinary long-wall system. The top band of coal may be worked first, the strata allowed to settle, and the next band worked, and so on until the full thickness of coal has been exhausted. In some parts of this country, and in many coal-fields abroad, the seams lie at a very high inclination, and are worked as in metalliferous mining. Some of the brown coal deposits abroad are found within a few feet of the surface, and the coal is worked in the open or quarry fashion, the surface soil being first turned over to expose the coal.

Whilst dealing with the subject of working coal seams, it will not be amiss to consider the maximum depth that it is considered possible to reach in coal-mining. The Royal Commission on Coal Supplies, 1903-05, took 4,000 feet as the limit of depth. At the Pendleton Collieries in Lancashire the workings are now over 3,200 feet from the surface, and at the Produits Colliery in Belgium a depth of 3,773 feet has been reached. With the continued improvements in mining methods and machinery, there is every reason to believe that the 4,000 feet limit will not prove an unsurmountable obstacle. The pressure of the strata at this depth will certainly be enormous, but whilst this may decrease the percentage of round coal and increase the cost of maintaining the roadways and of timbering, it should assist in the working of the coal.

The great difficulty of deep working is the increase in temperature and the humidity of the air. There does not appear to be a uniform rate of increase of temperature with depth, though in this country the rate of increase is found to be approximately 1 degree Fahrenheit for every 60 feet of depth. It is quite possible to work in dry air at a temperature of 95° Fahrenheit; in fact the temperature of the lower workings at the Pendleton Collieries is 93½° Fahrenheit, but in moist air the limit of working is reached at about 80° Fahrenheit, as at this temperature workmen are very soon fatigued.

The problem of temperature and humidity will no doubt be overcome to a great extent by the passing of large volumes of dry air through the workings of deep mines on even a more elaborate scale than is done at present, and it is quite possible that some means will be devised of cooling the air and reducing its temperature before it enters the workings.

The Royal Commission did not take into account any seam less than one foot in thickness in estimating the coal resources of the country, though seams one foot thick and under are worked at the present time in conjunction with beds of fireclay or other mineral. There must be quite a number of these thin seams in the different coal-fields of this country, and no doubt as the thicker beds become exhausted, more attention will be paid to the possibility of working the thin mines at a profit. Generally speaking, the output per man is less in thin mines than in thick ones, but if the roof and floor is of such a nature as to require very little maintenance and the coal is of good quality, the total cost of production will compare very favourably with that of mines of ordinary thickness. The more extended use of coal-cutting machinery in thin mines will certainly help in this direction, as already in many instances the introduction of mechanical coal-cutters has resulted in successful working.

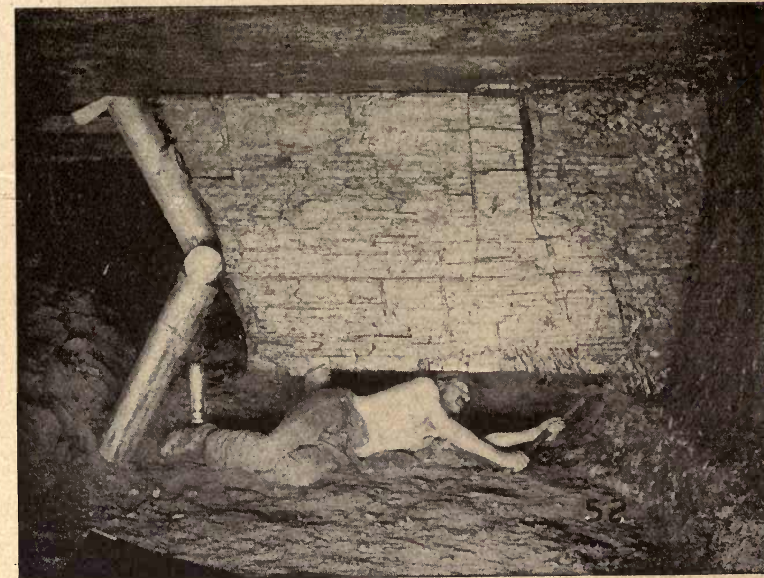
CHAPTER VIII

MACHINE MINING

THE hardest, and most exhausting work in the getting of coal by hand is the preliminary undercutting which is usually done in the lower part of the seam. Whilst engaged in this work, the miner is often forced to remain in a crouched position, half lying, half kneeling, for hours at a time. To undercut the coal a reasonable depth means that he must practically lie under the coal which is only supported by the holing sprags or props, and a large proportion of accidents at the coal face are caused through the coal falling without warning, and crushing the unfortunate workman underneath.

Undercutting the coal by hand must of necessity result in a certain amount of very small coal being made. This coal, in some districts, is unmarketable, and is simply thrown back into the goaf or waste. The percentage of small coal made is not very high in the case of a coal seam of moderate thickness (say from 4 to 6 feet) but in a thin seam a very high proportion of small coal is made, with a corresponding low selling price.

Very little is known relative to the early attempts in the use of machines for undercutting. The first patent appears to have been taken out by a Michael Menzies in 1761. The intention of the inventor was to transmit power from the surface through a number of rods and chains passing over pulleys to a machine fitted with a heavy pick, which was to undercut the coal. In the century following the attempt of Menzies, more than one hundred patents were taken out for a similar purpose. In 1847 a coal-cutting machine, made by W. Story, of Gateshead, was tried in one of the



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A MINER UNDERCUTTING BY HAND

collieries in the Lancashire coal-field, and from this time the experimental stage of the " iron man " may be said to end, and the more practical stages begin.

Machines for undercutting the coal are now extensively used in this country and abroad, particularly in the United States. In the latter country there are about 13,250 coal-cutting machines at work, producing about 174,000,000 tons of coal annually. In this country the majority of machines are installed in thin seams or in seams of excessive hardness, and in numerous instances have enabled mines to be worked at a profit which would have been impossible otherwise. The quantity of coal cut by machinery in this country amounts to nearly 16,000,000 tons, or approximately 6 per cent. of the total output, Scotland, and the Yorkshire and North Midlands districts producing between them the greater portion of the output. In the United States the percentage of cut coal to the total output is about 35, showing how much more extended is the use of machines in that country as compared with the United Kingdom.

Coal-cutting machines may be divided into two classes: Percussive and Rotary. Percussive machines are used for driving advance headings and in pillar-and-stall work, whilst rotary machines are used in long-wall workings, though in America there are several machines of the latter type used in pillar-and-stall workings. Compressed-air was the sole motive power used in the earlier forms of coal-cutters, but electricity has in recent years become a formidable rival for driving rotary machines, particularly in non-gaseous mines, on account of its greater efficiency and flexibility. Many attempts have been made to operate percussive machines by electricity, but up to the present with little success. There are, in this country, about 570 rotary machines at work driven by compressed-air and 990 by electricity. The percussive machines number 580, all except four being driven by compressed-air.

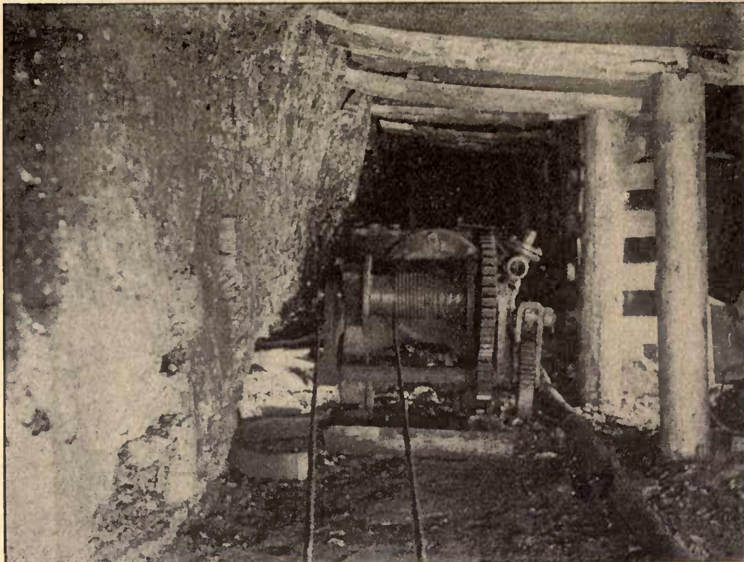
Percussive machines are made in two different forms, known respectively as puncher and heading machines. The puncher machine is usually mounted on wheels, and is provided with handles which permit of its being turned into any required position when working. It is placed on a sloping board about 8 feet long and 3 feet wide, close to the coal face and dipping towards it. The operator sits straddle-legged on the board at the back of the machine, and directs the cutting by means of a handle. The depth of cut varies from 4 feet 6 inches to 6 feet, with a width of from 5 to 6 feet at one setting of the board. This type of percussive machine is only used to a small extent in this country, though it has a high reputation in the United States and Canada.

The heading machine closely resembles the ordinary percussive rock drill used in tunnelling and sinking. It is fixed to a vertical column or stand, and is provided with arrangements by means of which the operator can tilt or slew the cutter as desired. There are several advantages possessed by this class over the puncher type. It can be used for shearing and drilling after the undercutting is completed; there is very little shock to the machine-man when operating the machine; it can be fixed so as to undercut at any desired level in a seam, say, in a band of dirt or inferior coal, and the cut is almost parallel and not tapered as is the case with the puncher type. Well-known makes of this class of machine are the Radial-axe, Little Hardy and Siskol. The average undercut of a heading machine at one setting varies from 4 to 6 feet, and with a width ranging up to 12 feet.

There are three types of rotary coal-cutting machines: disc, bar, and chain, and all three types are used for undercutting in long-wall workings. The number of disc machines at present at work in the United Kingdom is 1,020, of which 578 are driven by electricity, and the remainder by compressed-air. In this type of machine the picks or cutting tools are fitted on the rim of a horizontal disc, which is made in sizes varying from 3 to 7 feet in diameter, 5 feet 6 inches being the size in common use. When the machine is set in motion the disc is caused to revolve, and the picks cut a narrow groove into the coal itself or in the clay under it as desired. The depth of cut depends on the diameter of the wheel used. The old form of machine was fitted with wheels which ran on rails, but the majority now work on flat steel skids resting on the floor. Whilst cutting is in progress the machine drags itself forward by means of a small haulage gear attached to one end of the machine frame. This consists of a drum which is rotated by a ratchet arrangement working off the main gearing. On the drum is a steel wire rope, which passes round a small pulley attached to a prop, about 20 yards in front of the machine, and then back to the frame to which it is securely attached.

Side skids are also attached, one sliding along the coal face, and the other along a row of props set parallel to the face at the other side of the cutter. By this arrangement the machine is kept close up to the face whilst at work, and the maximum depth of cut is thus obtained. If the position of the picks on the wheel is reversed, the machine is enabled to cut in the opposite direction along the face.

The Diamond machine is a well-known type of disc machine at work in this country, and is generally used for hard cutting on account of the comparatively low speed



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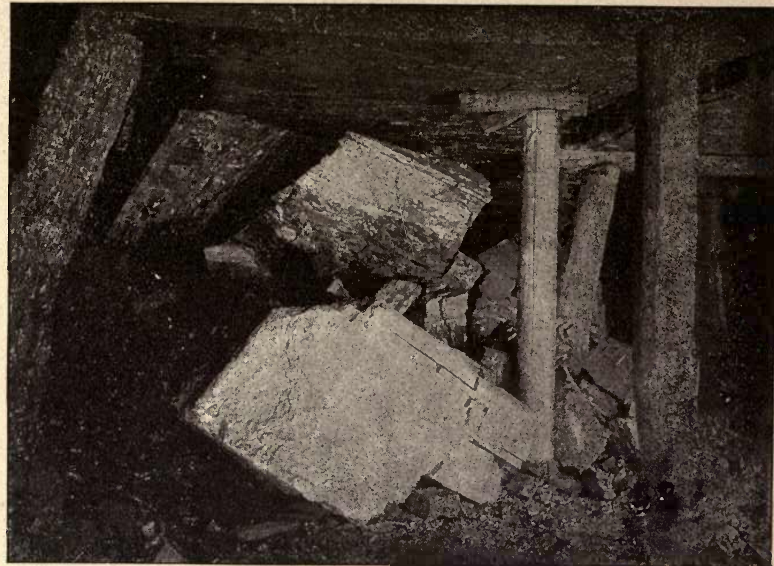
A DISC COAL-CUTTING MACHINE AT WORK

of the cutters, though the coal must be fairly strong to enable it to hold up when undercut. In the illustration on page 37 a Diamond coal-cutter is shown at work. The electric machine is made in two sizes ; one, with an overall height of 17 inches, fitted with two 10-horse-power motors ; the other 24 inches high, with two motors of 18-horse-power. The speed of the motors is low, and the discs make from 12 to 20 revolutions per minute according to size.

In the Bar machine a tapered steel bar, fitted with cutters round its edge, is used instead of a horizontal wheel. Some seams are of a very tender nature, so that the coal tends to fall over as soon as it is undercut. Wedges or sprags are set in the cutting as soon as possible when the cutter is clear, but with the disc machine there is always about 5 or 6 feet of coal left unsupported, according to the size of the disc. The result is that the coal often falls over and jams the disc. A good deal of valuable time is in this way often lost, as the coal has to be cleared away before the cutting can start again. When this is the case the bar machine possesses a great advantage over the disc, as the coal can be supported up to within 12 inches of the cutter bar. The bar, usually about 4 feet 6 inches long, is fixed at one end of the machine and is made to cut its way into the coal, no " stable " being required as is the case with the disc. A to-and-fro motion is given to the bar (which is threaded) as well as a rotary one, and a good deal of the cutting dirt or coal is brought out of the holing automatically. There are 390 bar machines at work in this country. Electricity is the motive power for 290, and compressed-air is used for the remainder.

The chain machine is a type used extensively in America for undercutting, both in long-wall and pillar-and-stall workings; a well-known American machine



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MACHINE-CUT COAL

being the Jeffrey Header. Chain machines for headings have been tried in this country, but have only proved moderately successful. There are, however, quite a number at work for undercutting in long-wall workings ; the total being 158, of which 125 are electrically driven. As the name implies, a chain is substituted for the disc or bar. The chain which carries the cutting tools is an endless one, and works round a jib, which projects from one end of the machine. The jib is from 12 to 15 inches wide, and can be swung through an arc of 180 degrees, so that, like the bar, it can cut its way into or out of the coal, and the cut can be made upon either side of the machine. The depth of undercut is usually about 4 feet 6 inches, the width depending on the size of jib used. This is rarely more than 18 inches, so that the coal can be spragged up quite close to the machine. For this reason the chain machine, like the bar, is generally used for undercutting in coal of a tender nature.

Coal-face Conveyors

Where machine coal-cutters are employed, the removal of the cut coal from the face to the haulage roads must be carried out regularly and systematically, otherwise delay in cutting is bound to follow. Mechanical conveyors are used in many mines at the coal-face to expedite the removal of the coal, instead of filling it into tubs in the ordinary way. Conveyors used in conjunction with coal-cutting machinery have proved very successful, especially in thin seams where the cost of making and maintaining roadways of sufficient size is naturally very high. With a conveyor the roads leading to the coal-face can be made at much greater distances apart than where the coal is filled out by hand, and this means a considerable reduction in the underground cost. There are 324 conveyors at work in the United Kingdom at the present time.

The earliest form of conveyor consisted of a small shallow wagon holding a few hundredweights of coal, and drawn by hand across the face by means of a rope. The coal was discharged into the tub by means of a sliding door fitted in the bottom of the wagon, the top of the tub being below the level of the tank bottom. This primitive form of conveyor is now very seldom used, as only a small output can be dealt with.

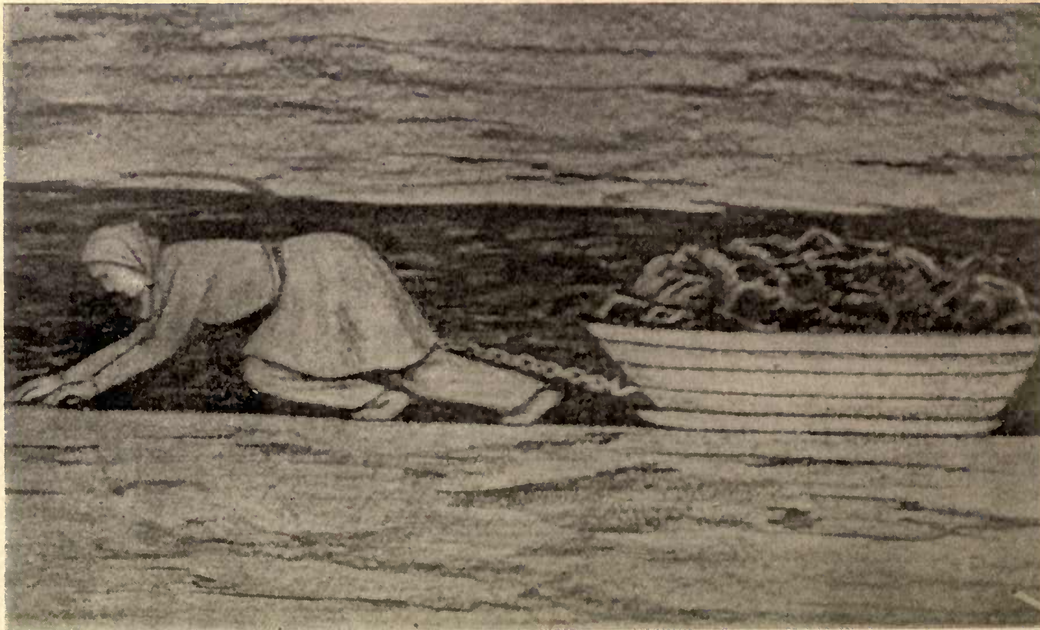
On the continent a shaker type of conveyor is in use. The conveyor is given a to-and-fro motion by means of eccentrics, causing the coal filled on to it to be carried along to the loading place at one end of the shaker. This form of conveyor has not yet been tried in the United Kingdom ; the one generally used being either a low jointed carriage in sections which can be drawn across the face, a well-known type of which is the Gibb conveyor, or a long stationary trough and endless chain like the Blackett. This conveyor consists of sections of sheet steel in 6 feet lengths, carried on similar lengths of angle iron framework. The sections are standardized and bolted together to permit of speedy erection or dismantling when desired. Each trough is slightly dished so as to fit into its neighbours, and can be erected or dismantled without bolts. An endless chain of special design works along the inside of the trough, and carries the coal along with it to the discharging end. The chain is carried round a sprocket wheel at either end of the trough and returns underneath, being supported by rollers. The total length of the conveyor may be anything from 60 to 100 yards, but the best practical working length is found to be about 80 yards. The height of the conveyor itself over the troughs is about 10 inches; the discharging and the tail ends are a little higher but will easily go under 24 inches. The over-all width is 18 inches along the face. A main haulage road with a double line of rails so as to maintain a good supply of tubs is required at the discharging end; no other roads are necessary except at the other end of the conveyor for travelling purposes. This end, known as the mooring end, is generally secured by chains to a strong timber baulk. The motive power may be either compressed air or electricity; if the latter, a totally enclosed motor is used. The whole of the gearing is enclosed and runs in oil. About 20 to 25 tons per hour can be comfortably dealt with off one conveyor. As the coal-face advances the whole arrangement is moved forward bodily, or where the roof is not very good, in sections.

CHAPTER IX

UNDERGROUND HAULAGE

BEFORE the introduction of tramways in coal-mines, the conveyance of the coal from the face was carried out entirely by manual labour, and it is interesting to compare the very primitive methods in use at the beginning of the nineteenth century with some of the present elaborate haulage installations. Women, and even children of tender years, were largely employed to convey the coal along the underground roadways. The coal was in some cases carried in baskets on the back, or the basket was drawn along by means of a chain attached to a belt round the waist, the chain passing between the legs of the woman or child who dragged the basket along on hands and knees. Sometimes the baskets were fitted on to a kind of sled with wooden runners, and barrows were used in some instances.

About 1842 Lord Ashley created great indignation throughout the country by his statements concerning the working conditions of women and children in mines. A Royal Commission was appointed to enquire into the allegations, and the result was the passing of an Act prohibiting the employment of women underground. Improvements in the haulage of coal were gradually effected by the use of wheeled tubs running on wooden rails, and drawn along by hand or horses. Wrought iron rails were afterwards tried, but these in turn gave way to steel, now used in all mines. Tubs or wagons for underground use vary in shape and size in different districts, being regulated to some extent by the thickness and inclination of the particular seam. In the North of England the holding



WOMAN DRAGGING COAL UNDERGROUND

capacity varies from 6 to 15 cwts., whilst in South Wales it reaches from 25 to 30 cwts. In Lancashire and the Midlands, the capacity varies from 6 to 12 cwts.; in these two coalfields a common size is one holding 10 cwts. The body of the tub may consist entirely of wood or steel. Sometimes a steel bottom is used with the ends and sides of wood. A steel tub costs more than a wooden one, but its life is considerably greater, and as there are no open joints in the body, coal dust cannot escape on to the haulage roads. The use of steel tubs is likely to be considerably extended under the rules of the Coal Mines Act, 1911, relating to the prevention of coal dust underground. The gauge of the track on which the tubs run depends to a great extent on the size of the latter, varying in different districts from 1 foot 8 inches to 2 feet 10 inches. In the by-roads, rails of bridge section and weighing from 14 to 18 lbs. per yard are used. They are generally cut in 4 feet lengths and simply nailed to the sleepers. In the main haulage roads flat-bottomed T rails weighing from 18 to 32 lbs. per yard, in 12 to 20 feet lengths, are laid. These rails are fish-plated together and spiked to the sleepers.

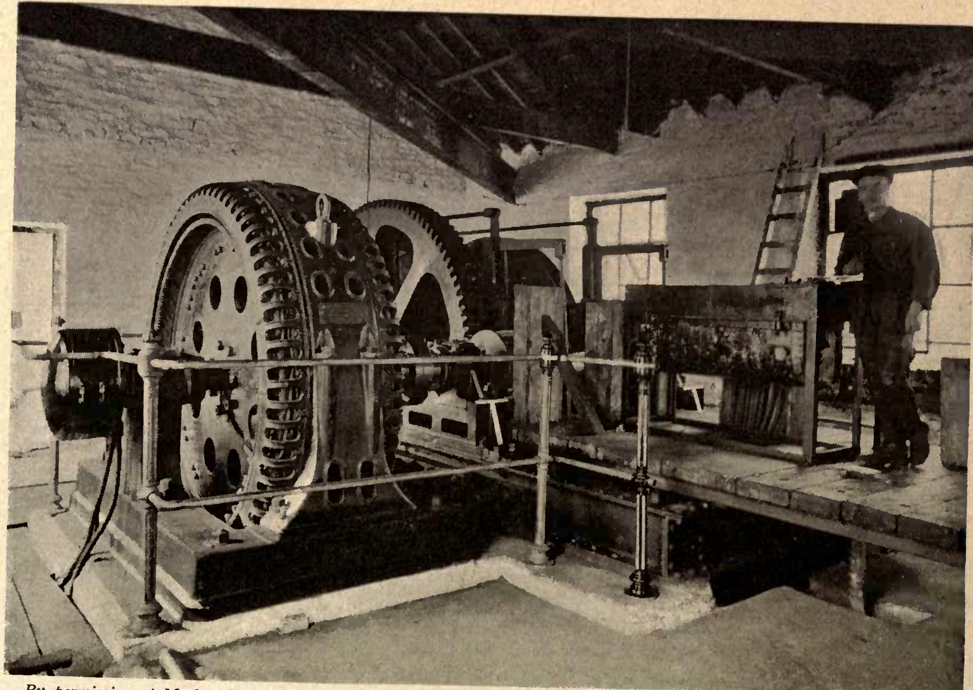
Underground haulage at a modern colliery may be divided into two sections: main, and secondary haulage. The main haulage is in nearly every case carried out by mechanical power, and where large outputs are dealt with, is often of an elaborate description. Secondary or auxiliary haulage along the branch roads leading to the face of the workings is generally performed by manual labour, horses, or a combination of both. The tubs are taken from the coal face to the nearest shunt by hand, and from thence by horses to the main haulage road. At many new collieries, however, some form of mechanical power is used for the whole of the haulage, almost from the coal face to the shaft bottom.

The chief systems of mechanical haulage are direct or main-rope, main-and-tail rope, and endless-rope or chain. The direct-rope system is used in inclined mines for hauling coal from the dip side of the winding shaft. Only a single line of rails is required, and the tubs are taken along in sets of from 6 to 50 in number, at speeds varying from 6 to 16 miles per hour. The gradient of the road must be sufficient to permit the empty set to run down by gravity and draw the haulage-rope behind it. In practice, the inclination must be at least 1 in 28. The objection to this system of haulage is the high speed and the intermittent supply of coal at the shaft, but it has one great advantage in only requiring a single track.

The main-and-tail rope system, like the direct-rope, only needs a single road, and is used in mines with a varying gradient where the direct-rope system could not be adopted owing to the flatness of the roads. The tubs are conveyed in sets, and at about the same speed as in direct-rope haulage. Two ropes are used, the main rope and tail rope, and two separate drums are fitted to the hauling engine. The main rope draws the full set to the shaft, and the tail-rope draws the empties in-bye to the workings. This rope is smaller in section than the main-rope, and is twice the length of the haulage road. It passes from its own drum on the engine to the end of the road, round a return pulley, and is connected to the back end of the set. From the drum to the return wheel the rope is carried on small hanging pulleys, fixed against the side of the road. This system has the same disadvantages in common with the direct-rope system as regards speed and the delivery of coal, and like direct-rope haulage is seldom adopted in new mines, unless it is impossible to maintain a double road owing to the nature of the roof and sides.

The endless-rope system requires a double track; one for the full tubs and the other for the empty ones. The rope, as the name of the system implies, is an endless one, and passes from the driving pulley at the commencement of the system, along the haulage road to the far end, round a return wheel fitted on a tightening carriage and back to the driving pulley. The rope is thus continually moving in the one direction, so that empty tubs can be taken in to the workings on one track, and at the same time full tubs can be brought out on the other. The rope only runs at a very slow speed (from $1\frac{1}{2}$ to 3 miles per hour), and the tubs are attached either singly or in sets. The rope may run either over, under, or at the side of the tubs. In Lancashire the over-rope system is usually adopted, whereas in the Midlands the under-rope method is the favourite.

The hauling engines for this system are sometimes placed on the surface, and an endless driving rope taken down the shaft to transmit the power to the driving pulley underground. This method is satisfactory where steam power is used, and the shaft is of moderate depth, but if electricity is available, and the depth of the shaft considerable, it is better to take the power underground and operate the driving pulley direct by motor. The endless-rope system is used more extensively than any other system, as a regular supply of coal to the shaft is constantly maintained. The slow speed of the system also results in less wear and tear of the rolling stock, and less liability to accident. In the Burnley and Accrington district of the Lancashire coal-field, a chain is substituted for the rope. This arrangement has been in use for many years, but has not extended beyond the district named. The chain works on top of the tub which has a fork attached to one end. No clip



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220 HORSE-POWER ELECTRIC HAULAGE GEAR

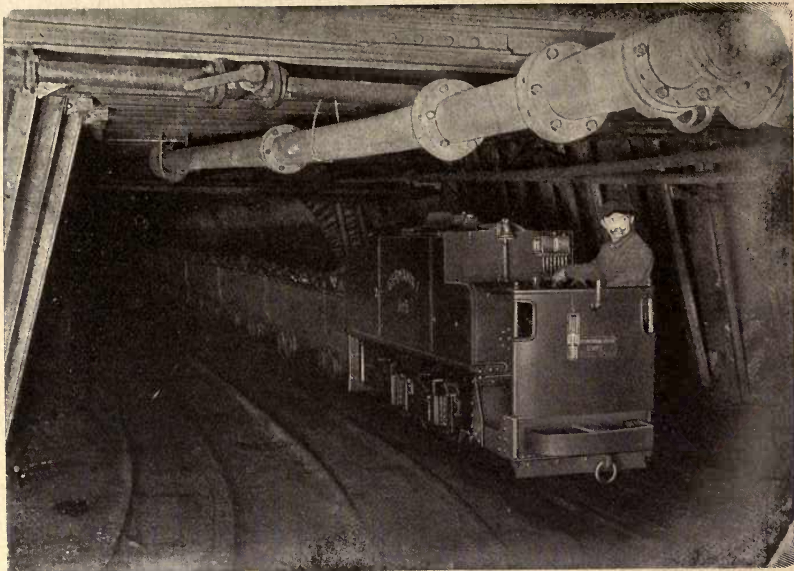
is required as the links of the chain fit into the fork and carry the tub along. With this simple arrangement, the attaching and detaching of the tubs to the chain can be carried out automatically wherever desired. The endless-chain cannot be used to the same extent as a rope as the weight of the chain becomes too great, and requires too much power to drive it.

In inclined mines where a portion of the workings are above the level of the shaft, the haulage can be carried out by gravity inclines or "jigs." One arrangement of "jigging" is to have a wheel, fitted with a good brake, at the top of the incline. A rope is taken two or three times round the wheel, one end is attached to the set of full tubs at the top of the "jig," and the other end to the empty set at the bottom. As the full tubs descend the incline the same number of empties are drawn up. To work this arrangement the inclination must not be less than 1 in 20. The number of tubs forming a set may be anything from 4 to 30. If there are a number of "putting-on" places in the incline, or if a large output is to be dealt with, the best method is to lay the jig out on the endless-rope system. Pulleys are fixed at the top and bottom of the incline, and an endless rope passed round both. The top pulley is fitted with a strong brake, and the bottom one is fixed on a tightening carriage, so that the rope can be kept at the proper tension. The tubs are attached to the rope by clips, or lashing chains. The same advantages are obtained from this method as from the ordinary endless-rope system, *i.e.*, slow speed, regular output, and slight risk of accident.

Locomotives, especially designed for underground service, are used at many American and Continental collieries for hauling tubs underground. Compressed-air and electric locomotives are generally used in

America, whilst internal combustion locomotives are favoured in Austria, France, and Germany. Any type of mine locomotive is only suitable where the road is flat or the gradient very slight, the limit of working being reached if the inclination exceeds 1 in 11. Compressed-air mine locomotives were tried in this country as far back as 1887, but did not prove a success. Modern types have, however, given every satisfaction in Canada and the United States where the conditions are more favourable, and there are about 550 of these locomotives in use there at the present time, 275 being at work in the Pennsylvania coal-field alone. The compressed-air is conveyed from the surface to charging stations at various points of the mine. The locomotive is fitted with one or more storage tanks which are charged at a station with a sufficient volume of air at a high pressure for a round trip, after which the locomotive returns to the nearest charging station for a fresh supply of air. Electric locomotives may be either of the overhead trolley, or storage battery type. The former type is only used in mines free from firedamp. Mine locomotives fitted with internal combustion engines using petrol, benzol, or methylated spirits are used on the continent, about 600 being in use at the present time ; several have also been introduced into Canada recently. The illustration on page 51 shows a 16 Horse-power "Otto" locomotive belonging to the Gelsenkirchen Mining Company in Westphalia, for a 22 inch gauge. The engine is fitted with a two-speed gear for 4 and 7½ miles per hour.

Underground locomotives are made in various sizes and power, varying from 6 to 50 horse-power. The speed on a level road varies from 4 to 14 miles per hour, with loads of from 15 to 150 tons.



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UNDERGROUND LOCOMOTIVE DRIVEN BY PETROL

CHAPTER X

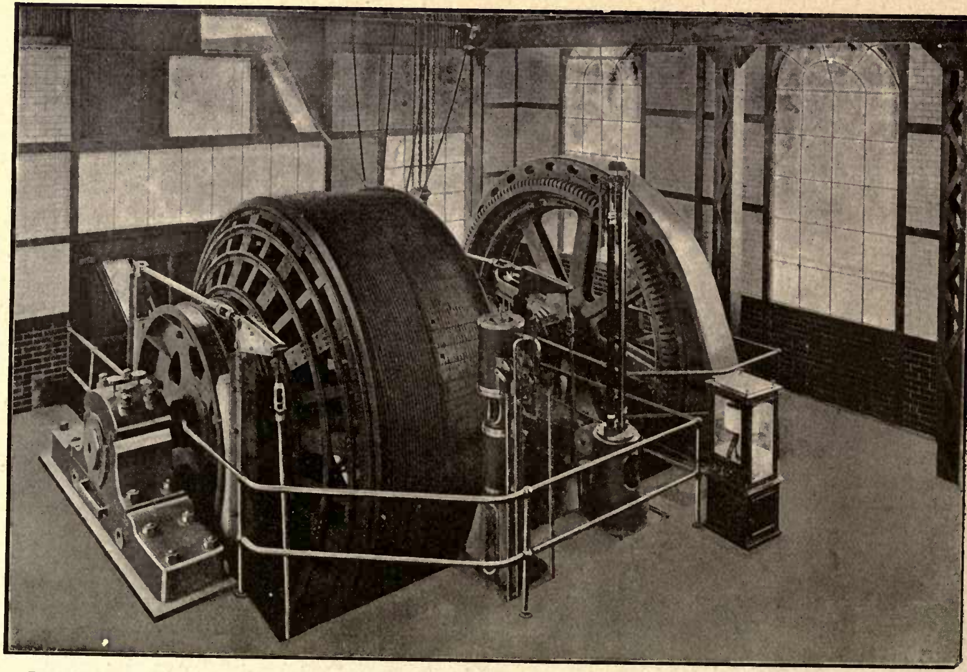
RAISING THE COAL TO THE SURFACE

As mentioned in an earlier chapter, mining for coal was only carried on in those seams which outcropped at the surface. Headings were driven in from the surface, and the coal carried out in baskets. When the coal close to the surface had been worked out as much as possible, shallow shafts were sunk and the difficulty of hoisting was overcome by fixing ladders in the shaft up which the coal was carried by women and boys, or a windlass was used in some instances. Owen's *History of Pembrokeshire*, written about the year 1602, states: "They used not engines for lifting up the coles out of the pitt, but made theire entrance slope, soe as the people carried the coals uppon theire backes along stayers, which they call landwayes; whereas nowe they sinke theire pittes downe right fouresquare, about 6 or 7 foote square and with a wyndles turned by foure men, they drawe up the coles a barrel full at once by a rope." The shafts in those days were not more than 40 yards deep.

Horses were also used for hoisting by means of an arrangement known as a "gin." A drum was placed over the shaft instead of a windlass, and to one end was attached a cog-wheel. Another cog-wheel, fixed on a vertical shaft, geared into the first toothed wheel, and, when turned by a lever or arm drawn by horses, caused the drum to revolve. Two ropes were fitted on the drum so that one basket was lowered whilst the other was raised, leaving only the weight of the coal to be raised by the horses. If an explosion occurred in the workings underground, the drum was often damaged so that this arrangement was in time replaced by a vertical gin fixed some distance away from the shaft top. Usually eight horses were required to work the gin, in four relays of two at a time, and a good day's work was about 90 tons from a depth of 120 yards.

In 1763, Joseph Oxley brought out a steam engine for winding. This was considered a wonderful invention, though only capable of drawing coal at the rate of one basket a minute. In 1782, James Watt considerably improved the construction of engines for winding purposes, and it is on record that one of his engines, erected in 1784, continued to work as late as 1863. Wonderful improvements have been effected since then, and at the present time it is quite common for winding engines in this country to bring up at one time 5 tons of coal at an average speed of 2,100 feet per minute.

Up to the time of the Hartley disaster in 1842, the majority of mines were only connected to the surface by one shaft. This was divided into two compartments by a wooden partition for ventilating purposes, and was used for winding coal and men, and for pumping water. After the terrible accident at the Hartley Colliery, when the beam of the pumping engine fell down the one and only shaft, destroying the ventilation, and causing the death of nearly every person underground, it was made compulsory to have at least two shafts or outlets to each mine. At many collieries three shafts are put down, one being used for pumping purposes only. In the old days of shallow shafts the diameter rarely exceeded 8 feet ; nowadays the diameter is anything from 16 to 24 feet according to the output proposed to be wound. When steam was first used as a motive power vertical winding engines were adopted, but these have long since given way to the horizontal type. All winding engines of any size are fitted with both steam and foot brakes, so that the engineman is able to hold the cages at any point



By permission of the British Westinghouse Electric and Mfg. Co.,

ELLCTRICALLY-DRIVEN WINDING ENGINE

in the shaft. At many collieries a safety appliance is fitted to the winding engine, which automatically shuts off the steam and applies the brake if the speed of the engine exceeds a fixed limit during any part of the winding; thus the danger of the engineman losing control of the engine through sudden illness is removed.

A well-known appliance of this description is the "Visor," which controls the speed of the engine and comes into action before any damage is done if the engineman starts in the wrong direction, or if the cages are overwound. The winding drum may be either cylindrical or spiral in shape; the former offers no advantage to the engine, but is the most general owing to certain disadvantages of the latter type. Cylindrical drums are made up to 24 feet in diameter; the sides are usually built up of steel and joined by timber "lagging" on which the two winding ropes coil and uncoil.

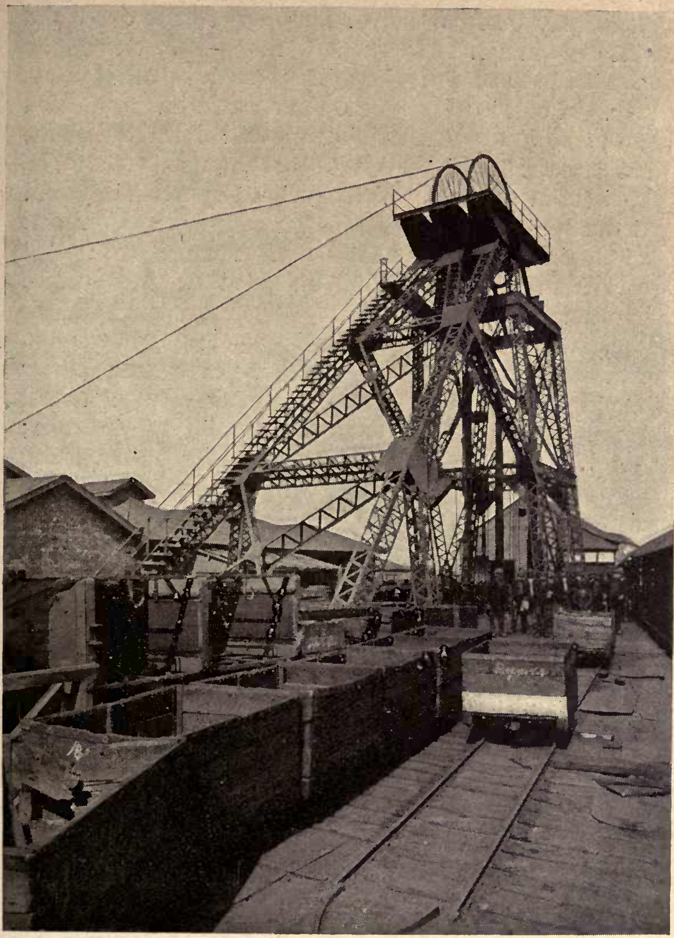
Electrically driven winding engines have been in operation for some time at several collieries in France and Germany, but little progress has been made in this country. This is chiefly due to the high class of steam engine available for winding purposes, and the character of the work to be performed when winding. Another stumbling-block is the heavy initial cost of the plant. There are several systems of electric winding; the Ilgner and the Westinghouse being perhaps the best known.

The illustration on page 54 shows the first large direct-connected electrically driven winding engine put into operation in this country; the installation being carried out by the British Westinghouse Company at the Maritime Pit of the Great Western Colliery Company. When operating at full load the engine makes 70 winds per hour, raising a net load of 2½ tons from a depth of

1,110 feet, or 175 tons of coal per hour. A special feature of the installation is that the power is applied to the winding drum by a three-phase motor, taking direct current from the mains and not through transforming apparatus as with systems previously put forward for this class of work. The winding engine consists of a spiro-cylindrical drum of from 7 feet 6 inches to 15 feet in diameter, designed for a rope $5\frac{1}{2}$ inches in circumference, and drawn by a direct-connected three-phase motor of a normal capacity of 700 horsepower. The winder is equipped with a compressed-air brake, recording tachograph, and devices for preventing overwinding. Overload-winding is also automatically stopped in case of failure of the electric or air supply.

Up to a comparatively recent date the headgear, on which are fixed the winding pulleys, was constructed of timber, usually pitch-pine, but steel has been used at a great many new mines during the last few years. The first cost of a steel headgear is certainly more than for one made of timber, but it is far more suitable for quick winding and heavy loads, especially from great depths, besides lasting considerably longer and being practically fireproof. This, in itself, is a great consideration from a safety point of view.

The height of the frame from the banking level depends to a great extent on the type of cage, an average height being 60 feet. The winding pulleys, the centres of which rest upon the main legs of the headgear, are generally made the same diameter as the winding drum; the larger sizes are made in segments bolted together. For ordinary loads the rim and boss are made of cast-iron, but when the load is excessive wrought-iron and steel are sometimes used. The cages in which the full and empty tubs are raised and lowered in the shaft are made of steel for the sake of lightness.



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A MODERN STEEL HEADGEAR

There may be from one to four decks in a cage, and each deck may hold from one to four tubs. A common form is the three-decked cage holding three tubs in each deck. A roof is fitted to the top deck for the protection of the workmen when riding up and down the shaft, and under the Mines Act of 1911, gates have to be provided at the ends which previously were quite open. At the more modern collieries where very large outputs are obtained, the several decks of the cages are loaded at the shaft bottom and unloaded at the surface simultaneously.

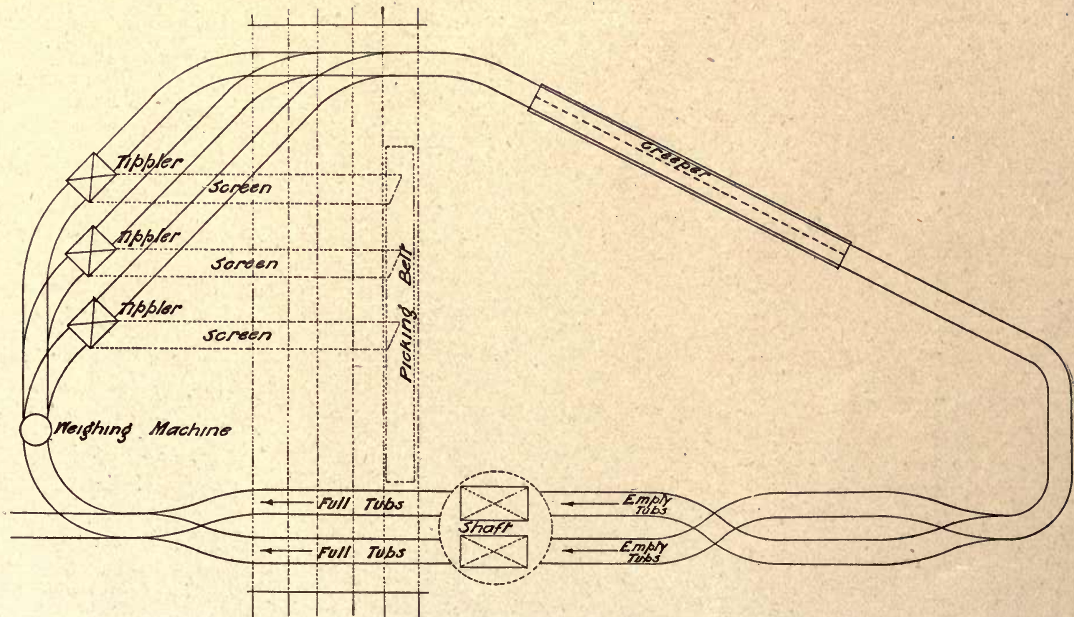
The winding ropes, which are connected to the top of the cages by short chains and pass over the headgear pulleys to the winding drum, are made of plough steel and may be similar in form to an ordinary wire rope; that is, made of six strands twisted round a hemp core, or of a special form known as "locked coil." In this form the inside strand is built up of ordinary round wires, but the outer coils are of special shaped wires so fitted as to interlock one with another, and form a smooth outer surface, the rope resembling a flexible rod of steel.

SURFACE ARRANGEMENTS

CHAPTER XI

BANKING AND SCREENING

THE proper laying out of the surface arrangements at a colliery is almost as important as the setting out of the underground workings. The extent of the plant is largely influenced by the daily output and the quality of the coal mined. At many collieries, coal is wound at both the upcast and downcast shafts, the coal being brought to a common pit-bank. Thirty years ago, when the best and cleanest seams were worked, there was very little cleaning as understood at the present day. At many collieries the whole of the coal was tipped direct into carts or wagons without any pretence at screening or cleaning. With the exhaustion of the better class seams and the working of dirty and inferior ones, cleaning plant of a more or less elaborate nature has been installed at many mines with a view of obtaining as good a price as possible for the fuel. The illustration on page 60 is a sketch-plan of a common form of banking and tippling arrangement. The track from the winding shaft to the weighing machine is graded so that the full tubs run of themselves to the machine where they are weighed, afterwards running into tipplers where the coal is emptied out of the tub on to the screen. Side-tipplers have now quite superseded the old-fashioned end-tippler, and may either work mechanically or by gravity. An excellent type worked on the latter principle is one capable of holding 4 tubs at a time, and only needing one small boy to operate it.



SKETCH-PLAN OF A MODERN PIT-BANK

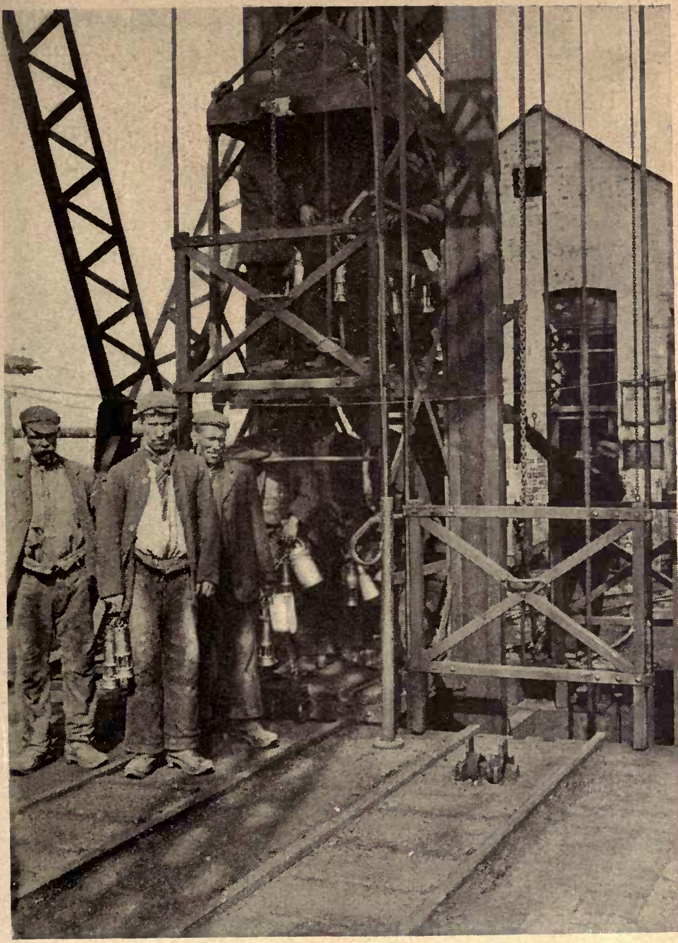
The empty tubs pass out at the back of the tippler and run by gravity to the creeper chain, by means of which they are raised the requisite height to permit of them running back to the empty side of the shaft. The average gradient of the roads is about 1 in 50. Another arrangement is to raise the full tubs by a creeper chain (after they have passed over the weighing machine) sufficiently high enough to run through the tipplers and back to the shaft. The number of tipplers depends on the daily output or the number of seams worked. Each seam is treated separately, and has its own independent screening arrangements.

In the earliest screening plant the idea was simply to divide the coal into two sorts—large and small—with no arrangement for picking out the dirt before the fuel was put into wagons. The screens consisted of shallow troughs fixed at an inclination of from 1 in 2 to 1 in 3; the bottom being formed of fixed bars, spaced according to the size of coal it was desired should pass through. The large coal passed down the screen into the wagon, and the small fell through the bars into a hopper underneath, where it was filled into wagons or taken to the boilers. This simple method of screening is now replaced in all but the smallest of collieries by some type of improved screening and cleaning plant of which there are several.

One of the best-known forms of screen is the shaking or jigging screen, which is used at almost all collieries of any importance. The screen consists of an iron pan, the bottom of which is covered with wire mesh or perforated iron plates, the size of the mesh or perforation depending on the size of coal required. As the coal is tipped on to the screen, the latter is given a quick to-and-fro movement by means of two eccentric rods connected to the screen and worked by a small engine. The shaking motion, together with the slight inclination, causes the coal to move slowly along towards the end of the screen. The several sizes of coal made vary at different collieries according to the quality of the coal worked, and the demands of the consumers. At most large collieries at least four sizes are made: "slack," "nuts," "cobbles," and "round-coal." There are collieries in the Midlands, however, where as many as ten different sizes of coal can be obtained.

A common arrangement where four sizes are desired, is to have each screen fitted with three different sizes of openings, the smallest size being at the upper end, through which the smallest coal or slack passes and falls on to a slack belt or into a hopper. Lower down the screen the openings are a little larger, and through these the nuts pass on to a travelling belt. The largest size of opening for separating the cobbles from the round coal is at the lower end of the screen; the cobbles fall through the openings, and are delivered on to another belt. All the round-coal left on the screen passes off at the lower end on to a separate travelling belt. At some collieries the small coal is further sorted into two or three different sizes by a separate screening arrangement. The small coal from the main screening plant is conveyed by a belt to the auxiliary screen and divided into "peas," "slack," and "dant." The last named class of all is very small coal indeed, and is not generally filled into wagons for sale, but is used at the colliery boilers for steam raising purposes. The "peas" and "slack" pass from the screen into hoppers, and are loaded into wagons.

A picking or travelling belt is an endless belt of iron plates, wire mesh, or canvas, on to one end of which is delivered the coal from the screen. The coal is carried slowly along on the belt, which is supported by rollers, and men, women, and boys, stationed at each side, pick



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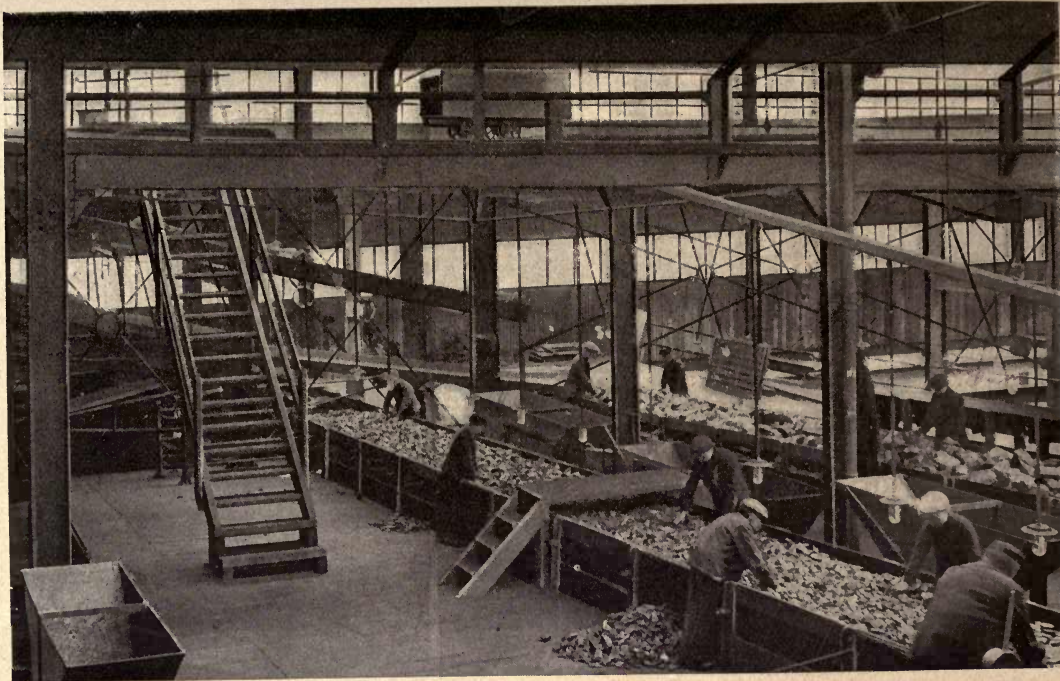
MEN LEAVING THE CAGE AT THE SURFACE

out any pieces of shale, stone, or inferior coal. Picking belts are generally provided for round coal, cobbles and nuts; iron plates are used for round coal belts, and wire mesh or canvas for the smaller sizes of coal. Belts are made up to 100 feet in length, though 60 feet is about the average. The width varies from 2 feet 6 inches to 4 feet, and the speed from 20 to 50 feet per minute. The clean coal falls off the end of the belt on to a lowering arm, and is delivered gently into the wagons underneath. The arm or jib can be raised or lowered by means of a chain and small winch, so that the coal is put into the wagons with practically no fall, and with the minimum amount of breakage. Each tippler has its own screen, picking belt, and lowering arm, and where coal is raised from different seams which are to be kept separate, a tippler is provided for each seam.

At some collieries horizontal conveyor screens are now used in preference to the inclined shaking screens. A conveyor screen is really a combined picking belt and screen, and, like the ordinary shaking screen, is given a to-and-fro motion. A well-known type is the Marcus conveyor. It consists of a mild steel trough about 30 feet long and 3 feet 6 inches wide, the bottom of which is fitted with bars. The trough is carried on rollers, and receives a peculiar reciprocating motion from the driving mechanism. This causes the large coal to be conveyed along the trough, whilst the small falls through the bars into hoppers. The large coal passes off the end of the conveyor, and down a lowering arm into wagons. As the screening plant is horizontal, a considerable amount of head room is saved as compared with the ordinary jigging screen.



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SCREENS AND PICKING BELTS AT A MODERN COLLIERY

CHAPTER XII

COAL-WASHING

SMALL coal or slack was washed years ago at those collieries where coke was produced, but the washing arrangements were generally of a very simple character. In the majority of cases the plant carried out its purpose, namely, to reduce the percentage of ash in the coke; but it had several more or less serious defects, the chief of which was the large quantity of water required, and the loss of a certain amount of coal during the process. With the gradual exhaustion of the cleaner and better class seams in many districts it has become necessary to install costly washing plant for the better cleaning of the inferior coal, so as to send it into the market in as good a condition as possible. On the Continent the system of washing the larger sizes of coal has been in use for years, but it is only within a comparatively recent date that large plants for a similar purpose have been erected in this country.

The principle of coal-washing is based on the difference between the specific gravity of coal and that of the impurities mixed with it. The average specific gravity of coal is 1·3, and of the dirt mixed with it, such as shale, clay, etc., 2·3. If a quantity of, say, coal and shale of similar size were dropped into a tank containing water, the shale, by reason of its greater specific gravity, would fall through the water at a higher velocity than the coal, and thus form a layer at the bottom of the tank, with the coal resting on top of it in a separate layer. It must be borne in mind that whilst the washing of coal will free it from such impurities as shale, bass, and ironstone, no arrangement has yet been devised which will separate impurities forming part of the coal itself, such as phosphorus and sulphur. The percentage of sulphur may be lowered slightly by washing, but that of phosphorus very little.

The earliest form of coal-washer consisted of a wooden trough, about 100 feet in length, 30 inches in width, and 12 inches deep, fixed at an inclination of about 1 in 20. The small coal was put in at the top of the trough, and was gradually carried down to the bottom by a stream of water. Small doors, or dams, about 4 inches high, were fixed at intervals across the trough for the purpose of retaining the pieces of dirt; the coal, being lighter, was carried over the doors to the bottom, where it was caught in a hopper and drained before being taken to the coke ovens. Many improvements have been made in the original type, and there are now several well-known trough washing-machines of English manufacture giving every satisfaction.

In the Elliott trough-washer the coal is first elevated on to a screen over the troughs, and separated into two or three sizes, each being delivered on to a preliminary washing table, which takes out the rougher or larger sized dirt in each sort of coal before it is delivered into the washing troughs. The troughs are made of sheet steel, wrought or cast-iron, the bottom being flat and the sides sloping outwards; the width at the bottom is 27 inches, and at the top 39 inches. At each end of the trough two sprocket wheels are fixed, which carry two endless chains, to which serrated scrapers are fixed at suitable distances from each other. These scrapers are of the same section as the lower part of the trough, and travel along to the upper end of the trough, which is always fixed at an inclination of 1 in 12. The scraper chains are endless and are driven by the sprocket wheels at the upper end, and run back over the trough; roller brackets being bridged over to carry the chains to the sprocket wheel at the lower end.

To obtain the best results from coal-washing, the fine dust should be removed from the coal before washing, as the dust renders the water too dense to properly wash small sizes, besides increasing the amount of "smudge." If the coal is to be used for coking, the dust taken out can be added after washing. On the Continent great attention has been paid for many years to the improvement in coal-washing machinery, and there are now at many British collieries very costly and elaborate washing arrangements of continental design. The majority of foreign washers are not on the trough principle, but of a type known as "jiggers." These were first used for ore-washing, but were afterwards tried, with considerable success, for the washing of coal.

The ordinary jigging machine consists of a washer-box divided into two unequal compartments connected at the bottom. Close to the bottom of the larger of the compartments is a perforated plate or wire mesh on which the unwashed coal is placed. The washer-box is filled with water so that the coal is covered to a depth of about 10 inches. A piston is fitted in the smaller compartment, and is made to move up and down at the rate of about 70 strokes a minute. The pulsating movement given to the water causes it to raise and lower the coal and dirt lying on the grid. As the dirt is heavier than the coal it gradually separates from it, and forms a layer on the grid, whilst the washed coal lies in a separate layer on the top of the dirt, and is from time to time washed out through an opening fixed about 12 inches above the grid, the dirt being carried away through another opening a little lower down. To wash very small coal a modified jigging machine is used known as the " felspar " jigger. A layer of felspar about 3 inches thick is laid on the grid, the openings of which are large enough to allow the dirt to pass through. The pulsating action of the water causes the dirt and coal to separate in the usual way, but the dirt gradually finds its way through the bed of felspar and the grid to the bottom of the box, whilst the coal is carried over the opening above the grid as in the ordinary jigger.

In almost every type of coal-washing machine the coal is divided into sizes before washing. One well-known exception is the washing system designed and perfected by Mr. F. Baum, of Westphalia. In this system any coal below $3\frac{1}{2}$ inch mesh is washed without previous classification in the washer box. This system, which was brought out about 1902, has met with great success in different parts of the world, and several installations are at work in the United Kingdom.

In the Baum system compressed air is used instead of a piston to produce the pulsation of the water in the washer box. The coal to be washed may be any size below $3\frac{1}{2}$ inch mesh (or smaller mesh to suit any particular requirements). The coal is brought in wagons to the washery building, where it is emptied into a hopper. A bucket elevator raises the coal to the top floor of the washery, and delivers it down a shoot into a washer-box. Here the coal is separated from the heavier dirt which passes down an enclosed passage to a dirt elevator. The coal, along with the lighter dirt, overflows into a second washer-box for a further treatment, the dirt finding its way to another dirt elevator. Any small dirt passing through the grids is conveyed by dirt worms to bucket elevators and deposited into dirt bunkers. The bunkers are perforated so as to allow the contents to drain to some extent. The washed coal is carried from the washer-box by the washing water through an opening above the grid, thence along a trough to a classifying drum of large diameter. The drum is fitted with superimposed sieves, and the screening is facilitated by a current of water, which forces the coal through the holes of the different sieves of the drum. Each size of coal, with the exception of the smallest, falls into troughs and is carried by a jet of water on to draining boxes, and finally into storage hoppers, there to be loaded into wagons. The smallest size of coal is carried along with the washing water, and collects at the bottom of the drum casing. It is elevated to a fine-coal washing-box and subjected to a second treatment, to remove the last traces of dirt, as the coal, which is usually $\frac{3}{8}$ inch cube, is used for coking purposes. The washed fine-coal accompanied by the washing water, passes along a trough and shoot on to a draining conveyor where the water is drained off and at the same time clarified.

CHAPTER XIII

COKE-MAKING

WHILST coal has been mined in this country for hundreds of years, it was practically only used for domestic purposes up to about the sixteenth century. Iron-making (at that time one of the most important industries of the kingdom) was carried on with the aid of charcoal, but the rapid exhaustion of the timber resources in many districts caused an Act to be passed in 1558 prohibiting the felling of timber for burning iron, except in one or two counties, and attention was therefore paid to the substitution of coal for charcoal. An attempt was first made by Dud. Dudley in 1618, but it was not until 1733 that Abraham Darby, of Coalbrookdale, succeeded in using coke for iron smelting. The increasing demand for coke from that date was one of the factors which assisted to a great extent in the development of the coal industry.

For many years the preparation of coke from coal was carried on in a most primitive and wasteful manner. The coal to be coked was first arranged into circular or rectangular heaps on the ground, and almost or wholly covered with a wet layer or fine coke-dust or earth. To provide a supply of air, channels were left in the heaps just above ground level, and connected to one or more upright chimneys or holes in the centres. The chimneys were provided with cast-iron lids for making them air-tight when required. To ignite the coal, pieces of burning wood or coal were dropped down the chimney, and the fire gradually spread outwards through the heap. The covering of damp coke dust was kept as air-tight as possible during this time, and as soon as the smoke ceased to issue from the chimney all openings were blocked up and the heap covered with wet earth. Improvements were made in this wasteful method from time to time, and about 1620 the "beehive" coke oven was introduced.

In the earliest type of beehive oven the heated gases given off during the distillation of the coal were allowed to escape direct into the atmosphere, but as time went on it was found advantageous to use the hot gases for steam raising by connecting the ovens to the boilers, and attempts were made by several persons to design beehive ovens with a view to the recovery of the by-products. In 1862 Pernolet patented a process "to utilise the products of distillation of coal so as to reduce the price of coke." Unlike the ordinary form, no air was admitted, and the heat was applied externally by burning the waste gases in flues underneath the oven; the volatile products being carried off through pipes fixed in the dome.

A battery of ordinary beehive ovens is made up of two rows of chambers placed back to back, with a main flue running down the centre, connected to each chamber by an opening. The ovens are each about 11 feet in diameter and 7 feet in height. They are dome-shaped, and built of fire-brick so as to withstand great heat. An opening, about 18 inches diameter, is provided at the top of each chamber for charging purposes. In front is a doorway for withdrawing the coke, and this is made almost air-tight whilst coking is in progress. Fine coal or "slack" is put through the opening at the top until almost level with the top of the doorway; this is then bricked up with the exception of one or two small openings left for air. As soon as the coal in the oven is well alight all openings are made up, and the gases generated are led by means of the main flue to the boilers. After an interval, which depends on the size of the charge, the door is pulled down, and the red hot coke inside the oven cooled down with water and drawn out with the aid of a long rake.

The beehive oven produces an excellent coke, but is wasteful in many respects. A portion of the fixed carbon in the coke is consumed, due to the admittance of air into the oven whilst coking is in operation, and the valuable by-products contained in the gases are either burnt away in the oven itself or at the boilers. Modifications of the beehive oven, such as designed by Pernolet for the recovery of by-products, have been used in this country and abroad with a considerable measure of success, but of recent years—particularly at Continental collieries—the beehive oven and its modifications have been superseded by some type of retort oven. The installation of a by-product coking plant entails a far higher expenditure than the ordinary beehive type, but the recovery of the by-products very soon enables a reasonable return to be made on the capital cost. The chief by-products are ammonia liquor, tar, and benzol. From the first-named is prepared sulphate of ammonia, used extensively as a fertilizer for cereals, besides other ammonia salts. From the tar is extracted pitch and heavy oils. Benzol is used in the manufacture of explosives, and from it is derived aniline, which is used extensively in the colour industry.

In the modern retort oven the air is excluded altogether, and the gaseous products are driven off by external heat. The by-products are drawn off by exhausting machinery, and extracted by a special recovery plant. For a long time there was an unreasonable prejudice against coke made in retort ovens, but this has been gradually overcome. The coke obtained from the earlier type of retort oven was of a more or less black appearance, and on that account was thought to be of an inferior quality to the silvery grey coke obtained from the beehive oven. The appearance of retort-oven coke has been considerably improved upon, and it is now admitted that as regards quality there is little or no difference between the two classes of coke.

The first battery of retort ovens in Great Britain was erected in 1882 by Messrs. Pease and Partners at their collieries in Durham, and was of the Simon Carvés type. At the present time there are about 250 separate coking plants at work in this country, excluding those at gas works, and at 80 of these by-products are recovered. Retort ovens may be broadly divided into two types; horizontal and vertical-flued ovens. Among the best known of the former are the Semet-Solvay, Colin, and Huessener. The Simon Carvés, Kopper, Otto-Hilgenstock, and Otto-Hoffman ovens have vertical flues.

A description of the Simon Carvés' system is given for the purpose of explaining the working of a modern coking plant. There are two types of ovens in this system, regenerative and non-regenerative. Ovens with regenerators are designed to obtain from the coal a large amount of live gas over and above the quantity necessary for heating the battery. This surplus quantity is reduced as very hot air is used to obtain the combustion of the gas, but, on the other hand, the waste gases leaving the regenerators on their way to the chimney are not hot enough to be used for steam raising purposes. When it is desired to drive gas-engines with the live spare gas from the ovens, or to use this gas as an illuminant or otherwise, it is better to adopt ovens with regenerators. When, however, it is proposed to obtain a large amount of steam from the waste heat from the ovens, the non-regenerative type is preferable, but in this case the amount of spare live gas in excess of that required for heating the battery is reduced. A battery of ovens consists of from 35 to 50 long, narrow, rectangular chambers, erected on a strong concrete bed. Each chamber is 32 feet 9 inches long, 8 feet 2 inches high, and 20 to 22 inches wide. The charge of about $11\frac{1}{2}$ tons is put in by hand through holes in the top of each chamber, or by means of a machine which first compresses the charge to a solid cake, and afterwards delivers it into the oven through one of the doorways provided at each end. When a chamber is charged, the doors are closed and plastered with puddled clay to make them air-tight. The chambers are always maintained at a red heat by the burning gases in the horizontal and vertical flues surrounding them, and distillation of the coal commences at once. The gases generated are drawn off into a gas collector, afterwards passing through cooling and washing apparatus, with the aid of mechanical exhausters, and are led back to the heating flues. The coking process takes from 36 to 48 hours, according to the quality of the coal, and when completed the end doors are opened, and a ram (which can be fitted on to the compressing machine if the latter is used) forces the red-hot coke out of the oven on to the coke bench, where it is cooled down with water either by hand or by the aid of a quenching machine.

Until quite recently the method of recovering the by-products in connection with coke ovens was similar to that adopted many years ago. The process resulted in a loss of heat, and attempts have been made to discover a more economical and " direct " process, by which the waste of heat can be avoided.

In the Simon Carvés direct " process " the gases given off during the carbonisation of the charge in the oven are first collected and exhausted into a centrifugal separator. This machine is of the cyclone type, without any moving parts, and in it the heavier and denser tars are removed. Afterwards the gases pass into a dynamic centrifugal separator where the lighter and more fluid tarry matter still contained in the gases is separated. The tars from both extractors are collected and drawn into a special collecting tank. The gases, which are now free from all traces of tar, are taken through an exhauster into a saturator, in which the ammonia is caused to combine with sulphuric acid to form sulphate of ammonia. This crystallises from the liquid, drops to the bottom of the saturator box, and is raised by an elevator and deposited on to a draining table, where all superfluous acid is separated from the sulphate and runs back into the saturator. The sulphate is afterwards taken from the draining table into a centrifugal dryer, where it is thoroughly dried and then put into the store-room ready for sale.

In this process, condensing and scrubbing plant, cooling water, liquor circulating pumps, and tanks for the decantation and storage of the liquor are dispensed with. As no ammoniacal liquor is formed during the process, ammonia stills, liquor superheaters, lime mixing, pumping machinery, and lime settling tanks are not required. Whenever it is desired to recover the benzol contained in the gases or to use some of the gas in gas-engines or for lighting, the whole or a portion of the gas must be cooled down after it has left the ammonia recovery plant.

CHAPTER XIV

AERIAL ROPEWAYS

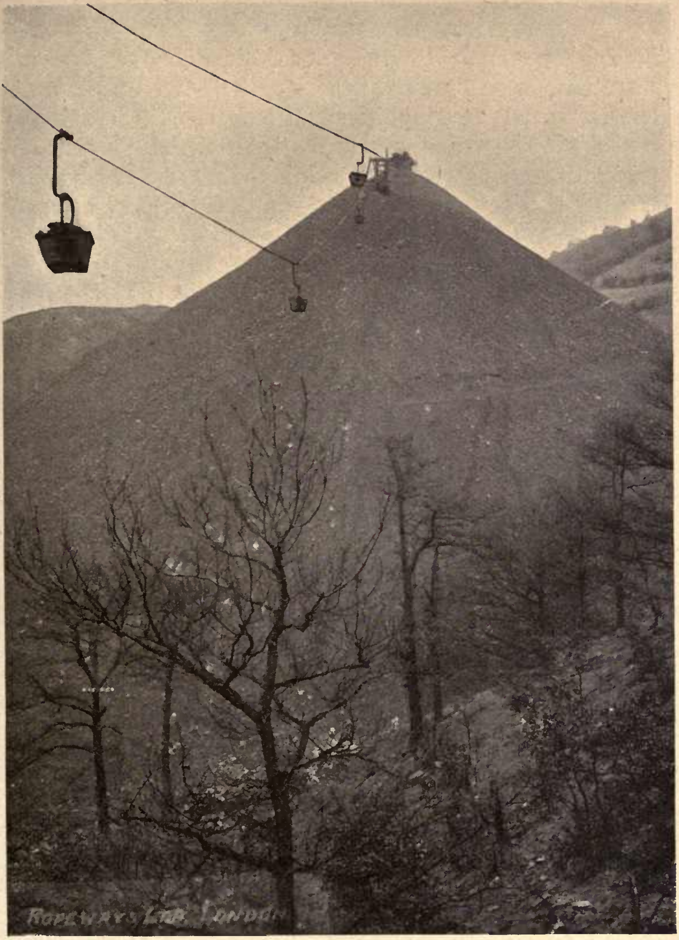
AERIAL ropeways now form part of the surface plant at several collieries, both at home and abroad, for carrying out such operations as conveying dirt from the pit bank or washery to the dirt heap; conveying small coal to the washery and from thence to the coke ovens. This system possesses many advantages compared with other means of transport, especially when the colliery is situated in rough and mountainous country, as often occurs abroad, and where it would be impracticable to construct railways or roads except at great expense. It has been installed in this country when owing to buildings, roads, streams, etc., other means of conveyance would have proved exorbitant in cost. An aerial ropeway does not interfere with any traffic beneath; it is not subject to stoppages on account of floods or falls of snow, and can work as well during the night as in the day. Another advantage is that there is very little interference with the surface over which the ropeway passes. No great purchase or lease of land is necessary, as the supports for the rope are placed at comparatively long intervals and occupy but a small space, and the intervening ground is free for agricultural or other purposes, the rope and buckets travelling at such a height above the surface as not to interfere in any way with workmen, buildings, or cattle in the fields below. Only a right of way is necessary from trestle to trestle for the purpose of examination and lubrication of the working parts.

Broadly speaking, there are two distinct types of aerial ropeway: (1) That in which the loads are suspended from carriers or small trollies running along fixed rail cables and turned or controlled by a separate traction rope. (2) That in which a single endless constantly-turning rope not only supports the loads, but carries them along.

The advantages claimed for the latter type are that it is simple in construction and manipulation, and altogether gives better all-round results as regards wear and tear. When, however, very steep grades have to be overcome, or for short distances where heavy quantities have to be conveyed, the double system is perhaps the best.

In the single rope system, an endless-rope is used, which may be either self-acting or driven by an engine, according to the difference in inclination between the terminals. The power may be either steam, oil, gas or electricity. The rope is taken round a driving pulley three or four times, and is supported at intervals by wooden or steel trestles, on the top of which are fixed the pulleys on which the rope runs. The loading station is usually a low structure built on the ground level to facilitate loading from shoots, etc., whilst the unloading station is often elevated for the convenience of emptying the buckets into wagons, kilns, etc., or foi the formation of a stock heap. Intermediate loading or unloading stations can be arranged, and the buckets can, by means of shunt rails at terminal or intermediate stations, be diverted in any required direction for loading or unloading. The buckets, after being emptied, pass round on to the return rope, and are taken back to the loading station. To keep the rope at a proper tension it is taken round a pulley fitted in a wooden frame working on wheels or slides. Weights are attached to the back end of the carriage, and any slack rope is immediately taken up.

The illustration on page 79 shows an aerial ropeway



By permission of Ropeways, Ltd.

AERIAL ROPEWAY FOR THE REMOVAL OF PIT RUBBISH (single rope system) constructed by Ropeways, Limited, for the removal of pit rubbish at a colliery in South Wales. The plant has a nominal capacity of 100 tons per hour, but in actual working frequently deals with 140 tons per hour. The dumping frame is fitted with gear for raising it and moving it longitudinally, and the frame is raised or moved forward as required.

CHAPTER XV

THE MANUFACTURE OF BRIQUETTES

THE making of coal briquettes was first attempted during the reign of Queen Elizabeth, and numerous patents have been taken out since then, but only a few have proved of any commercial success. The manufacture of briquettes from fine coal is not carried on in the United Kingdom to anything like the same extent as on the continent, where the industry, particularly in Germany, has become quite an important one. The majority of the plants at work in this country are in South Wales, and the greater portion of the output is used by the Navy for reserve purposes in hot climates, as this kind of fuel is said to stand better than Welsh coal. A large quantity is also exported to the continent for domestic purposes, and to tropical countries for use on railways, etc. The output from the whole of the plants in the United Kingdom is at present about 1,608,000 tons, and out of this, 1,471,000 tons are exported, principally to Italy, France, Spain, and Brazil. The making of briquettes by hand was explained so far back as 1776 by a German named Jars, who described in a publication the making of briquettes by mixing small coal with loam.

The first briquette plant in France was erected in 1842 at Bèraud, and by 1867 there were 31 such plants at work, producing over 714,000 tons annually. The production in France now reaches 3,000,000 tons a year. A great portion of this is consumed by the Navy, and the different railway companies. Up to 1880 very few plants were at work in Germany, but from that time rapid developments have taken place, and now Germany heads the list in the world's production. In 1885 there were about 140,000 tons of true coal, and about 1,000,000 tons of brown coal briquettes made. Now the production amounts to 16,800,000 tons of brown coal and 5,000,000 tons of true coal briquettes. Briquettes are manufactured in Belgium, but, like the United Kingdom, the greater portion of the output, which amounts to 2,700,000 tons, is exported. They are also made on a small scale in Austria-Hungary, Spain, Italy, Russia, and Holland, and a few machines have been recently erected in China, India, and Australia. Several briquetting plants have been erected in the United States, where the yearly output is about 212,400 tons. It may be of interest to give the specification issued by the French Navy and the Belgian State Railway as to the manufacture and quality of briquettes used by them—

"(1) The briquette must be hard, homogeneous in density and size, only very slightly hydroscopic, and it should burn almost without smoke or odour. (2) The dust or breakage caused by handling and transportation should not exceed 5 per cent. (3) The specific gravity should not be less than 1·19. (4) The briquette should ignite readily, burn with a cheerful flame, and retain its shape until completely burned. (5) The ash should not exceed 9 per cent., and the evaporation results should at least equal those of the best lump coal, from the screenings and dust of which the briquette was made. (6) The quantity of hard pitch to be used as a binder should amount to 8 per cent., and the weight of a sample briquette should not exceed 22 lbs."

Briquettes are made in all shapes, but perhaps the most convenient for use on railways, steamships, etc., is the rectangular shape, weighing from 4 to 20 lbs.

each. For domestic purposes small cylindrical, ball and egg-shaped briquettes are the most popular, of about 5 ounces in weight. The heating power depends on the quality of the coal used, and the binding material. So far the most suitable binder is pitch obtained by the distillation of coal tar. Many attempts have been made with other mixtures, but with little success. Messrs. William Johnson & Sons, of Leeds, recently supplied the Italian naval authorities with a briquette machine guaranteed to produce 150 tons per day of rectangular briquettes, weighing approximately 7 lbs. each, or, if required, "eggettes" of about 5 ounces in weight.

In this machine the coal is first of all delivered into a softener, where any superfluous moisture is driven off, and the coal made into a suitable condition for briquetting. From the softener the coal is elevated into a hopper under which is a mixer and measurer. The pitch is delivered into a hopper, and is passed through a machine, where it is broken into small pieces. It is then elevated into a storage hopper, and from there passes into a mixing and measuring appliance. This latter arrangement is so speeded as to carry forward the proper amount of coal and pitch, and at the same time thoroughly mix the two constituents. The mixture then passes into a disintegrator, where it is ground into a fine powder, and is by means of an elevator delivered into a cooking chamber. The pitch is here melted by the injection of steam at the proper temperature, and the whole forms a semi-plastic mass. From the cooker the material is delivered into the briquette press which makes and moulds the briquettes, and delivers them on to a conveyor. When cool, the briquettes are ready for loading into wagons or for being consumed.

CHAPTER XVI

THE SHIPPING OF COAL

WHILST this country no longer holds the blue riband as the greatest coal-producing country of the world, it is a matter for congratulation that its export trade is still the largest. Coal is shipped at many ports around the coast to foreign countries, and British possessions over the seas, and a large quantity is taken by ships for their own use.

The six principal coal shipping ports of the United Kingdom, according to the amount of coal exported, are Cardiff, Newcastle and South Shields, Hull, Newport, Sunderland, and Blyth. In 1840 there was shipped from Cardiff (which is now the premier shipping port of the world, and the main outlet for the great South Wales coal-field) 44,000 tons of coal. In 20 years this had risen to 1,750,000 tons, and in 1911 to over 21,000,000 tons. There is shipped from Newport about 5,700,000 tons per year from the same coal-field. Hull is the principal port for the Yorkshire and Midland coal-fields. The coal trade of this port has developed rapidly within the last few years, concurrent with the opening out of the great South Yorkshire coal-field. In 1900 the coal exports amounted to 2,500,000 tons, whereas now the quantity is nearly 6,000,000 per year. The ports of Newcastle and South Shields, Sunderland, and Blyth, are the chief outlets for the Northumberland and Durham coal-fields. The exports from the first-named port amount to about 20,000,000 tons per annum. Sunderland exports about 4,800,000 tons, and Blyth about 4,400,000 tons per year. Other British ports of lesser importance are Glasgow, Swansea, Methil, Grimsby, Goole, Port Talbot, Hartlepool, and Grangemouth.

QUANTITY OF COAL SHIPPED FROM THE UNITED KINGDOM IN 1911.

Port.	Coal exported to Foreign Countries.	Bunker Coal for ships on Foreign Voyages.	Bunker Coal for ships on Coastwise Voyages.	Coal Shipped Coastwise.	Total.
	tons.	tons.	tons.	tons.	tons.
Cardiff	16,127,777	2,515,078	99,253	2,644,390	21,386,498
Newcastle and South Shields ..	12,498,066	2,321,379	217,457	5,085,684	20,122,586
Hull	3,349,590	1,377,537	60,199	1,035,432	5,822,758
Newport	4,324,917	624,357	20,811	688,335	5,658,420
Sunderland	2,840,087	306,552	58,499	1,617,881	4,823,019
Blyth	3,692,233	378,658	17,970	281,739	4,370,600
Glasgow	2,002,225	1,279,779	265,009	514,971	4,061,984
Swansea	2,929,982	389,223	71,698	326,964	3,717,867
Methil	2,543,446	224,802	8,713	217,129	2,994,090
Grimsby	1,654,112	1,100,091	11,237	78,871	2,844,311
Goole	1,260,361	110,248	61,092	1,350,950	2,782,651
Port Talbot	1,650,538	159,701	15,111	326,874	2,152,224
Hartlepool	1,391,180	280,958	24,107	429,985	2,126,230
Grangemouth	1,417,248	173,841	51,243	198,539	1,840,871
Other Ports	6,917,504	8,021,985	1,449,526	7,207,277	23,596,292
Total for all Ports in United Kingdom	64,599,266	19,264,189	2,431,925	22,005,021	108,300,401

The table on p. 85 shows the quantity of coal shipped for different purposes from the United Kingdom in 1911.

The coal handling plant is often of an elaborate description where fuel is exported in large quantities, so as to permit of its being shipped in the most expeditious manner possible. One form of loading arrangement consists of a shoot and movable spout, by means of which the coal is discharged into the ship's hold. The coal wagons are provided with bottom doors, out of which the coal falls and slides down the shoot, along the spout, and into the hold. With end-door wagons a hydraulic arrangement is provided to tip the wagons up. Powerful cranes are sometimes used which lift a wagon, or parts of it, bodily, right over the hold. A system of elevators and belt conveyors is adopted at some ports by means of which the coal is first emptied from the wagon into the hopper of an elevator, then raised a certain height, where it is discharged on to an endless belt conveyor, carried along, and discharged into the vessel by a special form of shoot which can be altered to suit the height of the vessel, and can also be adjusted radially to reduce the amount of trimming.

The rapid loading of ships with a minimum amount of breakage of the coal has been given great consideration in recent years, and several patent coal-shipping appliances have been designed and erected. One well-known arrangement which has met with much success is the Lewis-Hunter patent coal crane, which is used at Cardiff. Screened coal shipped by this appliance is claimed to be equal to double-screened coal shipped by the usual methods. Three or more cranes can be worked simultaneously into one vessel, and as much as 330 tons have been loaded by one crane in an hour, and 6,715 tons have been shipped into a vessel in eleven hours.

The coal is emptied from the wagons into a rectangular iron bin, pyramidal in shape, with a movable bottom. The empty bin is first lowered into a pit, the full wagon is brought on to a platform at one end of the pit, and the coal is tipped into the bin by a hydraulic tilting apparatus. The wagon, when empty, is taken off, shunted along with other empties, and another full one brought on to the platform. Whilst this is being done, the full bin is lifted by the crane, swung over the side, and lowered into the ship's hold. When the bin almost touches the bottom of the hold, the pyramidal bottom is lowered out, and the coal, sliding down the enclosed sides, is deposited very gently into the bottom of the hold. When empty, the box is raised by the chain and lowered into the pit to be filled with coal again.

A special arrangement used at Blyth, and known as the Handcock anti-breakage appliance, consists of a vertical tube suspended from a crane so as to reach to any required depth in the ship's hold. On three sides it is enclosed, whilst the fourth is fitted with a series of telescopic doors, the top one of which is attached to a telescopic spout or shoot by an automatic coupling. The height of the anti-breakage appliance can be adjusted independently of the shoot, that portion of the vertical tube below the shoot being always closed by the telescopic doors, whilst that above is open to allow an arrangement known as the "retarder" to work. Steel trays, pivoted to endless chains, receive the coal and lower it gently but rapidly to the bottom of the apparatus, where it is deposited with very little breakage into the hold. The trays are actuated by the weight of the coal itself, and the speed is regulated by an automatic brake. The capacity of the anti-breaker is equal to that of the shoot, 800 tons per hour having been loaded through one appliance. If required, the coal can be unloaded at the level of the dock into hoppers below its surface. The coal is then raised by a conveyor and discharged into the shoot or spout, the final discharge into the hold being regulated by the anti-breakage device. The whole of the machinery is erected on one structure, which travels along a pair of rails, so that the arrangement may be brought to either hold of the vessel. With two separate units of this description the two holds of a vessel can be filled simultaneously, and as much as 1,200 tons of coal can be loaded per hour.

There are in use at continental ports self-propelled coaling vessels for bunkering liners. In one form, the hold is divided into a number of compartments, so that from 600 to 1,000 tons are carried. By means of sliding doors, the compartments empty themselves, one after the other, into the buckets of a conveyor, which run in a tunnel along the bottom of the vessel. The coal runs over an automatic weighing machine before it falls over into a receiver, from whence it slides down a shoot into the bunkers of the vessel.

COAL-FIELDS OF THE WORLD

CHAPTER XVII

BRITISH COAL-FIELDS

A COAL-FIELD consists of a more or less large tract of country, the underlying rocks of which contain a varying number of coal seams, separated one from another by beds of shale, sandstone, etc. Although it is probable that the seams were deposited on a level surface, most coal-fields are found in the form of a basin, the seams out-cropping to the surface round the edges, and dipping towards the centre. The various seams of a coal-field differ greatly in character and even an individual seam does not always maintain the same quality throughout the field. A notable instance of this is found in the case of the anthracite mines of South Wales, which change from anthracite in the north-western part of the coal-field to semi-bituminous in the centre, and ordinary bituminous in the south-east. From some individual seams two or more different qualities of coal are obtained. For instance, the Barnsley Bed, a well-known seam in the Yorkshire coal-field, supplies both gas, steam, and house coal. The thickness of coal seams varies from a few inches up to a great many feet. In the United Kingdom the thickest seam is the famous Ten Yard or Thick Coal of South Staffordshire, which in some parts of the coal-field attains a thickness of 30 feet of almost clear coal. Abroad, seams of very great thickness are found. In India, beds 90 feet thick have been proved, and in China the extraordinary thickness of 200 feet is vouched for. In Victoria a bed of brown coal 150 feet thick is worked, and at Tamaqua, in Pennsylvania, there occurs a bed of anthracite 115 feet in thickness.

Coal-fields have been proved and worked in many countries throughout the world, and the results of prospecting carried out during recent years have proved the existence of valuable tracts of coal-bearing rocks in localities which previously were supposed to possess no coal resources. It would appear from the discoveries chronicled almost daily in the press and technical journals, that, in the near future, coal will be proved to exist to a greater or lesser extent in practically every part of the globe. At the present time mining is only carried out on a very small scale in many coal-fields abroad, principally on account of transport difficulties. As these difficulties are gradually overcome by railway and other rapid means of communication, coal-fields now lying almost dormant will become centres of life and industry.

Practically the whole of the coal in the United Kingdom is found in the upper part of the carboniferous system, known as the coal measures. The coal-bearing strata are generally found fairly close to the surface in the majority of the coal-fields, though from time to time extensions are found to exist under rocks of more recent formation. A notable example of this is the south-eastern extension of the Midland coal-field, where the coal measures are overlain by the Permian and Triassic rocks.

The principal coal-fields of the United Kingdom (shown on the map on page 91) are as follows—

The Northern coal-field, the Midland coal-field, the South Wales coal-field, the Lancashire coal-field, the South Staffordshire coal-field, the North Staffordshire coal-field, and the Scotch coal-field.

The Northern coal-field extends from the Croquet to the

MINERALS
OF
ENGLAND & WALES
English Miles
0 20 40 60 80
The shaded portions on the land show the Great Coalfields.
SCOTLAND
IRON
GLASGOW
EDINBURGH
Ayr
IRELAND
Whitehaven
IRON
ISLE OF MAN
IRON
Barrow
ZINC
LEAD
Newcastle (GLASS)
Sunderland
Middlesboro
Cleveland (IRON)
CATTLE REARING
NORTH SEA
YORK
Leeds
Bradford
MANCHESTER
Sheffield
IRISH SEA
ANGLESEY
LIVERPOOL
ZINC
LEAD
SLATE
Mold
Wrexham
POTTERIES
Stoke
SALT
IRON
Derby
Nottingham
The Fens
Ashby
BIRMINGHAM
IRON
SLATE
CARDIGAN BAY
LEAD
Norwich
AGRICULTURAL DISTRICT
Merthyr
Cardiff
BRISTOL
BRISTOL CHANNEL
LEAD
LONDON
HOP GARDENS
TIN
GRANITE
TIN
COPPER
STONE
ENGLISH CHANNEL
6
4
2
0
2
56
54
52
50

Tees, embracing an area of 1,000 square miles. In the south and south-west portion excellent house, gas, and coking coal is obtained, whilst the north and north-west supply first-class steam coal.

The Midland coal-field lies in the counties of Derby, Nottingham, and York, and is one of the most valuable of British coal-fields. Developments on a very large scale are taking place, particularly in the south-east portion, where a further 680 square miles of coal-field has been proved since 1905. In 1905 the probable extent of the coal-field was taken as 460 square miles. Boreholes at Selby, Thorne, and Crosby have proved the existence of the coal measures over a far greater area amounting to 1,100 square miles. Another bore hole is being put down at Newark, and this may prove more coal further south. Professor Kendall, who has been engaged for some time in proving the extension, stated before the British Association in 1910 that this new coal-field would be the hope and support of industrial England in the future.

The South Wales coal-field stretches from Pembrokeshire to Monmouthshire in the east, and is about 73 miles long by 16 miles wide. It is the only coal-field in Great Britain in which anthracite is found. The anthracite mines occur in the north-west portion of the coal-field, but gradually change into semi-bituminous in the centre, and ordinary bituminous coal in the south-east portion.

The Lancashire coal-field has an area of about 200 square miles, and is divided from the Midland coal-field by the Pennine Range. Successful developments are taking place to the south, which should tend to maintain the present output for some time.

The South Staffordshire coal-field extends from Rugeley in the north to near Harbourne in the south,

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MINERS RETURNING HOME

a distance of 22 miles with a width of about 6 miles. The famous thick coal seam (30 feet thick) is found in this coal-field.

The North Staffordshire coal-field underlies the Pottery district, and has an area of 100 square miles. This coal-field contains many valuable seams of coal, but a considerable number are very highly inclined and are known as "rearers."

The Scotch coal-field runs from the Firth of Forth to the Firth of Clyde, a distance of 90 miles, with a width of, approximately, 30 miles. The coal-bearing strata does not extend in a continuous line, but is broken up into a number of small detached areas. The principal seams in this coal-field are found below the Millstone Grit, and not above it, as is the usual case.

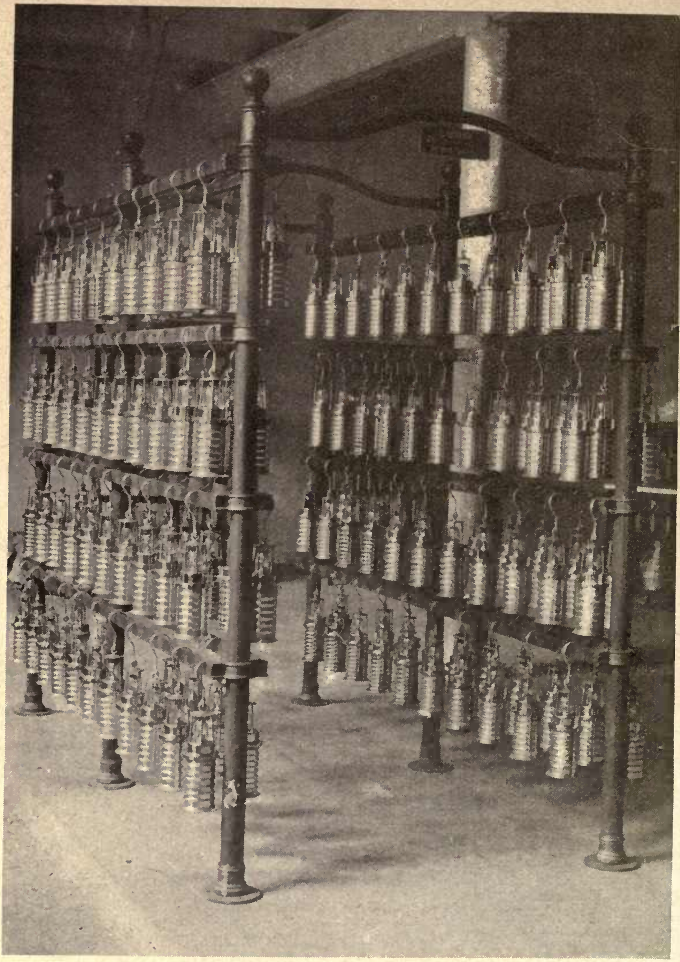
Other English coal-fields of lesser importance are the Cumberland, Warwickshire, Leicestershire, Shropshire, Somerset, North-Wales, and Forest of Dean.

The Kent coal-field has been a subject of interest to mining men and the public generally ever since the existence of coal measures was proved by Sir Edward Watkin in a boring put down under his direction on the shore near Dover some 22 years ago. Although two shafts were sunk close to the bore hole, no further discoveries of value were made until 1906. Since that date about £106,000 have been expended upon deep borings between Dover, Sandwich, and Canterbury, and by these borings, twelve in number, 96 seams have been proved with an aggregate thickness of 319 feet 11 inches. Fully 91 per cent. of these seams can be worked without damage or injury to one another. The average thickness of the seams works out at 3 feet 4 inches, and it is estimated that the proved field lies under an area of 150 square miles, and contains not less than 10,000,000,000 tons of coal. At Tilmanstone three shafts are now 1,140 feet deep, and are only 30 feet short of touching the coal measures. Shafts at the Guilford and Snowdon collieries are in an advanced state of development, while at Dover coal is already being raised in small quantities, and mineral is expected to be wound from the Tilmanstone shaft during the present year. Coal will probably be raised at Snowdon and Guilford in 1914, whilst the collieries at Wingham and Woodnesborough will be pushed on as soon as the railway now under construction reaches these localities.

Whilst coal is known to exist in several parts of Ireland, mining operations are only carried on at present to a small extent. Coal is worked in the counties of Antrim, Leitrim, Leinster, and Tyrone. The returns of the Geological Survey Office in Dublin show that surveys have been carried out proving the existence of at least 200,000,000 tons of coal in Ireland.

The following table gives the output for 1910 from the different coal-fields in the United Kingdom, and percentages of the total output—

Yorkshire Coal-field	66,756,799	tons	=	25·2	per cent.
Northern ,,	52,553,289	,,	=	19·9	,,
South Wales ,,	48,699,982	,,	=	18·4	,,
Scotch ,,	41,335,132	,,	=	15·6	,,
Lancashire and Cheshire ,,	23,766,377	,,	=	9·0	,,
Midland ,,	22,953,165	,,	=	8·7	,,
Small detached Coal-fields	4,862,166	,,	=	1·8	,,
North Wales Coal-field	3,410,876	,,	=	1·3	,,
Irish Coal-fields	79,802	,,	=	0·1	,,
	264,417,588	,,		100·0	,,



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PORTABLE ELECTRIC SAFETY LAMPS

CHAPTER XVIII

COLONIAL COAL-FIELDS

Of the British colonies and possessions, India is perhaps the richest, its resources as a coal-bearing country being immense. The chief coal-fields lie in Bengal, and the greater part of the output is raised from these. Coal is also worked in the Punjaub, Central Provinces and Assam.

The majority of the seams are of considerable thickness, but are not equal in quality to British coal. The output for the whole of the Indian coal-fields is now about 12,000,000 tons, of which Bengal raises 94 per cent. Only a very small proportion of the output is used for domestic purposes, the bulk being consumed in railway locomotives ; as bunker coal for steamers, and for steam raising at mills.

Canada possesses many valuable coal-fields, several of which are in active development. According to the Report of the Commission of Conservation, published in 1911, the coal-fields may be divided into four main divisions as follows—

(1) The eastern division containing the bituminous coal-fields of Nova Scotia and New Brunswick.

(2) The central or interior division, containing the lignites of Manitoba and Saskatchewan, and the lignites, bituminous, and anthracite coal-fields of Alberta, and the Eastern Rocky mountain region.

(3) The Pacific coast and the Western mountain division, containing the semi-anthracite and bituminous fields of Vancouver Island, the bituminous coal-fields of the interior of British Columbia, and the lignite of Yukon.

(4) The northern division, containing the lignites of the Arctic-Mackenzie basin. The total area of the Canadian coal-fields is estimated at 29,957 square miles, and to contain 172,057 million tons. The total annual production is now about 11,500,000 tons.

Rich tracts of coal-bearing country are found in the Commonwealth of Australia. New South Wales produces about 80 per cent. of the total production, which is now about 9,700,000 tons. It is computed that in this State alone there are from 24,000 to 28,000 square miles of coal-fields. Victoria possesses large deposits of brown coal, but up to the present time these have only been worked on a small scale. Tasmania and New Zealand contain many seams of coal, bituminous and brown, which are worked in various localities. The annual output from Tasmania at present is about 80,000 tons, and from New Zealand 2,197,000 tons. It is, of course, a well-known fact that the latter country is one of the most progressive of the British possessions, and it already possesses two mines worked by the State, namely, the Point Elizabeth and the Seddonville Mines. The output from these State-owned mines is now about 281,500 tons a year. The profits of both State mines during 1910 amounted to £1,051.

Coal-fields have been proved in several parts of South Africa. At the present time mining is carried on principally in Natal, Rhodesia, and the Transvaal. In the last-named country, especially, considerable expansion in coal-mining has taken place of recent years. Coal is also worked in Cape Colony and Orange River Colony, and deposits have been proved in Nyasaland and Basutoland. Several seams of brown coal have recently been discovered in Southern Nigeria.

CHAPTER XIX

FOREIGN COAL-FIELDS

Coal is found in about thirty states and territories of the United States. The total area of the proved fields is estimated at about 310,000 square miles, and there are in addition about 160,000 square miles of which little is yet known, but which may contain workable coal seams. It is also estimated that coal lies under an area of 32,000 square miles, but at such a depth that it is not considered workable as yet. This country easily heads the list as having the greatest extent of coal-fields in active working, the total production of 1911 being 84,000,000 tons of anthracite and 359,000,000 tons of bituminous coal, making a grand total of 443,000,000 tons.

The anthracite deposits are found in Eastern Pennsylvania, and comprise an area of 480 square miles, but from a point of output the coal-fields of the Appalachian region are at present the most productive. This region, which extends from Western Pennsylvania on the north, to Central Alabama on the south, and includes besides others the States of Ohio, West Virginia, Tennessee and Georgia, covers an area of approximately 69,300 square miles. In this area are included the best classes of bituminous coal found in the United States. In the interior Provinces, east of the Mississippi, are the coal-fields of Illinois and Indiana, and west, those of Iowa, Kansas, and Arkansas. The total area of the coal-fields of this interior Province is about 100,000 square miles. Lignite and bituminous coal is found in Colorado and part of New Mexico. The chief coal-fields of the Pacific States are found in

Washington, and coal is also produced in California not far from San Francisco.

There are three principal districts in which true coal is worked in the German Empire: the Lower Rhine and Westphalia, Silesia, and the Rhenish district. Deposits of brown coal are found in more or less abundance over nearly the whole of North Germany, but the principal brown coal-fields are situated in Central Northern Germany, and the Rhine Province. New deposits of brown coal have been discovered in several parts of Saxony.

Austria-Hungary possesses important deposits of both true coal and brown coal. The principal coal-field is in Upper Silesia, and is a continuation of the Prussian and Russian coal-field. The other important producing area is that of Central Bohemia. Coal is also worked in Central Moravia, and new deposits have been proved in Dalmatia. Most of the Austrian provinces yield brown coal, but Bohemia is by far the largest producer. Styria is next in importance. Important deposits are found in Upper Austria, and there are mines at work in several Hungarian provinces.

France has several coal-fields producing anthracite, bituminous, and brown coal. The two principal coal-fields are the Pas-de-Calais and the Nord, which produce between them about 65 per cent. of the total output of the country. The seams in these districts have been subjected to great disturbances, rendering them very difficult to work, and the majority of them are comparatively thin. Another coal-field of some importance is known as the Loire Basin.

Russia contains vast tracts of coal-bearing country which yet await development. The most productive coal region is the Donetz Basin, in the province of Ekaterinoslav, which covers an area of 16,000 square miles. Next in importance comes Poland, where both true coal and brown coal are mined. Other coal regions are the Urals, the Eskibastus district, and the Kusnetski Basin. Coal is abundant in East and West Siberia, but the quality is poor. In the Island of Shagalien coal is worked on a small scale by Russian convicts.

There are five coal-mining regions in Belgium, known respectively as the Couchant de Mons, Centre, Charleroi, Namur and Liége. Of these, the Charleroi region is the most productive, yielding about one-third of the total production. The estimated area of the coal-field is stated to be 532 square miles, but the recent borings in the Campine district which have proved the existence of new seams should increase the area.

Japan is rapidly coming to the front as a coal producing country in the Far East. The latest estimate of the coal resources of the country are put down at about 1,400 million tons, of which the Island of Hokkaido is assumed to possess 600 million. There are numerous collieries at work on the island, many being laid out on western lines. The quality of the coal is mainly bituminous, and several of the seams are suitable for coke and gas-making purposes, whilst others are noted as first-class steam coals.

Coal is widely distributed throughout the vast empire of China. The Province of Hunan is rich in anthracite, and in Honan brown coal is worked. The great coal-fields of Shansi are situated on a plateau, and the seams vary in thickness from 13 to 33 feet. The estimated quantity of ungotten coal in this province alone is 630,000 million tons. Other provinces containing coal-fields are Chihli and Shantung. There are in active operation some very large undertakings controlled solely by Europeans, or by Europeans and Chinese combined. Railways are now under construction which are intended to open out several important coal-fields, and no doubt with better transport facilities and Government assistance in granting reasonable concessions to foreigners, China will become one of the great coal producing nations of the world in the not far distant future.

While the countries described above are collectively the chief sources of the world's output of coal, the total amount is not inconsiderably increased by many other countries containing tracts of coal-land, which have only been proved of small extent or are only worked on a small scale at the present. In Europe: Spain, Holland, Turkey, Bosnia, Sweden, Bulgaria and Roumania are included in this class.

In Central and South America there are several more or less extensive tracts of coal country. Coal has been mined in Mexico, Chili and Peru for many years, but only in a primitive fashion, simply to supply local works and for domestic purposes. An extensive coal-field has recently been proved in the State of Pernambuco, Brazil. Like many others in different parts of the world, these extensive coal-fields await the completion of railways before a market beyond local demands can be reached.

CHAPTER XX

OUR COAL RESOURCES

MANY estimates have from time to time been made by scientists as to the coal resources of the United Kingdom and the probable duration of the coal supply. Professor Hull in 1860 stated that the supply would be practically exhausted in the year 2034. In 1865 W. Stanley Jevons, in *The Coal Question*, gave his opinion that the supply would last only 110 years. A Royal Commission was appointed in 1871 to consider the question, and from evidence received issued a report in which the available resources of the country in seams of 1 foot thick and upwards, and situated within 4,000 feet of the surface, were said to be 90,207,285,398 tons.

Another Royal Commission was appointed in 1903, and in the final report issued in 1905 the available quantity of coal in the proved coal-fields of the United Kingdom was put down at 100,914,668,167 tons, the same limit of working depth and minimum thickness of seam being taken as in the Royal Commission of 1871.

It is interesting to note that 79·3 per cent. of the available resources was estimated as contained in seams of two feet thick and upwards (excluding Ireland, Somerset, and Gloucester), and 91·6 per cent. in seams of 18 inches and upwards. A comparison of the estimates of the two Commissions shows that though between the 1st January, 1870, and the 31st December, 1903, 5,694,928,507 tons of coal were raised, the estimate of the last Commission was 10,707,382,769 tons in excess of the previous one. This is accounted for partly by the difference in the areas regarded as productive by the two commissions, and partly by

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discoveries due to borings, sinkings and workings, and more accurate knowledge of the coal seams.

The last Commission also state in their report that in addition to the coal within 4,000 feet of the surface, there are in the proved coal-fields considerable quantities lying at greater depths ; whether this coal or any part of it is recoverable or not depends upon the maximum depth at which it may be found possible to work in the future. The estimated quantity of such coal is assumed at 5,239,433,980 tons, but does not include a very large amount of coal which may be assumed to lie under the Cheshire basin at depths exceeding 4,000 feet. The Geological Committee appointed to enquire into the productive measures known or believed to exist outside the areas dealt with by the District Commissioners reported that the amount of coal which might be expected to be available in the concealed and unproved coal-fields at depths less than 4,000 feet was 39,483,000,000 tons (not including Gloucester, Somerset, and South Wales ; and not including the Kent Coal-field). To this figure must be added the under-sea area lying between five and twelve miles beyond high water mark in the Cumberland Coal-field, estimated by Sir Lindsay Wood to contain 854,000,000 tons, and under-sea areas in St. Bride's and Carmarthen Bays, estimated by Sir William T. Lewis to contain 383,000,000 tons. Of the 39,483,000,000 tons of coal supposed to exist in the concealed coal-fields, 23,000,000,000 tons were credited to the extension of the Yorkshire and Nottingham Coal-field. The concealed coal-field was estimated to extend to within six miles from Hull, eight miles from Grimsby, about four miles from Lough, and beyond Boston and Grantham on the south. The eastern extension has now been proved to extend considerably further south, and it is reasonable to assume that the available coal in the concealed portion of this coal-field is equal to twice the amount fixed by the Geological Committee in 1905, i.e., 46,000,000,000 tons. The available coal resources of the Kent Coal-field are now estimated at not less than 10,000,000,000 tons. The total quantity of coal assumed to be within 4,000 feet of the surface, including concealed and unproved coal-fields, works out from the above figures to the grand total of 174,635,000,000 tons, as shown in the table below—

	Millions of tons.
Quantity of coal in the proved coal-fields .	100,915
Available coal in concealed and unproved coal-fields (excluding Gloucester, Somerset, South Wales and Kent)	39,483
Under-sea area in Cumberland Coal-field . .	854
Under-sea area in South Wales Coal-field . .	383
Further extension of the Yorkshire Coal-field proved since 1905	23,000
Kent Coal-field	10,000
(millions)	174,635

The duration of the coal supply of this country is a problem in which several factors can only be approximately taken; hence the difference in the estimates calculated by various authorities from time to time. A great deal depends upon the maintenance or the variation of the annual output. The last Commission on Coal Supplies hesitated to prophesy how long the supply would last. They were of the opinion that the annual rate of increase of the output of coal could not long continue, and that some districts had already attained their maximum output, but that, on the other hand, developments in the newer coal-fields would possibly increase the total output for some years. The Commission considered that with the exhaustion of the shallower mines, the rate of increase of output would be slower, to be followed by a period of stationary output, and then a gradual decline.

Mr. R. Price Williams gave some interesting evidence before the Royal Commission relating to the growth of the population of Great Britain in connection with the probable coal supply. He estimated that, based upon the actual average decrements in the rates of increase in the coal itself during a period of over thirty years, "which has witnessed the greatest development of commercial and industrial enterprise this country has ever experienced," the total coal raised in the present century would be 41,333 million tons. In the century 2001–2100 he estimated it would be 53,467 million tons; in 2101–2200 it should be 54,169 million tons, and in 2201–2300, 54,203 million tons. Mr. Price Williams added weight to his argument that by the old basis of calculation the probable coal supplies of the future were exaggerated inasmuch that he cited Professor Jevons' estimate of the yield of coal for 1901 as being 331 million tons. The actual output was 220 million tons. He claimed that his figure showed "that the future effect of a continuation of the large decrement in the rate of increase in home consumption of coal will be further to diminish its consumption in terms of per head of population." Professor Jevons, allowing for a 3½ per cent. per annum increase in the output of coal, estimated that the yearly output would reach 680 million tons by the year 1926. Mr. Price Williams calculated, on the other hand, that it would not be reached until 2021.

From the time of the Royal Commission the annual output has steadily increased, and now amounts to nearly

272 million tons (1911), so that the period of stationary output mentioned by the Commission has evidently not yet been reached. Sir William Ramsay created quite a stir throughout the country when he stated, in 1911, that the coal supply would only last another 175 years. He based his statement on the fact that the increase in production was about $3\frac{1}{3}$ million tons per year, and the available quantity of coal 101,000 million tons. He ignored altogether the probability of any coal being worked from the concealed coal-fields mentioned by the last Commission, though in the opinion of other experts many of these coal-fields will in the future assist to a great extent in maintaining the output as the older coal-fields become exhausted.

CHAPTER XXI

COAL RESOURCES OF THE WORLD

It is generally agreed that the available coal resources of the proved coal-fields in this country as arrived at by the Royal Commission on Coal Supplies, 1903–5, viz., 101,000 million tons, is correct. To this may be added the extension of the Yorkshire and Nottingham Coal-field (46,000 million tons), and the Kent Coal-field 10,000 million tons), proved since the sitting of the Commission, making a total of 157,000 million tons. A further addition of 17,635 million tons may be made for the concealed portions of other coal-fields which are considered to be available, bringing the grand total to 174,635 million tons.

Experts have from time to time dealt with the coal resources of other countries, and the figures arrived at are of interest as showing approximately the available coal resources of the world. Sir William Siemens in 1877 estimated the coal resources of several of the chief coal-producing countries, and credited America with 192,000 square miles of coal, which was more than double the area he allotted in combination to the other countries of the world. In 1902 E. Lozé arrived at some very different figures. He calculated that China was the richest coal country in the world, having 232,500 square miles of coal; the United States 200,000 square miles, Canada 65,000 square miles, the United Kingdom 12,500 square miles, Japan 5,000 square miles, France 2,500 square miles, Austria-Hungary 1,800 square miles, and Germany 1,700 square miles. A later estimate of the coal-fields of the United States, and one that can be taken as more correct, gives a total of 496,480 square miles Canada was credited in 1911 by Mr. D. B.

Dowling, of the Geological Survey of Canada, with an area of 29,957 square miles of coal-lands. At the Congress of German Naturalists recently held at Carlsruke, Professor Engler, Director of the Institute of Mineralogy at Berlin, presented a memoir on the formation of coal and mineral oils. In this he gives the total coal reserve of Europe as 700,000 million tons, including the following—

Germany	416,000	million tons.
England	193,000	,, ,,
Russia	40,000	,, ,,
Belgium	20,000	,, ,,
France	19,000	,, ,,
Austria-Hungary . .	17,000	,, ,,

The reserves of the United States he places at 780,000 million tons, and those of the entire earth at 3,000,000 million tons. The German resources in his opinion will suffice for 3,000 years, those of England for 700 years, those of France, Russia, Belgium, and Austria-Hungary for 900 years. To the United States supply he gives a life of 1,700 years. Mr. S. A. Taylor, in his presidential address to the Coal Mining Institute of America, at Pittsburg, in December, 1911, gave some estimates of the present coal supplies, and his figures are interesting when compared with those of Professor Engler. Mr. Taylor estimated that the coal supplies of the United States, exclusive of Alaska, amounted to something over 3,000,000 million tons, and including Alaska, 3,200,000 million tons. Including brown coal and lignites, Germany had 145,000 million tons, Austria-Hungary, France, and Belgium had each from 16,000 million to 17,000 million tons, and Russia about 20,000 million tons. He placed the supply of Canada at 100,000 million tons.

CHAPTER XXII

WASTE OF COAL

WITH the present methods of mining coal, a not inconsiderable percentage of the mineral is lost, and, in a sense, wasted. There are several reasons for this loss of coal, the amount of which varies in different districts and at different collieries. Large areas of coal have to be left intact for the support of the shafts, engine houses, etc., and in many cases for the protection of buildings, railways, canals, and rivers. The amount depends largely upon whether the value of the coal is greater than the damage which would result by its removal, and under present working conditions this source of loss cannot very well be avoided. For some years the flushing system of packing the excavations made in mining the coal has been practised on the continent. This method of stowing the goafs has given every satisfaction, and has rendered possible the working of coal which under ordinary conditions it would have been necessary to leave intact. Briefly, the system consists of carrying sand and water into the mine workings through pipes from the surface; instead of sand, ground pit waste can be used. The mixture is carried through pipes to the workings, and allowed to flow into the goaf. The particular portion of the goaf to be packed is surrounded by a barrier of cloth, similar to brattice cloth, reaching from roof to floor. The sand or fine dirt is held by the cloth, whilst the water drains through, and in a short time the whole space is packed as solid as possible.

Barriers of coal are often left between adjoining collieries, and in many instances these barriers serve no useful purpose, and are unnecessarily large. In past years when colliery undertakings were on a comparatively small scale, a large amount of coal was left for ever in the form of barriers between the different concerns, but the present tendency to take large areas under lease is reducing the loss from this cause. Where old abandoned workings are known to contain large accumulations of water, it is in most cases necessary to leave large barriers for the protection of the present workings, though where arrangements to safely deal with the water can be made, it is often more profitable to tap the old workings by boring, and thus do away with the necessity of a barrier.

Large quantities of water have to be dealt with in working some mines, and the common practice is for each colliery undertaking to provide separate pumping plant to cope with it. Valuable areas of coal are often left between adjoining collieries, due to water difficulties and the disagreements arising as to who should bear the expense of pumping. It has been suggested that central pumping stations should be established in such districts with a view to recovering coal formerly abandoned, or cheapening the cost of pumping. Such an arrangement has been in operation for some years in the South Staffordshire coal-field. Under a scheme known as the South Staffordshire Mines Drainage, powerful pumps have been erected in various parts of the coal-field, the cost of maintenance, etc., of which is borne by the different colliery concerns interested. By this arrangement a large quantity of coal has been rendered available, which would otherwise have been lost.

Where very thick seams are mined, much coal is in some cases unworked for several reasons. Sometimes, from a point of safety, a portion of the coal is left in to form a roof, and the portion so left is in many cases never recovered. Most thick seams really consist of several beds of coal separated from one another by more or less thin bands of dirt. The beds vary in quality and thickness, and very often only the best of the coal is worked, the inferior coal being left in owing to its being unsaleable. In some districts the small coal made in working is left in the mine for the same reason. Better methods of working, combined with improvements in the methods of, and the appliances for, preparing and utilising inferior and small coal, and the higher appreciation of such coal, should go far to put an end to this waste.

It is a matter of regret that much valuable coal in most districts has been lost owing to mismanagement and unskilful working. A mine was opened out and worked in a more or less haphazard manner, and on the least difficulty arising the workings were abandoned and a new mine entered into. Through the want of method in laying out and working mines, much valuable coal has been lost in the past. At the present time, with improved methods of mining, the losses from this source have been considerably reduced, and no doubt in the near future, as the value increases and more perfect methods of mining and preparing the coal are utilised, the losses from this cause will be reduced to a minimum.

Sir William Ramsay, in his presidential address to the British Association in 1911, stated that "it was to the more economical use of coal that we must look in order that our life as a nation might be prolonged."

The approximate annual consumption of coal in the different industries of this country is given in the following table—

Railways	14,664,000 tons
Factories	57,000,000 ,,

Mines	19,500,000	tons
Iron and Steel Industries ..	30,500,000	,,
Export and Bunkering ..	84,024,000	,,
Miscellaneous	730,000	,,
Brickworks, Potteries, Glass-works, etc.	7,000,000	,,
Gas Works	16,500,000	,,
Domestic Purposes and Public Supply	34,500,000	,,

It can be assumed that about 80,000,000 tons of coal are annually used for steam-raising purposes in the United Kingdom, and it is estimated that from 30 to 40 million tons might be saved every year by the substitution of turbine engines in place of engines of the reciprocating type. With the ordinary reciprocating engine the coal consumption is from 4 to 5 lbs. per horse-power per hour, whereas with the steam turbine the coal required is only 1½ to 2 lbs. per horse-power hour, and with gas engines 1 to 1¼ lbs.

A considerable saving in fuel in connection with power production at collieries and works has been effected in recent years in several industrial districts, particularly in the counties of Durham and Northumberland. Several electric power stations have been erected, and electricity for power purposes is available from these central stations to the railways, industries, and corporations of the thickly populated districts between Middlesbrough and Newcastle. At some of the larger stations electricity is generated by turbo-generators driven by steam from coal-fired boilers, but there are also a number of smaller stations operated in conjunction with coke-ovens, the waste gases from which are used under the boilers for steam-raising purposes for the turbines. The many advantages of central power stations over small independent power plants, as proved in a practical manner in the north-eastern counties, should result in their extension to other industrial centres.

The adoption of gas engines using either specially prepared power gas or blast furnace gas, and oil-engines of the Diesel type, is largely on the increase, and will lead to the further displacement of wasteful and inefficient steam-engines.

A further economy in fuel is gradually being effected in coke-making by the substitution of the "by-product" oven in place of the old "beehive." Somewhere about 35,000,000 tons of coal are coked every year, and it is estimated that a saving of four to five million tons could be effected annually if the whole of the coal was coked in "by-product" ovens. The rapid strides made in recent years with this system of coking points to the gradual extinction of the "beehive" oven, and a consequent saving of valuable fuel.

About 35,000,000 tons of coal are consumed every year for domestic purposes, and according to Sir W. Ramsay "we are still utterly wasteful in our consumption of fuel in domestic fires." The adoption of stringent measures by the various civic bodies in different parts of the country with a view to the prevention of the smoke nuisance is a step in the right direction. Improved forms of grates, allowing of better utilisation of fuel; gas fires; electric radiators; and a system of central heating should result in a considerable saving of coal in the future.

THE COAL TRADE

CHAPTER XXIII

HISTORY OF THE COAL TRADE

THERE are no authentic records as to the commencement of the trade in coal, either of this or other countries, but as mentioned previously, the use of fuel was known 2,300 years ago to the ancient Greeks. It is proved beyond doubt that the Romans mined, and made use of coal during their occupation of this country, and it is reasonable to suppose that the natives of Britain at that period knew its value also, and would barter the mineral for other commodities. From the time of the Roman invasion up to the ninth century there is very little to be learnt about the industry in this country. In the Saxon Chronicle of the Abbey of Peterborough, it is stated that about 852, the Abbot let certain lands on condition that among other items he received yearly twelve cart-loads of fossil or pit coal. Records of later date prove that the monks were well aware of the value of coal. In 1180 the Bishop of Durham made a grant of land to a collier for providing coals for the cartsmith at Coundon in Durham. In the reign of Edward III a lease of mines at Whickham and Gateshead, in Durham, was granted by Bishop Bury to Sir Thomas Grey, and the Rector of Whickham for 12 years under a rent of 500 marks. In 1330 the Monastery of Tynemouth leased Elswick Colliery for £5 per annum. Many other monasteries in other parts of the country depended for the major portion of their revenue on the letting and selling of coal-lands as shown by various records dating from the twelfth to the sixteenth century. On the continent, coal was worked about the tenth century in Saxony, and in Westphalia about the end of the twelfth century. At this time a regular export trade in coal was in progress with various French ports from Newcastle, cargoes of corn being brought back. The fear of the coal resources not proving sufficient for home consumption was a matter of serious consideration even in the reign of Edward III, and caused that monarch to prohibit the sending of coal out of the kingdom except to Calais; and again in 1563 a Bill was brought before Parliament to prohibit the export of Newcastle coal. In the same year the export of coal from Scotland was prevented by Act of Parliament.

The first Government tax of coal was made in 1379. In 1421 a duty of 2d. per chaldron was paid to the Crown "on all coals sold to persons not franchised in the Port of Newcastle." (A Newcastle chaldron = 53 cwts.) This duty gradually got into arrears, and payment was demanded by Queen Elizabeth, who in lieu of payment created a duty of 1s. per chaldron. This was enforced until the time of Charles II, when it was settled on his natural son, the Duke of Richmond. In 1799 the Government purchased the tax for an annuity of £19,000, and it was ultimately repealed in 1831, the tax having been in force for nearly four centuries in the neighbourhood of the Tyne. Queen Elizabeth imposed a tax of 5s. per chaldron on coal sent over sea, and James I put on a further sum of 3s. 4d. per chaldron, and in addition 1s. 8d. for coal exported in foreign ships. After the Great Fire of London the Lord Mayor granted an impost of 1s. per chaldron to go towards the rebuilding of the City; this was later increased to 3s. per chaldron. In 1670 an additional tax of 2s. per chaldron was imposed by Parliament for the purpose of rebuilding fifty-two Parish Churches, and in 1677 a further tax of 3s. per chaldron for partly rebuilding St. Paul's Cathedral. These duties for rebuilding churches continued during the reign of Queen Anne. During the eighteenth century duties on coal varied considerably, and at one time rose up to 9s. 4d. per chaldron. These duties, except the City of London tax of 1s. 1d. per ton (up to 1894), have long since been repealed and the export duty on foreign coals was wholly repealed by Act of Parliament as from August 14th, 1850. Previous to this time the duties on coal exported from the United Kingdom amounted to 3s. 4d. per ton in British, and 6s. 8d. in foreign ships; the duty on small coal being 2s. per ton in British, and 4s. per ton in foreign ships. A duty of 1s. per ton was imposed in the early part of 1901 on all coal exported to foreign countries, with a selling price of more than 6s. per ton. This tax was put on by the Government to meet the added expenditure due to the South African War. It was repealed in the Budget of 1907–8, having produced £11,086,649 during the six years it was in existence. Up to 1660 there are no figures as to the amount of coal raised per annum throughout the country, but there is evidence to show that in 1602 the quantity of coal shipped from Newcastle was about 190,000 tons, increasing to 239,000 tons in 1609, and 290,000 tons in 1629. In 1704 the amount shipped reached 473,000 tons, and from the adjoining port of Sunderland 174,000 tons. The two ports together in 1750 shipped 1,193,000 tons. About this time coal was regularly shipped from North Wales and Cumberland to Dublin and other Irish seaports on the East Coast.

Glass-making was one of the first industries which depended on the use of coal. The manufacture of glass in England commenced about 1619 on the banks of the Tyne, and about that time attempts were made to substitute pit coal for charcoal in the manufacture of iron, though it was not until early in the eighteenth century that the substitution was successfully achieved. Up to that time the greater proportion of the coal raised was used for domestic purposes at home, or exported. In 1660 the total production of coal amounted to 2,148,000 tons, and at that time the only method of conveyance was by means of pack-horses, mules, and asses. In 1700 the output was 2,612,000 tons, and the extension of the canal system from this date up to 1800 was the commencement proper of the expansion of the coal trade. In 1750 the annual output had jumped up to 4,774,000 tons. Wooden railways for conveying mineral were introduced about 1632, and these gave way in 1794 to cast-iron rails, which in turn were superseded by malleable iron rails in 1815. Horses and mules were the only means of power for drawing the trucks along the rails, though in 1811 a locomotive engine was at work on the Wylam railway. From 6,205,000 tons in 1770 the output rose to 10,080,000 in 1800, and 15,635,000 in 1816. The Stockton and Darlington railway, opened in 1825, was the first public railway for the conveyance of coal and other minerals, and in the course of a few years many other railways were opened up and down the country. With the introduction of steam and railways there commenced a new era in the coal and other trades. In 1837 it is estimated that the production of coal in the United Kingdom amounted to 23,000,000 tons, and in 1850, 42,000,000 tons. From 1855 accurate Government statistics are available as to the coal production in this country, and the figures given prior to this date must only be taken as approximate. The table given on page 125 gives the total output and amount of coal exported for each year since 1855, and the wonderful expansion in the coal industry can easily be seen.

CHAPTER XXIV

COAL PRODUCTION AND CONSUMPTION OF THE WORLD

COAL, in more or less large quantities, has been proved in almost every part of the globe, and the countries in which it is mined increase in number every year. Many of these, however, at the present time only produce small quantities, though the production of the entire world has now reached a high figure. It is difficult to obtain any accurate figures relating to the production of countries other than the United Kingdom for more than fifty years back, but as it is during this period that coal-mining has developed so wonderfully, it is hardly necessary to go back to an earlier date when considering the subject from a commercial standpoint.

The tremendous expansion of the industry in several countries will be readily understood when it is borne in mind that in 1860 the total world's production was approximately 134,000,000 tons, of which 60 per cent. was raised by the United Kingdom alone. In 1875 the production had more than doubled itself, being nearly 278,000,000 tons. At that time the five chief coal-producing countries, in order of output, were—

Country.	Output.	Percentage of Total.
	Million tons.	
United Kingdom ..	133	48
United States	47	17
Germany	37½	13
France	16½	6
Belgium	15	5½

Only four other countries produced a million tons and over. In 1910 the production had risen to

1,035,000,000 tons, the United States being at the head with an output of nearly 448,000,000, or 43 per cent. of the total; the United Kingdom 264,500,000, or 25 per cent.; Germany 150,500,000, or 14 per cent.; France 37,250,000, or 3½ per cent.; Belgium 23,500,000, or 2¼ per cent. Nine other countries produced a million tons or over. It will be seen that the world's output was nearly eight times greater in 1910 than in 1860, and nearly four times greater as compared with 1875. Comparing the respective outputs of the five principal countries for 1875 and 1910 it appears that the United States has increased its output nearly ten times, whereas the United Kingdom has only doubled its output. Germany has increased hers four times, France a little over double, and Belgium very little, comparatively speaking. The following table shows the production in millions of tons from these countries for the last four available years—

Yrs.	United States.	United Kingdom.	Germany.	France.	Belgium.
1907	429	268	141	35½	23¼
1908	371¼	261½	145¼	36	23
1909	411½	264	146½	36½	23
1910	448	264½	150½	37¼	23½

Each of the above countries, with the exception of the United Kingdom, produced more coal in 1910 than in any other year. The increase in the United States and Germany was nearly 37,000,000 and 4,000,000 tons respectively, above that of the previous year. The output of the United Kingdom and Belgium was almost stationary; in fact the figures for the latter country show little variation since 1907. In 1899 the production of the United States exceeded that of the United Kingdom for the first time. Since that year the former country has held the position of premier coal-producing country of the world, and the output at the present time exceeds that of this country by also 70 per cent.

A few figures with reference to the production in British Colonies and Possessions are of interest if only to show the increase that has taken place in the last twenty-five years.

The following table shows the output of coal in the principal parts of the British Empire, from 1907 to 1910, in millions of tons—

Yrs.	India.	Australia.	New Zealand.	Canada.	South Africa.
1907	11¼	9½	1¾	9¼	4½
1908	12¾	10	1¾	9¾	5
1909	11¾	8	2	9¼	5½
1910	12	9¾	2¼	11½	6½

The above figures prove conclusively that the coal industry in our chief possessions is in a very healthy condition, and a certain measure of satisfaction is derived from the fact that whilst the United Kingdom no longer heads the list as the greatest coal-producing country in the world, she and her dependencies produce between them at the present time nearly one-third of the entire coal output of the world.

A larger number of persons are employed in coal-mining in this country than in any other, as shown in the table below—

Country.	Number of Persons Employed.[1]
United Kingdom	1,049,407
United States	725,030
Germany	690,668
France	196,783
Belgium	143,902

[1] The figures for 1910 are the latest available.

In comparing these figures with one another, and with the outputs of the respective countries, it must be remembered that there are included in the table all persons engaged underground in the working and winning of the coal, and those engaged on the surface in cleaning and sorting, and other duties connected with a mine. The output per person employed works out in the five chief countries as follows (1910)—

United States	617	tons.
United Kingdom	257	,,
Germany	239	,,
France	195	,,
Belgium	162	,,

The reason for the great difference in the production per person employed is accounted for by the fact that the majority of the mines in the United States are of moderate thickness, free from dirt, lie close to the surface, and are easily worked; whereas in the other countries the thickest and cleanest mines in many districts are practically exhausted, and the output is obtained from thin and inferior mines, often lying at a great depth. Naturally the output per man from a thin mine is less than that from one of a reasonable thickness, and this is further reduced if the mine lies at a considerable depth, as the difficulties are greater, and a very large number of men are required to keep the workings in proper order. The figures for the European countries are also adversely affected by the compulsory restriction of working hours underground. A considerable decrease in the yearly output per person employed has taken place in the United Kingdom for some years, dropping from 314 tons in 1886 to 292 tons in 1907, 257 tons in 1910, and 254 tons in 1911. The year 1910 was the first in which the Eight Hours Act applied, and there were also numerous strikes and stoppages in different districts, but taking everything into consideration, it appears that the increase in the number of persons employed is more rapid than the increase in the quantity of coal produced.

The output of coal can be considered from yet another point, namely, per head of population, and under this heading the United Kingdom beats every other country, as will be seen from the table below (1910)—

Country.	Tons per Head of Population.
United Kingdom	5·89
United States	4·86
Belgium	3·13
Germany	2·32
France	0·95

The quantity of coal consumed in the principal countries of the world for the last few years is given below in millions of tons. The consumption is arrived at by adding the imports to the home production and deducting the exports—

Country.	1907.	1908.	1909.	1910.
United States ..	418	361	399	434¾
United Kingdom ..	182½	176¼	177¾	180
Germany..	128½	129¾	129½	130¼
France	52¾	53	54¼	54¾
Russia	29½	30	28½	27½
Austria-Hungary ..	24½	25	25¼	24½
Belgium	22¾	22½	22½	23¾

From the above figures it would appear that more than twice as much coal is consumed in the United States as in this country, or, in other words, for every single ton that is used here, $2\frac{2}{5}$ tons are used in the United States. For 1910, the consumption in the latter country was almost equal to that of all the other countries in the table combined.

Another means of comparison worthy of notice is that based on the population of the countries under consideration. The United States again heads the list with a consumption of 4·72 tons per head, the United Kingdom comes next with 4·01, followed by Belgium with 3·17, Germany 2·01, and France 1·4. The two last-named show very low figures compared with the others, but these may be accounted for owing to the large amount of peat, wood, and lignite that is used for domestic and other purposes.

Whilst considering the question of consumption, it is of interest to note that more than one-quarter of the home consumption of this country is used by the three great industries: iron-making, gas-producing, and railways. 20,500,000 tons of coal are consumed in the production of pig iron; 15,000,000 tons in gas-making; and 12,500,000 tons for locomotive purposes, or a total of 48,000,000 tons out of 180,000,000.

PRODUCTION AND EXPORTS OF COAL OF THE UNITED KINGDOM

Year.	Total Production. Tons.	Exported. Tons.
1855	64,453,070	4,977,000
1860	83,208,581	7,413,000
1865	98,150,587	9,171,000
1870	110,431,192	11,485,000
1875	133,306,485	14,733,000
1876	134,125,166	15,556,000
1877	134,179,968	15,964,000
1878	132,612,063	14,321,000
1879	133,720,393	16,273,000
1880	146,969,409	19,101,000
1881	154,184,300	22,932,000
1882	156,499,977	23,739,000
1883	163,737,327	26,602,000
1884	160,757,779	26,009,000
1885	159,351,418	28,104,000
1886	157,518,482	30,362,000
1887	162,119,812	31,717,000
1888	169,935,219	34,570,000
1889	176,916,724	37,138,000
1890	181,614,288	38,660,000
1891	185,479,126	40,121,000
1892	181,786,871	39,381,000
1893	164,325,795	37,488,000
1894	188,277,525	42,687,000
1895	189,652,562	42,907,000
1896	195,351,951	44,587,000
1897	202,119,196	48,128,000
1898	202,042,243	48,267,000
1899	220,085,368	55,810,000
1900	225,170,163	58,405,000
1901	219,037,240	57,783,000
1902	227,084,871	60,400,000
1903	230,324,295	63,805,000
1904	232,411,784	65,822,000
1905	236,111,150	67,161,000
1906	251,050,809	76,788,000
1907	267,812,852	85,188,000
1908	261,512,214	85,306,000
1909	263,758,562	86,037,000
1910	264,417,588	84,542,000
1911	271,878,124	86,295,000

The Average Price of Coal per ton at the Pit, Total Value and Average Price per Ton in the London Market from 1886

Year.	Average Price at the Pit. United Kingdom.	Total Value.	Average Price in London Market.
	s. d.	£	s. d.
1886	4 10	38,146,000	14 9
1887	4 9¾	39,093,000	14 10
1888	5 0¾	42,971,000	14 10
1889	6 4¼	56,175,000	16 6
1890	8 3	74,954,000	18 7
1891	8 0	74,100,000	18 3
1892	7 3¼	66,650,000	17 7
1893	6 9½	55,810,000	19 0
1894	6 8	62,730,000	16 4
1895	6 0½	57,231,000	14 7
1896	5 10¼	57,190,000	14 5
1897	5 11	59,740,000	15 4
1898	6 4¼	64,169,000	16 2
1899	7 7	83,481,000	18 2
1900	10 9¾	121,653,000	22 9
1901	9 4¼	102,487,000	19 5
1902	8 2¾	93,521,000	18 1
1903	7 8	88,228,000	15 10
1904	7 2½	83,852,000	15 0
1905	6 11½	82,039,000	15 6
1906	7 3½	91,529,000	15 9
1907	9 0	120,527,000	19 9
1908	8 11	116,599,000	17 6
1909	8 0¾	106,275,000	16 11
1910	8 2¼	108,378,000	16 3

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