VERSITY OF ILLINOIS BULLETIN

ISSUED WEEKLY

l. XIII JUNE 26, 1916 No. 43

red as second-class matter Dec. 11, 1912, at the Post Office at Urbana, Ill., under the Act of Aug. 24, 1912.

DRY PREPARATION OF BITUMINOUS COAL AT ILLINOIS MINES

BY

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BULLETIN No. 88

ENGINEERING EXPERIMENT STA

PUBLISHED BY THE UNIVERSITY OF ILLINOIS, URBANA

PRICE: SEVENTY CENTS

EUROPEAN AGENT

CHAPMAN & HALL, LTD., LONDON

UNIVERSITY OF ILLINOIS
ENGINEERING EXPERIMENT STATION

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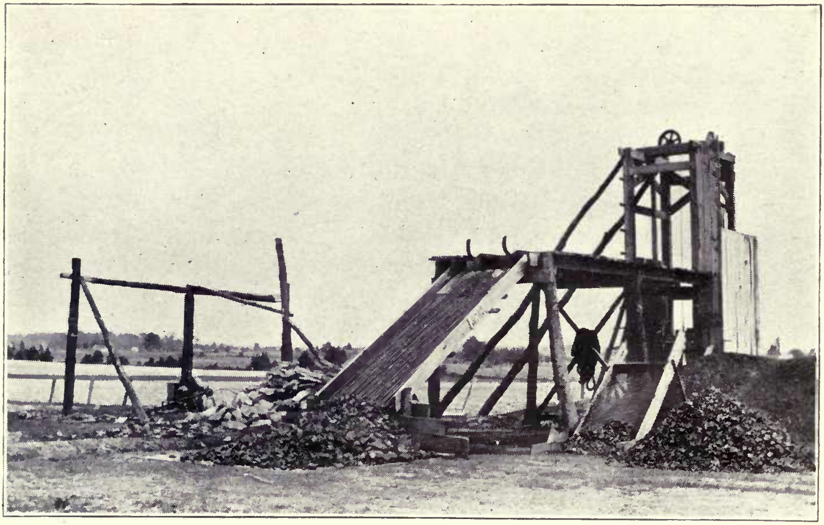

(Photograph by E. C. Lee.)

Fig. 1. Horse Whim at a Local Mine.

Fig. 2. A Modern Steel Tipple with Concrete Rescreener.

DRY PREPARATION OF BITUMINOUS COAL AT ILLINOIS MINES.

INTRODUCTION.

Coal, as it comes from the mine, is not usually in condition for direct delivery to the consumer, but must be first subjected to treatment or preparation in order to remove impurities and to secure the sizes suitable for the different markets.

"Preparation" of coal is understood generally to include that set of operations which begins after the coal is delivered to the mine tipple, and ends when the loaded railroad cars at the mine are weighed and ready for shipment. It is, however, often difficult to state the exact points at which preparation of coal begins and ends. On the one hand, preparation encroaches on the domain of the miner because much of the impurity may be separated from the coal at the face underground and because of the natural production there of various sizes of coal. On the other hand, coal is subjected to breakage and inspection after being shipped to market, and therefore repreparation may be necessary after delivery and before consumption. Thus, preparation may enter the province of the mechanical or fuel engineer.

In 1909 a committee of the International Railway Fuel Association, appointed to inquire into the difficulties encountered in producing clean coal, reported the causes for poor coal as follows:*

(1) The physical conditions of the seam, mine, and mine equipment.

(2) The class of labor that produces and handles the coal.

(3) The conditions surrounding the sale of the coal, including the prices obtained.

Any or all of these conditions may seriously affect the preparation required by Illinois coal.

In this bulletin the mining and marketing of the coal are discussed from the standpoints of contained impurities and breakage only as these affect preparation in the tipple and auxiliary buildings. Preparation of coal may be divided into two separate and distinct processes: (1) Wet preparation, called coal washing or jigging. (2) Dry preparation, including weighing, screening, dry cleaning, and loading. The first division of the subject has been covered by F. C. Lincoln in Bulletin No. 69 of the Engineering Experiment Station of the University of Illinois, under the title "Coal Washing in Illinois," and will not be considered here.

In the early days of coal preparation in the anthracite regions of Pennsylvania coal was frequently washed or rinsed with a spray of water in order to make easier the detection of intermixed refuse and to give it a better market appearance. Afterwards, cleaning of

*Proceedings of the First Annual Convention, 1909, p. 13.

coal by jigging was introduced and called coal washing, and thus the same term was applied to two different processes of coal preparation, giving rise to some confusion. Since in this state, in at least one instance, coal has been rinsed by a spray of water before hand picking, this process will be called rinsing and not washing, in order to avoid confusion with true coal washing or jigging.

The subject of dry preparation has been divided into two parts, the first of which considers the development, the standard methods, and the products of present practice and is treated in this bulletin. The second part, which will be an engineering discussion of the machinery, appliances, and costs of preparation, will be covered by future work.

The subject matter of the present bulletin is subdivided as follows:

Chapter I. Evolution of present preparation practice.

Chapter II. Standard types of Illinois coal mine tipples or preparation plants.

Chapter III. Impurities and breakage of the coal, making preparation necessary.

Chapter IV. Sizing and sizes of Illinois coal.

This bulletin is not intended as a reference for all the machinery and appliances used in dry coal preparation in this state, but merely outlines the standard practice; therefore the inclusion and description of certain appliances do not imply preferences, but rather indicate that data were available concerning them, that they illustrate the principle of a process, or that they are in common use.

Data for this bulletin were gathered by an inspection of about fifty mine tipples in Illinois during the summer of 1914, followed by visits or letters to the offices of many of the producing coal companies in this field. Access was also had to the data of the Illinois Co-operative Coal Mining Investigation.

The author wishes to thank Prof. H. H. Stoek, in charge of the Department of Mining Engineering, of the University of Illinois, without whose cooperation the bulletin could not have been written. Various engineering firms, including the Allen and Garcia Company, The Link Belt Company, Roberts and Schaefer Company, and the Wisconsin Bridge and Iron Company, all of Chicago, aided freely by suggestions and by drawings. Acknowledgment is due the various mining companies visited for their interest and the uniformly courteous treatment received from their staffs.

CHAPTER I.

Evolution of Present Preparation Practice.

DEVELOPMENT OF COAL PREPARATION.

During the year ended June 30, 1915,* the mines of Illinois produced 57,601,694 short tons of coal, valued at the mines at about $1.14 per ton or at a total value of $65,665,931.16. Of this total about 4,000,000 tons were treated by washing, while 53,600,000 tons were prepared to a greater or less degree in the dry state, principally by screening or sizing, and by picking. The run of mine coal produced amounted to more than 10,000,000 tons or 17.3 per cent of the total; lump coal amounted to 19,200,000 tons or 33.3 per cent; egg coal, 8,700,000 tons or 15.1 per cent; nut coal, 3,800,000 tons or 6.7 per cent; and pea, screenings, and slack coal, 15,900,000 tons or 27.6 per cent. The exact significance of these terms for designating sizes, is explained fully on page 103. Briefly, "run of mine" coal refers to coal shipped as it is mined, all sizes being mixed together. Lump coal refers to the largest sizes of coal, from which the fines have been taken by screening; thus, lump is made over screens ranging in size from a ¾-inch round hole up to 8-inch round hole. If the coarser sizes of screens, with 5-inch or 6-inch holes are used, the coal is passed over another set of screens having perhaps 3-inch round holes, the oversize produced being called egg coal. Nut coal refers usually to sizes made between 1-inch and 3-inch round hole screens. Pea coal is somewhat smaller, generally below 1 inch, and having only the finest sizes, say, under 5/16 inch round or square hole taken out. The smallest sizes of coal remaining after these processes are performed are usually called slack. The term screenings usually refers to sizes of coal passing 2-inch or 1¼-inch round hole screens from which no smaller sizes have been taken. The washing preparation in Illinois is confined entirely to coal under three inches in size.

The growth of the coal mining industry in Illinois, and the increasing importance of coal preparation are shown in Fig. 3, which is based on production figures compiled from the annual Illinois coal reports from 1882 to 1915. It should be remembered in considering these figures that during the earlier years a larger percentage than at present of the total tonnage came from longwall mines, which make less fine coal than the pillar and room mines.

In most bituminous coal fields the first seams mined were thick and contained the best quality of coal with a minimum of impurities. At first only lump coal was considered of value. Later it became necessary to mine relatively impure seams or thinner seams which, owing to the admixture of roof and floor impurities with the smaller amount of clean coal, might produce a coal which is relatively impure and which in either case must be cleaned and otherwise prepared for the market. Consumers also become more exacting as to size and

*Illinois Coal Report, 1915.

quality of the fuel and the general increasing value per ton permits more careful preparation of the impure coal and of the smaller sizes.

Germany, forced to use her lower grades of coal and to mine the thinner seams, led the way by introducing bituminous coal preparation

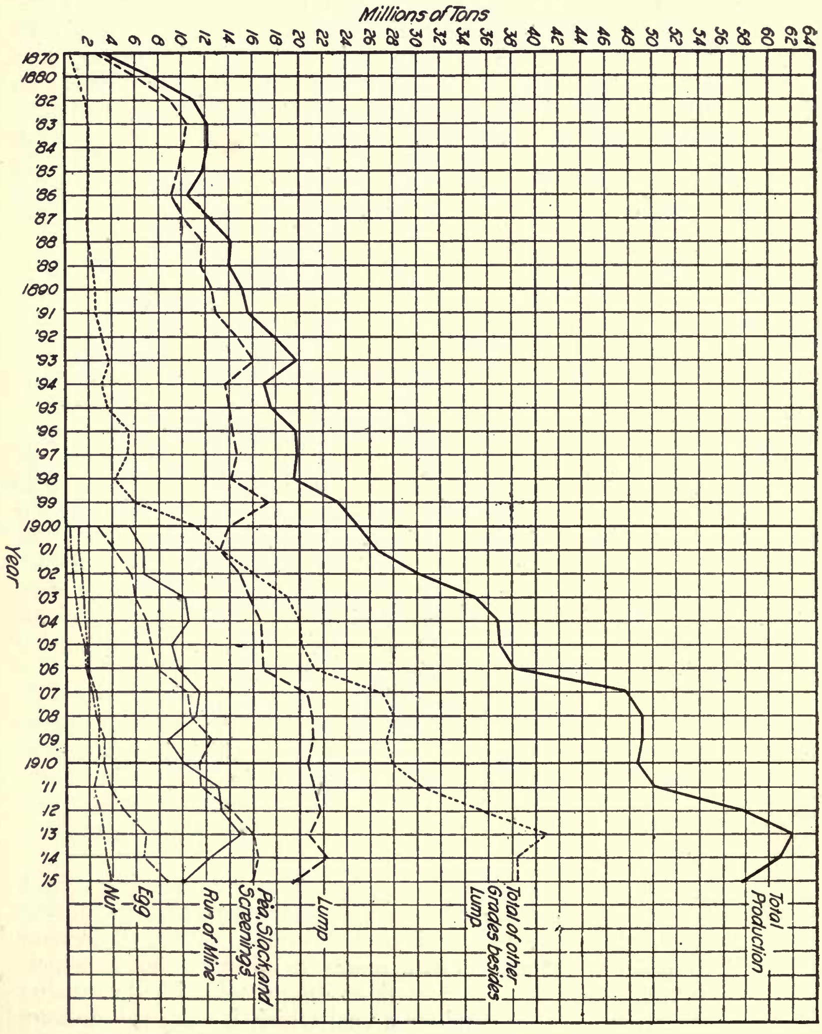

FIG. 3. YEARLY PRODUCTION OF DIFFERENT SIZES OF COAL IN ILLINOIS (1880-1915).

in the decade, 1870-1880. France and England followed as like pressure was felt, until by 1895 preparation by sizing and cleaning was highly developed in these countries. One German colliery at the present time prepares twenty sizes and grades of bituminous coal. Belgium divides her small production into five degrees of quality and into twelve standard sizes. In general, European technique in bituminous coal preparation is more advanced than in this country.

In America the close sizing and extensive preparation of Pennsylvania anthracite have been notable for nearly half a century. Probably the first bituminous region in the United States in which close attention was given to preparation was the Fairmount region in West Virginia, in which sorting and cleaning had become general by 1900.

In Illinois close preparation has been developed although scarcely ½ per cent of the coal resources have been extracted. The attention given to careful preparation has been increasing since the early nineties, the progress during the past seven years having been especially marked. The causes for this development are:

(1) The introduction of state laws regulating the weighing of coal and the basis of payment to the miner for his coal.

(2) The various struggles and consequent agreements between operators and miners dealing chiefly with payment for mining and with the cleaning of coal.

(3) The demand of the consumers, who, having become educated by the publicity given during the past few years to the purchasing of coal on specifications, are no longer content with the grades of coal they received a decade ago.

(4) The campaigns waged by the cities to abate the smoke nuisance.

(5) The excessive competition among producers, caused not only by the operation of too many mines and the consequent desire to keep these in constant operation; but also by the maintenance of highly organized selling departments, which have a tendency to introduce new sizes and trade names for coal.

(6) The general introduction of improved machinery used in coal mine tipples to prevent breakage and facilitate preparation.

HISTORICAL DEVELOPMENT OF ILLINOIS PREPARATION PRACTICE.

Early History and Methods.—Before the general advent of railroads in the middle of the 19th century coal from Illinois mines was transported largely by boat on the Illinois and Mississippi rivers. Gordon Buchanan* states that the early railroads hauled coal into Chicago with engines that burned wood. A large proportion of the tonnage in these early days came from the northern or longwall districts in which the proportion of large clean lump or chunk coal is high. This coal requires little preparation. The earlier U. S. Census Reports, particularly those of 1870 and 1880, give statistical information concerning Illinois production, but, since little weighing was done at

*Black Diamond, May 17, 1913, p. 16.

the mines at that time, such information probably is not so accurate as that contained in later statistical records.

Little information concerning the preparation of Illinois coals prior to 1882 is available. The second biennial report of the Illinois Bureau of Labor Statistics, published in 1882, contains the first annual report on the coal industry of the state, although the first biennial report, published in 1880, contains the reports of coal mine inspectors to the governor of the state for the years 1879 and 1880. From 1882 until 1911 the Bureau issued each year an annual report or compilation of statistics on the coal mining industry of the state. After the first

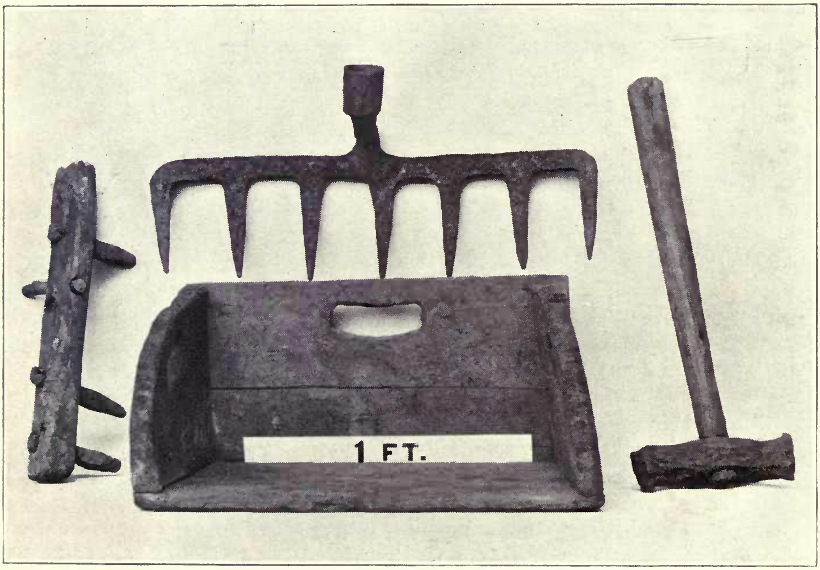

Fig. 4. The Miner's Rake (Wooden and Iron). Pan and Sledge. Museum, Department of Mining Engineering, University of Illinois.

two years it became the duty of the various mine inspectors to gather data, which was in turn compiled by the secretary of the Bureau. Since 1911 these annual coal reports have been issued by the State Mining Board.

The expression "coal is coal" might appropriately be used in speaking of the early periods of mining in Illinois, since the practice of selling coal as brought to the surface with no attempt at preparation before shipment was generally followed. A rough separation of the fines from the lump coal took place underground at the face and during the period of loading the coal into the mine cars. Instead of the customary miner's shovel of today the coal was loaded with a tined fork, having spaces between the tines of from ¾ inch to 1½ inches. This allowed the finer coal to pass through the fork, after which it was thrown back into the gob and left in the mine. While such a fork is still used at coke ovens to free the coarse coke from the "breeze" during the loading process and is also used by retail coal dealers for the purpose of delivering clean coarse coal when necessary, it has passed out of use in the preparation of Illinois coals, excepting in some of the small local and coöperative mines.

The common round hand screen, or coal miner's riddle, with square mesh wire cloth, having perforations varying from ½ inch to 2 inches in size, was also used by the loaders underground for screening out the smaller coal which was to be left in the mine and for carrying the coarser coal to the mine car.

The rake and pan method of loading coal was formerly in common use in Illinois mines.* After the largest lumps of coal had been loaded into the mine car by hand, the remainder was raked onto an iron or wooden plate or pan and transferred to the mine car, while the fine coal and dirt not gathered by the rake were left in the mine. "The pan was in fact a hand scoop made of sheet wrought iron or steel, the front end being flat and open, the sides being usually curved outward and upward with handles affixed for lifting and carrying; they were also made with straight sides. The back of the pan was straight up. The conditions under which the pan was used varied its dimensions. The purpose of the pan was to have only clean lump coal carried to the pit box or car; and whether this coal was loaded on the pan by hand or scraped on by a rake or fork, the end attained was the same. In some parts a penalty was attached to any person found loading coal with a shovel."†

Fig. 4, is a photograph of an old pan, part of a wooden rake, an iron rake, and a sledge recently found in abandoned workings in the Belleville district, and presented to the Mining Museum of the University of Illinois. These implements were practically out of use by 1884. They were, however, used in a few mines until the strike of 1897, after which their use was discontinued.

Another common method of preparation underground was by the use of "grills" or wooden bar screens. These were wooden bars, spaced ½ inch to 2 inches apart, nailed into a wooden framework, and set up at an angle of about 45 degrees. The coal, before being loaded was shoveled against these bars. The finer coal which passed through the bars was left in the mines and the oversize was rehandled and loaded. Similar practice may be seen with the common gravel screen of today.

The forms of underground preparation described made unnecessary the loading and hoisting of a product then considered useless; namely, coal equivalent in size to the screenings of today. Although a limited amount was utilized in the eighties, screenings were not even

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*Report of Ill. Bureau of Labor Statistics, 1897, p. xxxv.
†W. L. Morgan, Ex-State Mine Inspector. Personal communication.

considered as a coal in the tonnage reports of the State Bureau of Labor Statistics until 1891, and in some districts it was not until 1900 that they became a commercial product. The use of screenings began to assume important proportions about 1895. The total estimated production of lump coal for the period from the beginning of the industry (about 1830) to 1895 is 273,000,000 tons. The first report including screenings in the tonnage (1891) showed that, considering the state as a whole, 17.24 per cent of the coal produced was screenings. If this average be accepted for the preceding years there was probably a total of more than 57,000,000 tons of this small coal, which was either mined and left underground to be buried beneath the falling mine roof and consumed in gob fires or, if separated on the surface, was hauled to dump piles and there destroyed by spontaneous combustion.

When the mines grew, when steam hoists and improved systems of underground haulage were generally introduced, and when labor cost underground and the value of fine coal or screenings increased, the coal was hoisted as mined and prepared in the mine surface buildings or tipple. The introduction and use of the automatic stoker with fine hole or chain grates and other special grates which made possible the generation of power from the finer sizes of coal were important factors in the increase in use and value of these small sizes of coal. Such devices were introduced into Illinois about 1890 and during the succeeding ten years their use in large power plants became general. Then the consumer with the average steam plant realized the possible saving through their use in connection with cheap coal screenings, and within a few years these stokers became common. Now, there is a constant demand for the once despised waste product, coal mine screenings.

Weighing Practice.—Formerly payment to the miner and operator alike was made almost wholly on the basis of the bushel, there being usually 25 to 28 bushels to the ton. This standard is still used at some of the country "banks" or local mines. In some places an arbitrary standard was based on the volume of the box or contents of the mine car. An early report* records prices paid to the miner based not only on the short ton of 2,000 lb., but also on tons of 2,050 lb., 2,100 lb., 2,200 lb., and 2,250 lb.

By 1880 some of the larger mines had adopted weight by scales as a basis of payment, such weights being taken by company men, while others still adhered to the volume basis. This naturally led to considerable trouble between operator and miner, which, together with the difficulty experienced by the state in gathering adequate statistics concerning tonnage, led to the passage, in 1883, of a law governing the weighing of coal at the mines. (Ill. L. 1883, p. 113.) The act required that all coal companies in the state, shipping coal by rail or by water, should provide standard track scales at the

*Report of Ill. Bureau of Labor Statistics, 1885, p. xxvii.

mines and should weigh all coal hoisted before or at the time of loading for shipment. The weights so determined formed the basis upon which the wages of the miners were computed. The miners could employ their own check weighman who should be an employee at the mine. The act seems to have referred to lump coal only, since screenings were not considered salable coal. The act also declared that all contracts for mining coal not based on the stipulated requirements should be null and void. This was the first attempt in Illinois to regulate preparation practice.

Although most of the shipping mines complied with the act, it was immediately attacked in the courts, and though held constitutional, it was declared to apply only to mines at which weight was accepted as a basis of payment (Reinecke v. People, 15A, 241). In the case of Jones v. People (110 Ill. Rep. p. 590) the law was declared to have no application if the wages of miners were computed on a basis other than that of weighing; namely, on the basis of volume; and it was not held to require miners' wages to be based on the weight of coal mined.

The law was amended (L. 1885, p. 221) by the addition of a provision requiring shipping mines to keep their weights on record for inspection by miners, inspectors, and other interested persons. The law as amended did not require the check weighman of the miners to be an employee at the mine in question, but stipulated that both the company's weighman and miners' check weighman must make affidavit faithfully to weigh and record the coal. In the test case of Millet v. People (Ill. Rep. 117, p. 294) the court decided that if an operator bought and sold coal by weight, the law compelled him to keep reliable scales for that purpose, but it did not oblige him to make contracts for coal on a basis of weight. Moreover, it was declared that the requirement that operators should keep a record of weights for public information was the taking of private property for public use without a provision of just compensation and therefore was unconstitutional.

A bill passed in the state (L. 1887, p. 235) repealed the former laws of 1883 and 1885 and substituted a new law of different wording but having about the same practical effect. It provided, "that at all mines, where miners are paid by weight, a standard scale shall be provided for the weighing of all coal hoisted or delivered." According to this law the check weighman should be an employee of the operators of the mine, and all coal delivered by the miner should be weighed and the records kept open for the inspection of the miner and other interested persons. This act was held unconstitutional (Harding v. People, Ill. Rep. 160, p. 459) because it singled out an especial class of mines, and interfered with the right of the operators and miners to contract among themselves.

A new law, designed to correct the weaknesses of the old one, was passed by the legislature in 1899 (L. 1899, p. 301), and revised in 1911 (Ill. Stat. Ann. Ch. 93, 7501). Its provisions are substantially as follows: Operators at mines where miners are paid by weight of their output shall provide accurate scales for weighing such coal and the record so obtained shall be open to inspection by interested parties; a sworn weighman shall be provided by the company; and the miners may provide a sworn check weighman. This privilege is taken advantage of uniformly throughout the state, and there are today never less than two men in the weighroom of the mine tipple. As a result all contentions as to false weights, so prominent in the past, have disappeared.

At the present time, as a rule, at mines where the pit cars hold 1½ tons or more, the weight is read to the nearest 100 lb.; that is, the weighman and check weighman "give and take" on 50 lb. If the load weighs 4,135 lb., the miner is credited with 4,100 lb., and the company gains the extra 35 lb.; if the weight is 4,165 lb., the miner is credited with 4,200 lb. In mines with cars holding less than 3,000 lb., the weight is generally read to the nearest 50 lb., with "give and take" on 25 lb. The fact that at some mines three cars per minute are weighed, checked, and dumped from the tipple weigh box, makes it evident that considerable care and engineering skill have been devoted to bring tipple weighing to a degree which is nearly perfection. The beam scales formerly used have in many cases been replaced by the self-indicating dial scales, and in some of the newer tipples by automatic self-recording weighing devices. Thus, a just and equitable system of weighing, giving satisfaction to operator and miner alike, has been evolved.

Lump Coal vs. Run of Mine Payment.—During the same period in which the troubles over weighing occurred, a still sharper fight was being waged with reference to the quantity and kind of coal for which the miner should be paid. It had become customary at some of the larger mines to hoist all the coal mined, and to roughly clean and prepare it above ground before loading into railroad cars.

The common method of procedure then followed in Illinois, and still followed in Indiana, Michigan, Western Pennsylvania, and several other coal producing states, was to dump the coal from the mine car over a bar screen in the tipple. This bar screen consisted of a row of iron bars about ⅝ inch wide and 2 inches thick, set on edge with a space of about one inch between the individual bars, the whole rack being possibly 6 feet wide and from 8 to 15 feet long, and set at an angle of from 26 to 45 degrees. The oversize from the bar screen, or coal too coarse to pass between the bars, was weighed and sold as lump coal and the miner was paid, if by weight, according to the lump coal so produced. The finer coal passing through the screen bars, called slack or waste, was usually given away or hauled to a dump in the neighborhood. There was no market for this product since it could not be burned on the type of furnace grates then in use.

In the early eighties attempts were made to recover a part of these screenings. At a number of mines installations were made at the tipple by means of which the screenings were elevated and rescreened in a revolving screen, having holes about ¾ inch in diameter. The material passing through this screen was called slack and was discarded. The oversize, varying from about ¾ inch to 1 inch more or less in diameter, was called nut coal. This coal was in considerable demand, especially as a domestic coal and was used by miners and by the public if the mines were located in the neighborhood of a city. The records show that by 1887 most of the large mines in the central part of the state were equipped to rescreen the small coal, and the value of this rescreened, or nut coal, as noted in several contracts made between miners and operators, was about one-third that of the lump. The proportion of nut coal so recovered to the lump varied with the districts, the method of mining, and the size of screen used, but was estimated as 13 per cent of the lump.* This treatment of coal, making lump as oversize on the bar screen, nut as oversize, and slack as undersize in the revolving screen, probably constituted the fullest dry preparation that coal received in 1887, excepting in one or two cases in which four sizes were made, two from the lump and two from the screenings, to meet the demand of domestic city trade. By 1891 several of the city mines were making three distinct sizes of screenings. The largest, called nut, was above 1 inch or ¾ inch in size; the medium size, called pea, below nut and above ½ inch or ¼ inch, and the slack below this size was thrown away.

T. B. Comstock,† writing in 1887 on coal mining in Illinois, said that Pennsylvania methods were followed blindly; that market rating of coals was based on crude trials in unskilled hands; and that one of the subjects just beginning to attract attention was the sizing of coal for market. He noted that assorted products from one or two mining plants in the state threatened to revolutionize the trade. At these plants small portable crushers and screens were placed at the car door to prepare the coal before loading, but probably the extra cost was not covered by the increased profit. Commenting on the fact that washing and other methods of preparation received little attention, chiefly because consumers did not recognize the enhanced values of prepared coal, he prophesied, "The time will come when these advantages will appear as necessities."

At a few mines in the state miners were paid for gross weight of coal hoisted, an allowance agreed upon being made for slack. For instance, at Oglesby, in the longwall field, where conditions favored a minimum of slack, 36,000 lb. gross of coal were required to obtain payment on 30,000 lb. of lump, an allowance of 16⅔ per cent being made for slack. At Mt. Olive, in the central field, 20 lb. of coal were deducted for slack from each 100 lb. mined, an allowance of 20 per cent. However, these were isolated instances, as four-fifths of the product of the state was screened, the oversize only being weighed and paid for. The thought that they did not share in the revenue from this

*Report of Ill. Bureau of Labor Statistics, 1888, p. 331.
†Eng. and Min. Jour., Vol. 44, p. 24.

merchantable nut coal was a source of considerable grievance among the miners, but it was overshadowed by a greater one; namely, the lack of uniformity in width of opening and area among the bar screens at the various mines.

In 1885 the secretary of the Illinois Miners' Protective Association issued a report, part of which dealt with the miners' grievances against the lack of uniformity of weighing, screening, and preparing coal for the market, and in 1886, the report of the Illinois Bureau of Labor Statistics (p. 549) dealt at length with the question of screens. The report, of which the following is a condensed table, covered screening practice at 218 mines in the state.

TABLE 1.

SCREENING PRACTICE IN ILLINOIS IN 1886.

Number of Mines	Tons Screened Lump Coal Produced	Space Between Main Screen Bars	Tons of Nut Produced by Second Screen (Estimated)	Tons Total Product Lump and Nut	Per Cent of Nut Coal (Not Paid for by Operators)
12	175,425	½"- ¾"	20,579	196,004	10.0
98	4,352,252	⅞"	516,631	4,868,883	10.6
23	437,074	1 "	62,972	500,046	12.6
10	354,305	1⅛"	60,356	414,661	14.6
44	1,198,739	1¼"	224,417	1,423,156	15.6
25	665,533	1½"-1⅞"	167,220	832,753	20.1
6	175,409	2"-2½"	49,705	225,114	22.1
Total 218	7,358,737		1,101,880	8,460,617	13.0

This table represents 80 per cent of the production at that time, based on lump coal. By far the most common width of bar space was ⅞ inch, 62 per cent of the product being so prepared; in fact, this width of bar space was recognized as a standard in several parts of the state. The percentage of coal passing such a bar screen is about equal in amount to that passing the 1¼-inch round hole screen common today, except that the shapes of the larger particles of coal are of course different. This common screen, however, was overshadowed by those with 2-inch and even 2½-inch spaces. Such a screen must have allowed a considerable proportion of the miner's coal to pass through, probably an amount equivalent to that passing a 3-inch or even a 4-inch round hole screen. The average area of screen used in Illinois was about 60 sq. ft., usually 5 ft. wide and 12 ft. long, but certain screens were at least 16 ft. long and some had an area as great as 130 sq. ft.

This condition existed generally throughout the country. At 146 mines,* taken at random from bituminous mines in the United States, the screens used were mostly of ⅞-inch or 1¼-inch bar, though

*Mineral Industry, Vol. 1, 1892, p. 80.

some had spaces as large as 2½ inches. Forty-four of these mines produced and paid on a run of mine basis, while 102 were operated on the screened lump payment basis.

The cleanness of separation of lump and screenings was further affected by the slope of the screens. If the screens were set at a low angle the coal passed slowly over them,—in some cases having to be pulled over, and thus a maximum of coal was sent into the nut or through sizes. One or two strikes were caused because chains or logs were hung loosely close above the bar screens. According to the operators, the lump coal sliding down the bar screen with considerable force was turned over and freed from adhering dust; according to the miners, the lump coal was broken by such devices, and passed through the screen into the nut sizes for which they received no pay.

Such lack of uniformity in the preparation of coal led the miners to demand that screens be made of uniform size and opening, and that payment be made for nut coal produced. They claimed that the average realization to the operator for nut coal was five cents per ton of lump made. Their grievances on these subjects were: (a) The practice of changing screen openings from time to time. (b) Screens of largest size were found where they were least justified by market conditions. (c) The operator using a screen of only sufficient size to clean his coal could not compete with one using a screen which passed enough nut to pay his expenses. (d) The percentage of coal going through the screens was larger than that necessary to clean it. (e) The operators encouraged the use of an excessive amount of powder in order that they might receive the benefit of the large percentage of small sizes made by it, and an extra profit on the excess powder. (f) The operators tried to force the loading of the fine coal for which the miners received no pay.

The operators claimed: (a) Coal had to be screened to get a merchantable grade of lump. (b) Fair miners' wages were based on the percentage of lump and nut sold, even though the miners were nominally paid for lump only. (c) Since different degrees of friability of coals, and different methods of mining, tended to produce a variation in the percentage of finer sizes, a variation in the size of screens was necessary to make a uniform coal for a common market. For instance, coal shot off the solid as in the central part of the state made more fines than that mined longwall and wedged down as in the northern fields. (d) It was necessary to load out the fine coal to prevent gob fires.

Three remedies were proposed: (a) To use throughout the state a uniform bar screen of not more than ⅞-inch space. (b) To pay miners pro rata per ton for whatever proportion of the product was sold. (c) To weigh and credit to the miners all coal before screening.

Although the first of the above met with considerable favor, in 1883 a bill requiring the use at all mines of a screen of uniform dimensions and width between bars failed to pass the State Legislature. In the light of the history of coal preparation revealed during the next few years, it is a question if the passage of this bill might not have prevented the difficulty caused by the increased percentages of fine coal and refuse.

Legislation was then proposed to weigh and credit to the miner, before screening, all coal hoisted. The operators protested against payment on the "mine run" basis, their arguments being: (1) Installation of new scales and tipples would be necessary. (2) Domestic coal must be lump to command a good price. (3) An unskillful or careless miner might make double the amount of slack made by a careful one. (4) A dishonest miner could load dirt and rock in the bottom of his car. (5) The excess of powder used would shatter the coal. (6) The proposal amounted to offering a premium for dishonest work. (7) They would suffer on account of time wasted by weighing in the tipple. (8) If a carpenter is paid for his day's finished work, and not for the chips he makes, why should a miner be paid for the slack he makes?

To this report a reply was issued, signed by a committee of the United Mine Workers of Illinois, as follows:

(1) The miners' organizations during the last few years had forced some reduction in the size of screens used. (2) Where no miners' organization existed, screens were large enough to let through good sized coal. (3) Some of the mines had installed breakers to crush lump coal, proving that fine coal was not bad. (4) There was no law in Illinois limiting the size of coal screens, which varied from ⅞ inch to 2½ inches between bars and had an area of from 50 to 130 sq. ft. (5) Miners were forced to sign contracts stating that screens might be widened without violating such contracts between operator and miner. (6) Wages were based on the price of lump coal, but the operator derived an enormous revenue from screenings which was clear profit to the owner. (7) It was shown that at one mine on the Illinois Central Railroad, of 1,095 tons hoisted, 509 tons or 46 per cent, passed through the screens. (8) The allegation that practical and trained miners would attempt to produce slack was denied.

The same question of run of mine vs. lump coal payment was fought out in Ohio in 1913. A coal mining commission was appointed by the governor to inquire into the merits of the matter. In its report the commission took up exactly the same arguments for and against as those advanced in Illinois. Twenty-five years have thrown very little new light on the subject, the only additional arguments presented by the miners in Ohio being along the line of conservation. They claimed that under the lump system valuable coal was left in the ground, that pillars could not be economically robbed because of the undue crushing of the coal in them, and that they were unable to make fair wages under these conditions. The only new argument of the operators was that a trial of many years had disclosed the detrimental effects of the mine run law in Illinois.

Whichever side had the better of the argument in Illinois, on June 10, 1891, the Illinois Legislature (L. 1891, p. 170), passed a gross weight law, making it unlawful for an operator, whose men are paid on the basis of quantity of coal, to take any portion of the same by any process of screening, or by any other device, without fully crediting the same to the miner. The law required the weighing of all coal in the pit cars before being dumped, and gave the miners freedom to choose their own checkweighman. Nearly all the mines which paid their miners by weight complied with the law, which, "as a whole, has not seriously inconvenienced the business in spite of the claims of the operator that weighing before screening was impracticable without serious reconstruction of the surface plant."*

Generally in the American bituminous coal fields, as long as the coal has been paid for on a screened coal basis, little attempt at detailed preparation has been made. When paying for run of mine coal, however, the operators are forced, through a series of new conditions, such as necessity of disposing of the finer sizes, or by an increase of refuse in the coal, to make greater refinement in its preparation. Moreover, when the operator pays the miner for all his coal regardless of size, he may more easily install whatever system or make whatever sizes best meet his market conditions, since he has no agreement with the miners concerning screens.

Operators in Illinois were now free to screen and prepare the coal as they wished. Consequently, new devices for preparation were introduced among which was the shaker screen (see p. 44), which replaced the bar screen in a number of plants. The first screen of this kind in the state was probably installed in 1890 at the Gillespie Colliery of the Consolidated Coal Co. Since that time the old bar screens have been steadily replaced by shaker screens. As late, however, as 1893, a shaker coal screen exhibited at the World's Columbian Exposition attracted considerable attention. At a number of plants the bar screen was replaced by a revolving screen. It was found, however, that lump or larger sizes of coal were badly shattered during passage through this type of screen, and their use for lump coal was gradually abandoned, until at the present time the writer does not know of a single plant in the state which uses such a screen for the separation of the coarser sizes. For screening the finer sizes of coal, under 3 inches, which are not so much affected by breakage from fall, the revolving screen held its own until a very recent period.

In 1892 the screening or gross weight law of 1891 was attacked in the courts (Ramsey v. People, Ill. Rep. 142, p. 380) and declared unconstitutional, since "it required, regardless of contract, payment on the weight of coal before it was screened, and it thus so far

*Report of Ill. Bureau of Labor Statistics, 1891, p. 47.

limits the power of employers and employees to contract, as to deprive them of property and rights without due process of law." In spite of this decision, many mining plants which had been equipped for the gross payment basis continued to use it in preference to the old method, partly because consumers had begun to demand a variety of sizes, which could be produced more easily with the new equipment. In some cases as a result of a decided increase in the percentage of screenings and contained dirt, a reversion was made to the older method. As contracts between operators and miners were generally of a local or district nature, such changes were quite easily made. On the whole until 1897 the pendulum swung towards the abandonment of the gross weight system.

In 1895 new complaints were made against the enlargement of screen apertures, and it was claimed that the weighing of the coal was inaccurate. The annual reports of the State Board of Arbitration for 1895, '96, '97, and '98 cite numerous instances of coal mine strikes, the principal causes being those just mentioned and the renewed contention by the miners for payment by the gross weight system. The case was aggravated by the general industrial depression during these years and by a decreased demand for Illinois coal, due in part to natural gas displacing coal as a house fuel in the Chicago market,* to smoke ordinances passed in the cities,† and to the increased use of Ohio and West Virginia coal in Chicago and of Missouri coal in St. Louis.‡

On June 3, 1897, the Illinois Legislature passed a new gross weight bill, designed and worded to overcome the legal objections to the law of 1891 and to accomplish all that was intended by the previous law. The law (L. 1897, p. 270) provided "that every person engaged in mining coal . . . . shall be paid in lawful money . . . . for all coal mined and loaded into the mine car by him, including lump, egg, nut, pea, and slack, or such other grades as said coal may be divided into, at such price agreed upon by the respective parties."

As in previous cases the act was attacked in the courts (Whitebreast Fuel Co. v. People, Ill. Rep. 175, p. 51). Since it was held constitutional and is the basis for present laws, not only in this state but elsewhere, it is interesting to note that, "the application of the act does not extend to cases where there is a contract for compensation upon a different basis than that specified in the act, and the employer and miner are free to contract at such price as may be agreed upon by the respective parties. It does not require that the coal shall be weighed, or that the same price shall be paid for different grades."

The efforts of the miners to obtain their demands and to bring their contracts under the provisions of the act helped to bring on the great strike of 1897, which began in Illinois July 4, 1897, and

*Min. Ind., Vol. 1, 1892, p. 80.
†Min. Ind., Vol. 4, 1895, p. 164.
‡Min. Ind., Vol. 7, 1898, p. 185.

lasted about 100 days. The strike resulted in an almost complete victory for the miners, district after district acceding to their demands for higher wages and payment on the gross weight basis when the same was not already in force. The greatest change perhaps was made in the longwall field. On November 22, 1897, a joint conference of miners and operators of this field was held in Joliet, and the gross weight scale was adopted for the entire field. The system of paying for all coal mined, provided for in terms of settlement, was considered important enough to justify the miners of the northern field accepting a rate for mining a few cents less per ton than agreed upon at the previous State Convention.

The report of the Illinois Bureau of Labor Statistics for 1897 contains a full history of the strike. From the viewpoint of preparation, before the strike at 156 of 284 mines in the state, miners were paid on the gross ton basis and at 128 on the screened ton basis. After the strike 198 mines paid the miners on the gross ton basis and only 86 paid on the screened ton basis. These totals included 86.5 per cent of the total coal mine employees in the state, and probably about the same percentage of the total tonnage. The large mines were now all in the gross tonnage column. Little change resulted in the southern fields, which previously had been gradually changing to a mine run basis, based either on weight or on volume.

Operators' and Miners' Agreements.—The miners of the state had now become firmly organized as District No. 12 of the United Mine Workers of America, and following the national convention of that order at Chicago, January, 1898, District No. 12 met the Illinois coal operators associations at Springfield, February 24-26, 1898. The wage scales adopted at this joint conference by the different state districts were "understood in every case to mean that coal is to be weighed before screening and the system of paying miners by the ton of R. O. M. (run of mine) coal shall obtain in all the mines in the state of Illinois.* Thus the present system was adopted in Illinois, not so much through the strictness of the gross weight law, as by agreement between the operator and the organized miner.

The next year (1899) the first complete state agreement regarding mining prices and general conditions was adopted at a meeting between operators and miners held in Peoria. Concerning cleaning of the coal, no reference was made in the agreement regarding the mining of impurities or the increase in amount of screenings. Testimony given at this meeting, however, showed that at Streator the percentage of screenings increased 15 per cent and at La Salle from 2 to 5 percent through the same screens, as the result of a year's trial under the new gross weight system. There was, for the last time, some talk of accepting a double standard; namely, one price for lump and another for screenings, but no action was taken.†

*Minutes of Springfield Conference.

†Proceedings Joint Convention, Dist. 12, U. M. W. of A. and Operators, Peoria, 1899.

This first year under the new system has been called "an era of good feeling in the coal mining history of the state." The old grievances and troubles had disappeared and no new ones had arisen as yet. By the time, however, that the 1900-1901 agreement was made the modern refuse question had become so acute that the following clause was inserted: "Where slate, bone, etc., are sent up by the miners, it is the duty of the car trimmer or inspector, who shall be a member of the miners' union* and appointed by the operator, to call the attention of the weighman and check weighman to the same. If they agree, the offender shall be fined fifty cents for the first offence; one dollar for the second; and two dollars for the third or subsequent offence, or discharged by the company; providing that no miner shall be discharged unless he is guilty four times in one month."

This clause was evidently not sufficient to enforce the loading of clean coal since the Peoria agreement for the year ending March 31, 1903, contained more elaborate rules regarding preparation. These rules, except for minor changes, are in force today. The pertinent sections, as given in the 1915-16 ageement, are as follows:

Section 4. "The scale . . . shall be per ton of 2,000 lb. R. O. M. (run of mine) coal, practically free from slate, bone, and other impurities."

Section 5. (b) "The system of paying for coal before screening was intended to obviate the many contentions incident to the use of screens and not to encourage unworkmanlike methods of mining and blasting coal, or to decrease the proportion of screened lump, and the operators are hereby guaranteed the hearty support and cooperation of the United Mine Workers of America in disciplining any miner who from ignorance or carelessness or other cause fails to properly . . . load his coal."

Section 6. (a) "In case slate, bone, clay, sulphur, or other impurities are sent up with the coal by the miner, it shall be the duty of whomever the company shall designate as inspector to report the same, with the estimated weight thereof, and the miner or miners so offending shall have such weight deducted from the established weight of the car and for the first offence in any given calendar month shall be fined fifty cents; for the second offence in the same month he or they shall, at the option of the operator, be fined two dollars and for the third or any subsequent offence in the same calendar month, he or they may be fined two dollars or be suspended for not to exceed six days of mine operation.

(b) "For a malicious or an aggravated case, ... the operator may either indefinitely suspend or discharge."

The term "malicious or aggravated case" is then defined "as a case in which the quantity, character, or appearance of the impurities

*The 1904 and subsequent agreements provide that the company coal inspector "shall not be a member of the union."

indicate that they were loaded with intentional carelessness or wrong purpose. In case of discharge for an aggravated case as above, the inspector shall preserve the impurities for 72 hours, Sundays and legal holidays excepted. All impurities subject to being docked shall be preserved for the balance of the working day except at mines where it is impossible to do so without seriously impeding the mine. Where it is claimed by the operator that to so preserve the impurities will serously impede the output of the mine and where it is claimed by the miner that the case is not a malicious or aggravated one, the question shall be taken up jointly for determination."

(c) "The company weighman shall post in a conspicuous place at the pit head the names of all miners dealt with hereunder."

(d) "The inspector designated by the operator . . . . shall not be a member of the U. M. W. of A., and in the discharge of his duties shall not be subject to the jurisdiction of the union. Any miner . . . . seeking to embarrass the inspector . . . . shall, at the option of the operator, be suspended two days."

(f) "The proceeds from all fines shall be paid to the miners' subdistrict treasurer, and . . . . shall not be remitted."

"The foregoing is designed to secure to the operator the loading of clean coal, while protecting the miner from any abuse of the penal code."

It is evident from the various clauses noted that every possible means is being taken to compel the loading of coal free from impurities. The present demand of the consumer for clean coal has made it necessary that care be taken to load, at least as regards lump coal, only pieces that will pass inspection by the company coal inspector, or as he is often called, the "dock boss" or "rock man."

Regulations concerning fine coal and screenings have not been so thoroughly worked out. At present the only provisions in the operators-miners agreements regarding such coal are:

Section 5. (c) "That all 'bug dust'* or machine coal cuttings when practically free from impurities shall be loaded out with the snubbings† or other coal so as to produce a merchantable R. O. M. coal."

"The above does not contemplate any change in the present method of handling bug dust or machine cuttings in Franklin county, or other mines when it is necessary to load the same out before shooting the coal, as a protection against explosions or fire."

"Where the operator desires the bug dust loaded out separately, this shall be done by the miner working in his place during his regular shift at the regular tonnage price and the company shall furnish cars promptly to load the same."

Much of the roof, "draw slate," floor, and bands which comprise the bulk of the impurities mined with the coal either break into

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*See p. 101.
†See p. 106.

small pieces or tend to soften quickly on exposure to the air. Any piece of such impurity smaller than 1¼ inches in diameter passes into the screenings during the screening process of preparation. Since the impurities are small and pass quickly from sight through the screens, and since they mix with the dust and multitude of small

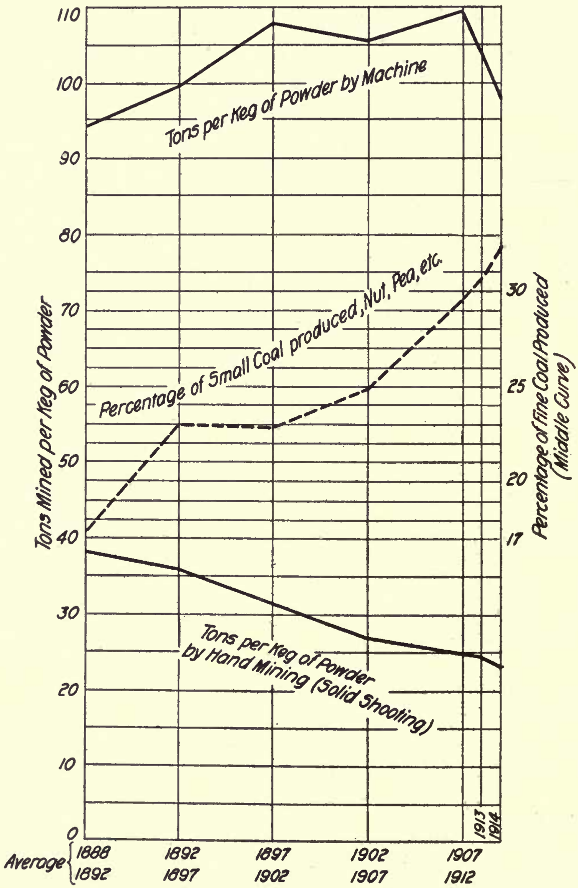

FIG. 5. TONS OF COAL MINED PER KEG OF POWDER (1888-1914).

pieces of coal which make up the screenings, they so blend with the prevailing black that close inspection is impossible. It is sometimes easier, while loading, to break a piece of flat shale with the back of a shovel so that the pieces will enter the screenings, than it is to pick this same piece out of the coal and throw it into the gob.

From a large number of analyses the Department of Applied Chemistry at the University of Illinois determined that, on the average, Illinois screenings contained about twice as much ash as the lump coal from the same mine. The writer has observed a like difference, varying considerably as to daily conditions at the individual mine. Samples of screenings taken on different days from the same mine often vary several per cent in ash content. The mere fact that a coal is of screenings size does not necessarily impair it for use in modern furnaces, but the value of screenings generally is lowered and sale retarded by a high and uncertain refuse content. Impurities in screenings, even though concealed to the eye, appear to their full value upon chemical analysis or in the furnace ashes. Thus, the increasing tendency of consumers to insist upon ash analysis and specifications is based on reason and is certain to continue.

The coal from some of the mines in Illinois is held in disfavor in the general market, and a differential price is made against it. Some of this coal is in every way equal in quality to that from more favored mines. Investigation reveals that carelessness in loading impurities and negligence in enforcing inspection are the main reasons for this condition.

Another clause of Section 5 in the recent joint agreements is of interest, since it relates to the effect of powder used on the sizes of coal produced. It is given as follows: "Where practicable, miners shall shoot coal with two pounds of powder or less."

In general, little or no powder is used in longwall mines, the coal being loosened by roof pressure or by wedges; in mines in which the coal is undercut only a moderate amount of powder per ton of coal is used; while in mines in which the coal is "shot off the solid," without previous preparation of the face, a much greater amount of powder is used since there is only one free face to break to.

Before the general introduction of the run of mine payment system in 1907, it was evidently to the miner's interest to shatter and break his coal as little as possible. This could only be done with a minimum of powder. The accompanying chart (Fig. 5), prepared from data in the annual coal reports, shows the number of tons of coal mined per keg of powder for each year since 1888, for both machine and hand mines (solid shooting). Since longwall mines come under the general heading of hand mines, and since they use little or no powder, they have been omitted from the compilations. The charts are based on five year averages in order to avoid accidental fluctuations.

The percentage of fine coal produced by the mines for the same period is also plotted in Fig. 5. Since the year 1900, the coal production has been reported in tons of the different sizes produced; namely, run of mine, lump, egg, pea, and slack. For general purposes of comparison the percentages since 1900 were obtained by considering run of mine as lump coal, and considering nut, pea, screenings, and slack sizes as fines. Since today these are mostly made through round hole screens, while before 1897 they were mostly made through bar screens, the first part of the curve up to 1902 shows an uncertainty due perhaps to the change from bar to round hole during these years. There has been a regular increase in the percentage of the fine sizes produced since 1902. Thus, from 17.3 per cent in 1892 to 22.9 per cent in the period from 1897 to 1902 and to 32.5 per cent in the year 1914, is a serious increase in fine coal in the state as a whole. The rise of this curve, coincident with the increased use of powder in solid shooting mines, recorded in the lower curve, is more than a coincidence, and shows plainly the close relationship between them.

It has been stated that as the amount of powder per hole increased so increased the percentage of fatal accidents.* This fact, more than the evil of increased coal breakage, led to the passage in 1903 of a law regulating the use of powder in coal mines (L. 1903, p. 252), which limited to about 5 lb. the amount of powder used in a single charge in seams over 5½ feet thick, and to about 4 lb. if the seam were under this thickness. The sections covering the above were repealed in 1913, and substantially inserted as Section 19, Act of 1913. The coal report of 1904 (p. 3) commenting on the law of the previous year states that disregard of its provisions had been general. It did not serve to stop the increase in the percentage of fine coal.

More legislative remedies were proposed: (1) All coal should be undercut. (2) Special shot firers should be employed by the company. Had the first measure passed and been enforced, probably the percentage of coarse coal would have increased. The second measure finally became a law July 1, 1905. It provided, "that where more than 2 lb. of powder are used in one blast . . . a sufficient number of practical miners to be designated as shot firers shall be employed by the company to inspect and fire all blasts in the mine."

Evidently the miners, now freed from firing their own shots, loaded heavier than ever, taking the chance that their holes would be fired without inspection. For this reason, apparently, the law was amended in 1907 (Sections 47, 47a, and 47b) forbidding a miner to alter a hole after inspection by the shot firer and forbidding the shot firer to fire an unlawful hole.

A. Bement† comments on the increased use of powder during the last few years, and in Bulletin No. 16 of the Illinois State Geological Survey he states that its increase per ton of coal produced was over 100 per cent between 1897 and 1908.

Laws and collective agreements in Illinois as regards percentage of fine coal and the contained amount of impurities have not proved wholly successful. The writer believes further action should be taken, especially regarding the impurities and excessive dust in screenings. The close competitive market prevailing today on all sizes of coal, and especially on screenings, makes it appear imperative that in the near future this coal be placed on the market in a cleaner condition without preparation.

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*"Powder Accidents in the Coal Mines of Ill." Issued by The Illinois Coal Operators' Association, 1909.

†Jour. West. Soc. Eng., June, 1909, p. 307.

The effort in Ohio, one of the mining states competing with Illinois, to avoid the difficulties in changing to the run of mine payment basis, if successful, may offer a remedy for many of the difficulties which have hindered effectiveness with the run of mine payment practice.

According to the new mining laws of Ohio, passed in 1914, payment to the miner is changed from the screened coal to the run of mine basis; but, in case the miner and his employer cannot agree, the State Industrial Commission has the power to fix, for any mine, maximum percentages of fine coal and impurities allowable in the miner's coal. Loading of excess impurity is made a misdemeanor and punishable by fine on conviction. Thus, Ohio has attempted to solve by law a matter which in other states has been regulated by collective bargaining between operator and miner.

A suggestion has been made to introduce a bonus system of payment to the miner for his lump coal, as a means of overcoming the evils of the present run of mine system in connection with breakage and impurities. Briefly stated, it is proposed to continue the present practice of paying an agreed price for all coal as mined and hoisted, but since clean lump coal is of extra value to the operator, it is suggested that he pay the miner for any excess of such product over a fixed percentage to be agreed upon for each district. This would not conflict with present state laws and would compensate both the operator and the careful and skillful miner. The possibility of such a method proving impracticable on account of difficulty in determining rapidly in the tipple the respective amounts of lump and slack in each miner's car of coal should be given consideration.

RECENT DEVELOPMENTS IN PREPARATION PRACTICE.

Fig. 3 shows that sizing and close preparation had become important enough by 1900 to justify the separation of the total production into the separate sizes produced. The public was beginning to demand sized coal. Fresh impetus to this demand was a result of the anthracite strike of 1902, when the public, deprived of closely sized anthracite, tried sized Illinois bituminous coal for the first time as a substitute. In the period from 1902-1907 many of the small companies were consolidated, and larger corporations entered the field and erected new and larger modern steel surface plants.

Beginning about 1906, considerable prominence was given to the abatement of the soft coal smoke nuisance in cities, and the burning of more closely sized coals proved to be of some advantage in overcoming this trouble. In 1908 considerable public attention was given to "The Purchase of Coal by the Government under Specifications," by Geo. S. Pope, Bulletin 428, U. S. Geological Survey, and reprinted as Bulletin 11 of the U. S. Bureau of Mines. The author (p. 5) states, "Until recent years coal consumers purchased coal merely on the statement of the dealer as to its quality, relying on his integrity and on the reputation of the mine or district from which the coal was obtained. It is surprising that the important question of whether value was being received for the money expended was not sooner seriously considered." In speaking further (p. 8) on the size of coal as influencing combustion, and without qualifications as to kind of coal or to conditions of burning, he states that, "coal of uniform size forms the most satisfactory fuel." Attention is also called in the bulletin to the limiting values of ash and refuse allowed and to the general advantages of some specification system. Frequent articles in the general press also emphasized the advantages to the consumer of prepared coal.

The period from 1907 to 1915, especially the last five years, is notable for the remodeling of coal tipples to handle larger outputs and to meet the growing demand for cleaner and more evenly sized coal. This has necessitated improvements in mechanical details, such as weighing devices, sizing screens, picking tables, and loading booms, and has caused the introduction of special engineering features in improved rescreening plants and special dry processes for cleaning the coal. A surface plant in Illinois must be capable of handling more than 4,000 tons per eight-hour day in order to be considered one of large capacity. At a mine in Macoupin county recently a record has been made of 5,116 tons hoisted and prepared in an eight-hour day, or an average of 640 tons per hour. Upon comparing this with a record of 1,655 tons hoisted in 9½ hours, or about 174 tons per hour, made at Braidwood, Illinois in 1888, and mentioned in Colliery Engineer* of that year as being remarkable, it is evident that remarkable changes have taken place not only in underground methods, but in weighing, handling, and general preparation at the surface.

The large increase in capacity of individual mines has at times tended towards overproduction with a consequent decreased profit per ton and increased competition. The average shipping mine in Illinois is operated 172 days per year. In other words, without increasing present mine plant capacity, if the mines were worked 300 days per year, Illinois could supply over 100,000,000 tons of coal per year. This factor has led to complication regarding preparation, some plants having introduced devices on account of competition rather than through real need of such treatment for the coal.

It has been stated that Illinois has been obliged to improve preparation, in order to keep ahead of her competitors in the neighboring coal fields. The interstate commerce in Illinois coals has extended to the west, perhaps as far as Omaha, to the southwest into Texas, and to the northwest into Minnesota and the Dakotas until competition with the high grade West Virginia and other eastern coals carried over the Great Lakes has become too severe. Thus, at various places Illinois coals may come into competition with West Virginia, Ohio,

*Vol. VIII, 1888, p. 222.

Kentucky and Indiana coals from the east, with the coals of Oklahoma and Arkansas in the southwest, and with the generally lower grade coals of Missouri, Kansas, and Iowa in the west. Further west, the eastern shipment of the bituminous coals of the Rocky mountains is the determining factor in the situation.

That Illinois has kept abreast and ahead of her competitors in preparation is apparent by noting the number of new screening and preparation plants erected in these competing states within the last two or three years. All things considered, there is probably no bituminous coal district in America having refinement in preparation equal to the general Illinois field, and especially equal to that at the tipples producing coal for domestic and retail use, in which an even size and freedom of impurities visible to the eye are prerequisites.

CHAPTER II.

Standard Types of Illinois Coal Mine Tipples.

INTRODUCTION.

Tipple Units.—At Illinois mines today the coal is hoisted to the surface for screening and final cleaning, although a rough preliminary hand picking often takes place at the face underground. This necessitates for preparation a surface structure composed of one or more of the following units:

(1) A headframe or tower over the mine shaft, supporting and taking the reaction from the pulleys or sheaves over which the hoisting rope runs, and which generally must further resist the shock of the mine car being dumped.

(2) A screen structure, sometimes called, if of the common type, a shaker house or shaker, containing the particular type of screen used to separate the mine run coal into various market sizes, and also some weighing device for the coal.

(3) Picking belts, for use in cleaning the screened coal, and loading chutes, etc., and for loading it gently into railroad cars.

(4) At certain mines the mine cars are run off the mine cage before being dumped, necessitating an additional structure in which the mine cars are handled and recaged, and in which disposition is made of the waste rock brought to the surface.

In Illinois these units are grouped into one general structure at the mouth of the shaft which is called the tipple. To avoid vibration and promote stability the screen frame in the tipple is generally built with independent supports and foundation. A frequent auxiliary and separate structure is the rescreening plant or rescreener, into which the smaller coal is re-elevated, and there separated into various small sizes. In the design of these units every precaution should be taken to prevent breakage of the coal, to obtain capacity, to do clean screening, and to avoid vibration, all with a minimum of labor. These are the five requisites of good tipples.

Materials of Construction.—Until about 1900, mine tipples in Illinois were built of wood, excepting the screens, chutes, etc. Since then the use of steel in the construction of tipples has become more and more common. In June, 1911, the state legislature passed an act requiring that all structures thereafter erected on the surface within 100 feet of the mouth of any shaft, slope, or drift should be built of metal, rock, clay, cement, clay or cement products, or a combination of the same. Tipples erected since that time have been made of steel, and although concrete and other fireproof materials have been used in other parts of the country for mine tipples, they have not as yet found favor in this state.

Many of the older wooden tipples have given remarkable service, especially those well built and cared for, and in many districts are still the common form. A number of the earlier steel tipples were constructed of a comparatively large number of small steel members, and following the custom prevalent at the wooden tipples, the sides, especially over the shaft, were tightly enclosed, usually with corrugated iron. Since the hoisting shaft is generally the upcast air shaft, the corrosive action of this moist mine air on the thin steel framing of the tipple was rapid, especially on those members closest to the mouth of the shaft. In the later steel tipples trouble from this source has been eliminated by any or a combination of the following simple precautions:

(1) Leaving the sides of the headframe open.

(2) Spreading the legs of the headframe; thus removing them from the shaft collar.

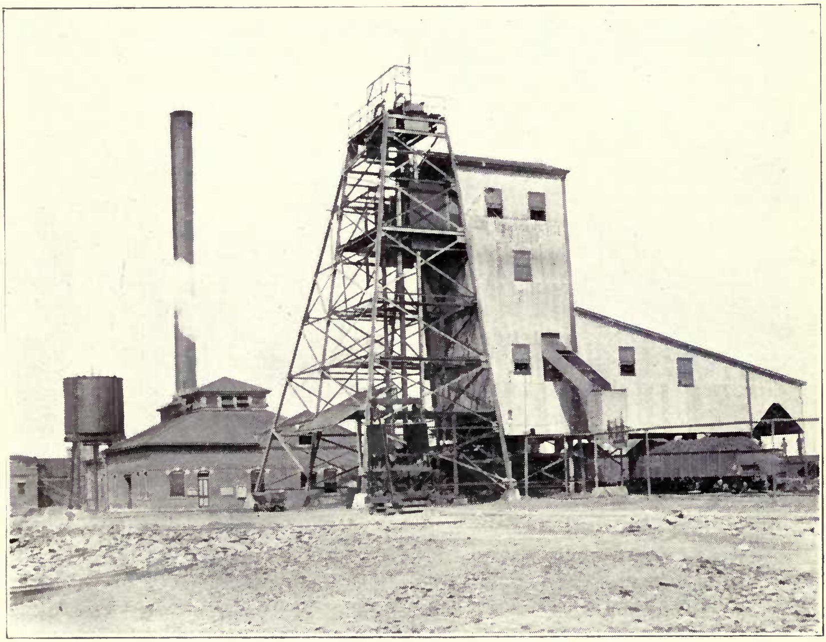

Fig. 6. Class I Tipple.

(3) Using a few large steel members for headframe construction, instead of the more quickly corroded small sections.

(4) Encasing in concrete the legs or posts close to the shaft.

(5) More frequent scraping and painting.

It is to be regretted that so many correctly designed steel headframes in this state have been allowed to deteriorate solely through lack of attention on the part of the operator. No design can withstand for many years the severe conditions imposed without being properly protected by an occasional coat of paint. If this simple expedient is carried out, there is no reason why the steel tipple should not last almost indefinitely.

Types of Tipples.—Mine tipples differ according to (a) their structural material, (b) method of receiving coal (whether from a shaft, slope, or drift), (c) position of hoisting engines in reference to the axis of the structure, (d) type of mine car dump used, (e) method of handling mine cars of coal and waste, (f) whether or not the coal is rescreened, and (g) the type of screen used to prepare the coal.

In Illinois the structural material is uniformly wood or steel, and as shaft mines are most common, mine tipples may be grouped into three general classes or types as follows:

(1) Those equipped with self-dumping cages and with shaker screens for sizing the coal.

(2) Those equipped with self-dumping cages and with gravity bar screens for sizing the coal.

(3) Those equipped with rigid or fixed cages, with cross over dumps in the tipple to empty the mine cars, and with shaker screens for sizing the coal.

To illustrate the general practice in coal preparation, one tipple representing each of the three types just mentioned, has been chosen at random from a number of similar ones in the state. Although constructed of steel they are by no means the largest or most recent installations in each class, but each represents many features found at many of the tipples in the state. The designs illustrated are for steel construction, but they are also representative of wooden construction since there are no especial differences in principle, operation, or appliances. Any of these types may have an auxiliary rescreening plant.

Although the length or long axis of a tipple is usually perpendicular to the long axis of the shaft, in several cases, in order to accommodate a more favorable position of railroad tracks, the screen structure is built at an angle to the long axis of the shaft, and in several instances parallel to it.

Hoisting engines may be placed so that the hoisting ropes will run over the sheaves either in the same plane as the long axis of the shaft or perpendicular to it. In the first case the headframe is said to be "end pull" and the pulleys or headsheaves are tandem and in approximately the same vertical plane. Headframes in the second case are "side pull" and the pulleys are parallel. Neither type is more popular in Illinois. Both types are often used in the same district, the choice depending on the designer, the operator, the permanent position of some part of the old plant necessary to combine with the new structure, the ease of conveying coal to the boiler room, the topography, the position of railroad, etc. Accidently the three plants chosen to illustrate typical surface plants in this chapter are of the end pull type. The frontispiece (Fig. 2) shows a side pull headframe.

CLASS I. TIPPLES EQUIPPED WITH SELF-DUMPING CAGES AND WITH SHAKER SCREENS FOR SIZING THE COAL.

The type of tipple commonly used in Illinois at room and pillar mines and in which the bulk of Illinois coal is prepared for the general market belongs to Class I and is shown in the photograph (Fig. 6) and in sectional elevation (Fig. 7). The operation is best explained by following the course of the coal from mine car to railroad car.

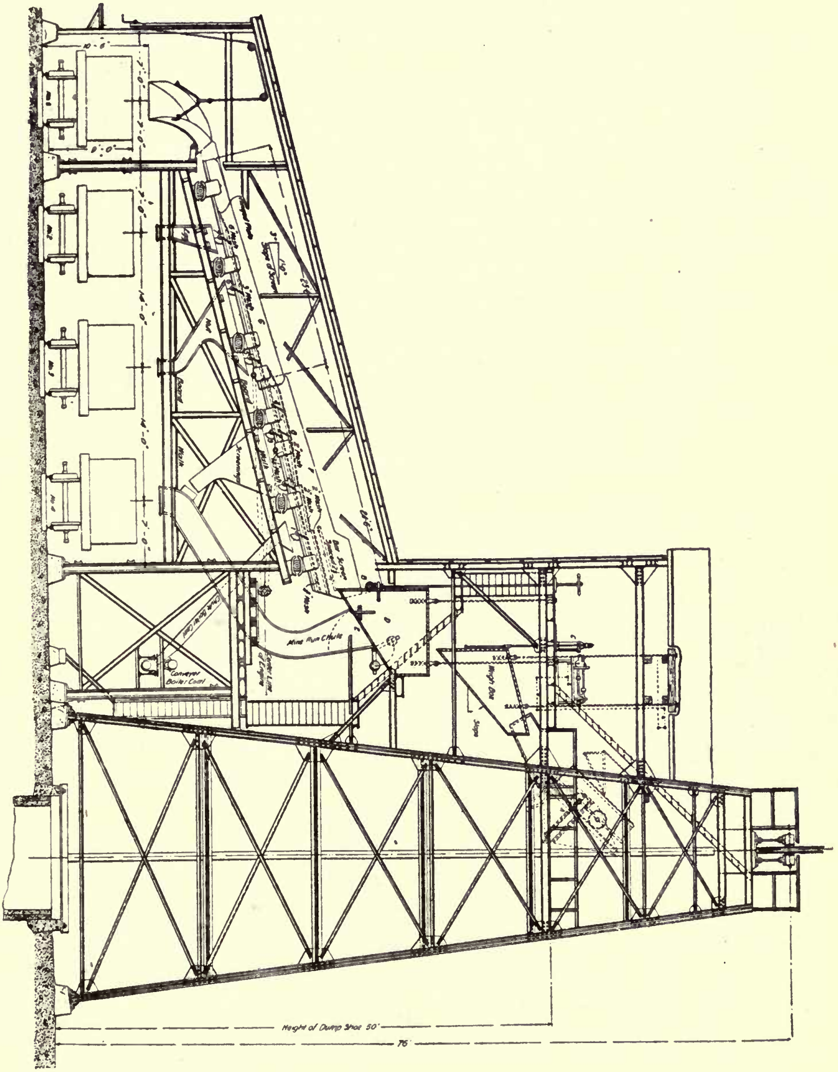

FIG. 7. ELEVATION OF CLASS I TIPPLE.

The self-dumping cage *A,* containing the end dump mine car, dumps at a height of about 50 feet above the ground, this height varying with the design of the tipple, the kind of screen used, the number of railroad tracks to be served, etc. The general scheme is to elevate the coal sufficiently before dumping to enable all necessary preparation to take place and the coal to be loaded into railroad cars without re-elevation. As the cage tips, the coal slides out of the mine car over the dump chute and into the weigh box. The weighman, or in the larger mines a check puller at the scale, takes the miner's check from the mine car in order that proper accounting for the coal contained may be rendered.

After the coal has been weighed, the gate *B,* controlled by hand or by the piston *C,* is opened, thus allowing the coal to fall into the hopper or pocket *D.* In many mines this hopper is absent, the coal being dumped directly from the weigh box on the shaking screen. At other mines an automatic feeder which supplies the coal evenly to the shaking screen is installed instead of this hopper. A valve *E* may be opened to allow rock, refuse, or run of mine coal to enter the mine run chute and thus be loaded into a railroad car on track 4. Above the screen proper is a relief bar screen 6 ft. long and with 2½-inch spaces. This prevents a rush of coarse coal on the upper fine screens and in general prevents their choking; thereby increasing capacity and the completeness of screening. The coal from *D* falls on this relief bar screen and thence to the top section of the upper shaking screen *F,* which in the case illustrated, is 10 feet wide and 24 feet 6 inches long.

The top section *F* of the shaking screen has three decks; the upper one is equipped with a screen plate with 2-inch round perforations, the middle one with a plate with ¾-inch round holes for the upper ten feet and 1¼-inch round holes for the lower end, and the bottom plate is solid, excepting for discharge gates or doors, Nos. 1, 2, 3 and 4.

The lower section *G* of the shaking screen has approximately the same area as the upper one and has two decks only. The top one is fitted with sections of plate having 3-inch round holes and 6-inch round holes as shown, and the bottom deck is solid excepting for the discharge doors.

The driving eccentrics of the shaker screens have a throw of about 6 inches and make about 100 revolutions per minute. To minimize vibration the motion of one screen opposes the other and their total weights when vibrating, including the loads of coal, are approximately the same. The screen supports are independent of the rest of the tipple. The slope of the screens is usually 3 to 4 inches per foot. The chutes leading to the cars are curved and built at a low angle in order to prevent breakage and spilling of the coal during the loading of the railroad cars. The boiler coal chute takes the finest coal, ¾-inch screenings, to the trough conveyor leading to the boiler room of the power plant.

With such an arrangement of screens and chutes, by opening or closing variously the gates, numbered 1 to 8 inclusive, in the bottom plates of the screens, a great number of sizes of coal can be made without changing the screen plates. The possible sizes are given below in Table 2, and Table 3 gives the arrangements of the gates necessary to obtain the different combinations of sizes.

TABLE 2.

SIZES OF COAL PREPARED. CLASS I TIPPLE.

Combination Number	Size of Coal			
	On Track 1	On Track 2	On Track 3	On Track 4
1	¾″ lump			¾″ screenings
2	2″ "		¾″x2″ nut	¾″ "
3	6″ "	2″x6″ egg	¾″x2″ "	¾″ "
4	1¼″ "			1¼″ "
5	2″ "		1¼″x2″ "	1¼″ "
6	6″ "	2″x6″ "	1¼″x2″ "	1¼″ "
7	3″ "		1¼″x3″ "	1¼″ "
8	6″ "	3″x6″ "	1¼″x3″ "	1¼″ "
9	6″ "	1¼″x6″ "		1¼″ "
10	2″ "			2 ″ "
11	3″ "		2 ″x3″ "	2 ″ "
12	6″ "	3″x6″ "	2 ″x3″ "	2 ″ "
13	3″ "	3″x6″ "	3″ screenings	
14	6″ "		3″ "	
15	6″ "	6″ egg run		

TABLE 3.

OPERATION OF SCREENS. CLASS I TIPPLE.

To Make Combination Number	Open Gate Number	Close Gate Number
1	2	3, 8, 4, 5, 6, 7
2	2, 4, 5	3, 8, 6, 7
3	2, 4, 5, 7	3, 8, 6
4	2, 3	8, 4, 5, 6, 7
5	2, 3, 4, 5	8, 6, 7
6	2, 3, 4, 5, 7	8, 6
7	2, 3, 4, 5, 6	8, 7
8	2, 3, 4, 5, 6, 7	8
9	2, 3, 4, 7	5, 6, 8
10	2, 3, 8	4, 5, 6, 7
11	2, 3, 8, 6	4, 5, 7
12	2, 3, 8, 6, 7	4, 5
13	4, 5, 6	2, 3, 8, 7
14	4, 5, 6, 7	2, 3, 8
15	4, 7	2, 3, 8, 5, 6

Besides these sizes mine run or unscreened coal can be loaded on track No. 1 by closing all the gates or on track No. 4 by opening the valve *E* and running the coal through the mine run chute. The usual combinations of sizes of coal prepared are 1¼-inch or 2-inch screenings, 2-inch to 3-inch nut, 3-inch to 6-inch egg, and 6-inch lump. At many tipples, having adjustable screens of this type, only the above standard sizes are prepared, since it is found that changing the screens and valves to prepare different sizes lowers the capacity, especially if close screening of the smaller sizes is attempted. If there is a demand for sized nut coal, a separate rescreening plant is used.

A plant of this size will prepare up to 4,000 tons in eight hours, and similar tipples are in operation which will handle 6,000 tons daily if required.

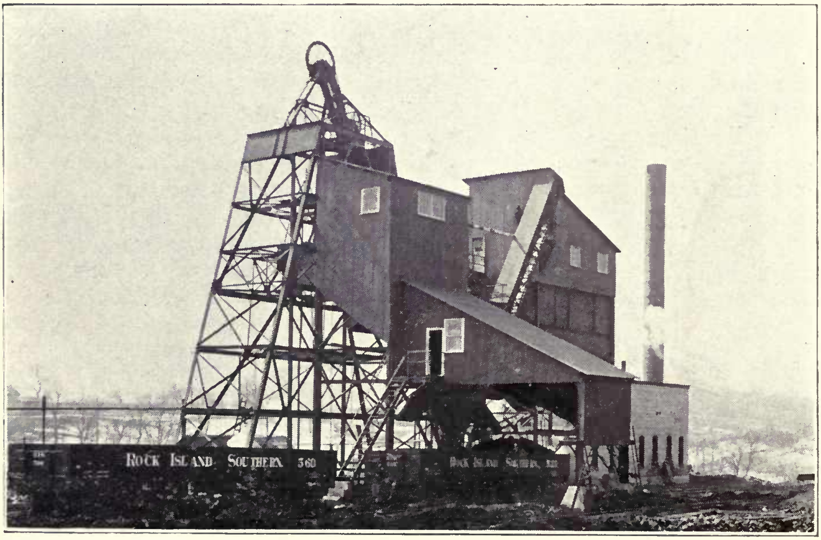

Fig. 8. Class II Tipple.

CLASS II. TIPPLES EQUIPPED WITH SELF-DUMPING CAGES AND WITH GRAVITY BAR SCREENS FOR SIZING THE COAL.

Although the gravity bar screen has been replaced generally by the shaker screen, on account of the better sizing, less breakage, and less headroom and slope required, yet at many mines, especially if the coal is prepared for a special market, the gravity bar screen is still used, because of its low cost of installation and upkeep, simplicity, and freedom of the tipple from vibration, as well as its almost unlimited capacity.

Fig. 8 shows a photograph, Fig. 9 a ground plan and end elevation, and Fig. 10 a side elevation of a bar screen tipple and accompanying surface plant. The self-dumping cage (Fig. 10), dumps the coal from the mine car into the weigh box, and after being weighed, it flows on the top bar screen *AA′*. This bar screen is in two equal sections, 6½ feet wide and 8 feet long, and is set at an angle of 27 degrees, which is just enough to allow the coal to slide over it by gravity. The spaces between the bars are 5 inches in width. Lump coal passes over the bars *AA′* into chute *B*, set at the same angle, and from here into the railroad car on track No. 1. The coal passing the 5-inch spaces

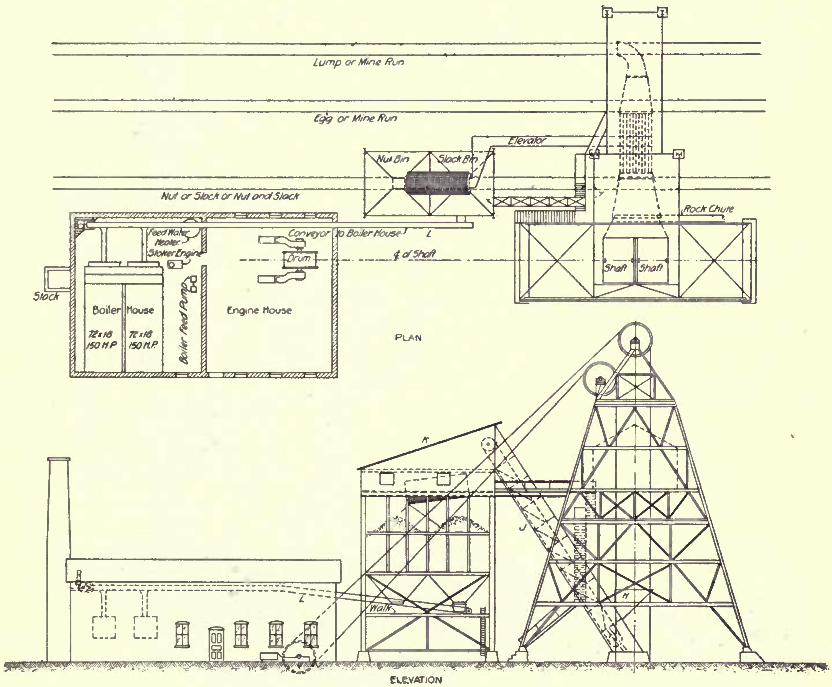

Fig. 9. Ground Plan and End Elevation of Class II Tipple.

of the screen *AA′*, falls on the lower bar screen *DD′*, which is of the same width as *AA′*, is 12 feet long, is set at an angle of 32 degrees, and has only 1-inch spaces between the bars. Thus, the coal between 5 inches and 1 inch in size passes over the lower screen into chute *E*, from which, as egg coal, it is loaded on track No. 2.

The smallest coal, having passed through screen *DD′*, is collected by chute *F* and may be loaded on track No. 3 as raw or untreated screenings. By means of a hinged gate *G* this coal may also be deflected into chute *H* and from here to the elevator *J* (Fig. 9), leading to the rescreening plant *K*. This particular rescreening plant is provided with a revolving screen 5 feet in diameter and 12 feet long, sloping 5 degrees, and enclosed with wire screen cloth having ¾-inch diameter square meshes. The oversize falling into the steel nut bin is called rescreened nut or pea coal; the undersize ¾ inch to zero in size, called slack, falls into the steel slack bin. The capacity of each of these bins is about 60 tons. Railroad cars can be loaded underneath as desired. A conveyor *L* carries part of the slack to the boiler room.

By lowering veils or blank plates over the screen *AA′*, it is possible to load mine run coal on track No. 1. Also by opening the chute

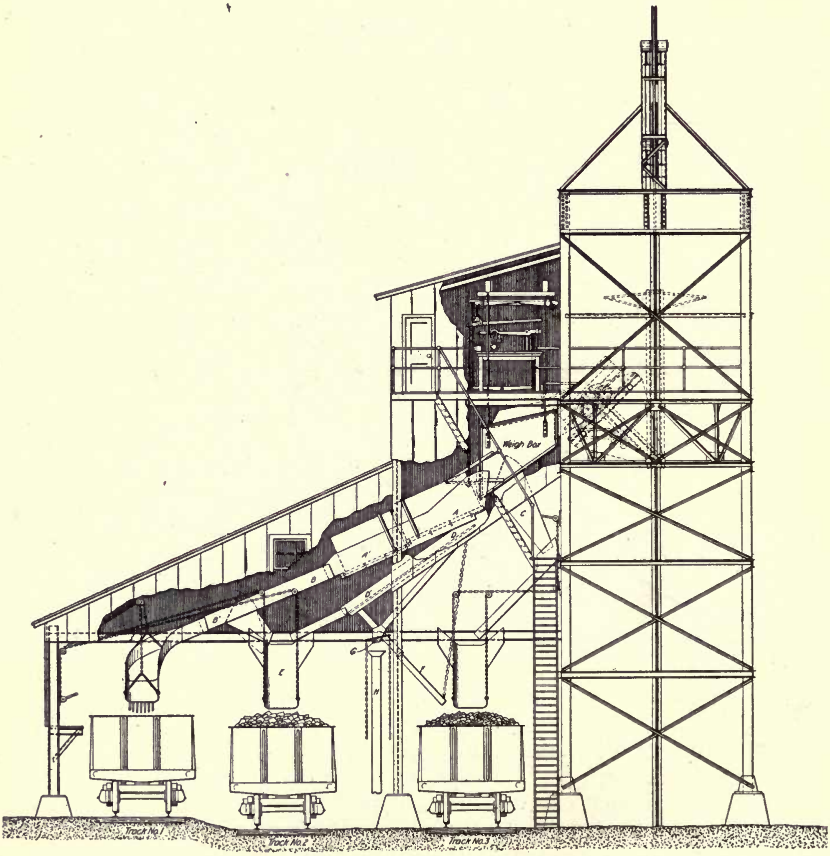

Fig. 10. Side Elevation of Class II Tipple.

B′, the oversize from the 5-inch bar screen may be loaded on track No. 2. Provision is also made for running either mine run coal or refuse from the weigh box directly into the chute *C* and from here into the railroad car on track No. 3. By using veils on the screens as required, together with the rescreener, the combinations of sizes given in Table 4 are possible in the tipple described.

TABLE 4.

SIZES OF COAL PREPARED. CLASS II TIPPLE.

Combination Number	Size of Coal			Rescreener	
	On Track 1	On Track 2	On Track 3	Nut or Pea	Slack
1	mine run				
2	5″ bar screen lump	5″ bar egg run			
3	5″ bar screen lump	1″-5″ bar egg	raw screenings		
4		1″ bar screen lump	" "		
5			mine run		
6	Raw screenings in combinations 3 and 4 may be rescreened into			¾″ sq. to 1″ bar	¾″ sq. to zero

The average daily capacity of the tipple illustrated is 800 tons, but at individual tipples of this class in the state more than 5,000 tons daily are prepared.

CLASS III. TIPPLES EQUIPPED WITH RIGID OR FIXED CAGES, WITH CROSS-OVER DUMPS IN THE TIPPLE TO EMPTY THE MINE CARS, AND WITH SHAKER SCREENS FOR SIZING THE COAL.

The tipple illustrated by the photograph (Fig. 11), and shown in side elevation (Fig. 12), has found favor in and is confined almost wholly to the longwall field in the northern part of Illinois for the following reasons: (a) Many of the mines are from 300 to 600 feet deep and at some two seams at different levels have been worked from the same shaft. (b) The thin seams and method of working usually necessitate small mine cars holding 1 to 1½ tons, and to secure adequate hoisting capacity, two cars are often hoisted end to end on the same cage. (c) One car of waste is also often hoisted to three cars of coal, and large amounts of timber are lowered.

The loaded cars (Fig. 12), are pushed from the cage along a track having a gradient with the load of about 1½ per cent, to some form of crossover or end dump and dumped into the weigh box. The empty car runs down the sharp grade *A* (6 to 12 per cent), through a spring switch at *B* to the kickback at *C*, while returning the empty car runs by gravity down the side track *D* (1½ per cent grade), to the transfer car *E*. When two mine cars have entered the transfer car, it is moved up inclined tracks by means of an air or steam piston, not shown, until the mine cars arrive at the level of the cage. By this time two more full cars have been hoisted and the mine cage is in the position referred to in the beginning. By means of a piston working in the long plunger *F* a ram *G* gently pushes the two empty cars into the cage, at the same time forcing the two loaded cars off.

The tracks, dumps, etc., in the tipple are in duplicate to provide for the cars coming from the cage in the other compartment of the shaft.

Mine cars containing shale or refuse are taken over the cross-over dump without dumping and switched to a track leading to the left end *H* of the tipple where their contents are dumped into a chute, usually by means of a horn dump, after which the cars are returned to the empty tracks *D*. In the same way, coal intended for local or

Fig. 11. Class III Tipple.

wagon trade is dumped into a chute at *H* and roughly bar screened before being loaded into the wagons.

Cars to be loaded with timber are taken through the end *J* of the tipple to an elevator (shown in Fig. 11), lowered to the ground, loaded, and returned to the system at *E*.

The screening plant in such a tipple may consist of either gravity bar screens or shaker screens. As illustrated in Fig. 12 on the shaker screen *M* one, two, or three sizes of coal can be prepared at once. It is of all steel construction and rests on independent foundations.

The coal dumped into the weigh box is weighed by scales in the weighroom *K*, the check puller at the dump having taken the miner's

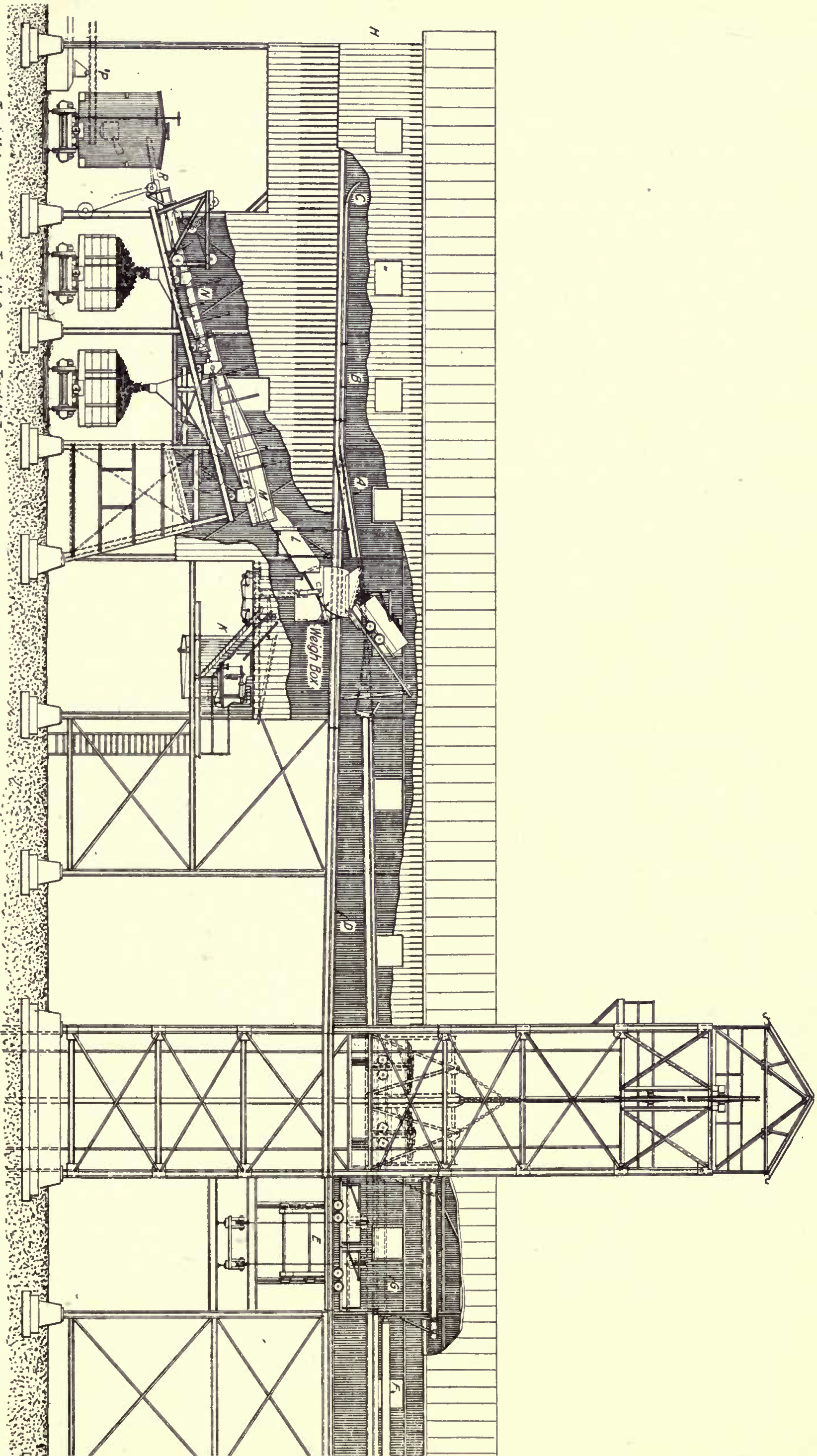

FIG. 12. SIDE ELEVATION OF CLASS III TIPPLE.

check from the car and dropped it into a chute (not shown), which carries it to the weigh room, so that proper credit is given for the coal.

The coal passes over the dead plate or chute *L* to the upper shaking screen *M,* which is 8 feet wide by 16 feet long, and consists of plates with 1⅛-inch round hole perforations. The undersize from here is loaded as screenings on track No. 3. In some cases it is washed before being marketed. The oversize of the screen passes over a short dead plate to the lower shaking screen *N* of which the upper part consists of 5-inch hole plate. Thus 1¼-inch to 5-inch egg may be loaded on track No. 2. The lump or chunk coal passes over the 5-inch screen and through the adjustable chute *S* into the car on track No. 1. If it is necessary to load box cars, the box car loader is run out from *P* into the car as shown, and the chute *R* is adjusted to feed it. It is possible by veiling the screens to load mine run on either track No. 1 or No. 2, or to load 1¼-inch lump on track No. 1.

Owing to facts previously stated, the capacity of these tipples is relatively small in comparison with those at pillar and room mines, a daily production of 1,500 tons being considered large. A large proportion of the coal produced is clean lump, and consequently, most of the screening plants in tipples of this type are small and simple.

CHAPTER III.

Impurities and Breakage.

PART I. GENERAL.

Removal of impurities and avoidance of breakage are the two standards by which coal preparation is measured. The object of coal mining is not only to produce the greatest possible tonnage at the least cost, but to produce the greatest possible percentage of clean lump coal. Perfect mining would mean, not only the extraction of all the coal, but the winning of it in a perfectly clean condition with 100 per cent lump. Were this possible, subsequent mechanical breakage could easily and cheaply produce finer sizes, as needed, in as pure a condition as the original lump.

"On the whole, Illinois has pure coal compared with many sections and it is possible to clean lump by hand in the railroad car. If the market calls for a steam coal, very little preparation is necessary. If the market requires domestic, we must screen and pick and even rescreen. The biggest problem is to load without breakage."*

No seam of Illinios coal is free from at least small amounts of impurities. Since mines situated in widely separated districts over an area of approximately 36,800 square miles are worked in five different seams, great variations are possible locally in the nature and in the extent of the impurities in an individual seam and in the physical characteristics of the coal itself.

The most persistent impurity in Illinois coal is the famous "blue band" or shale band in seam No. 6, which averages 1 to 2 inches in thickness, and is situated about 20 inches above the bottom of the seam. It extends with considerable regularity over an area of at least 5,000 square miles.† Impurities such as pyrite ("sulphur") and shale bands are of frequent local occurrence in all the seams. On the whole, it cannot be said that any one district in Illinois has an advantage over others in this respect. Considerable variance occurs among mines in the same district, however, not only in the impurities in the coal, but also in the care displayed in removing the same before the coal is shipped to market.

Friability means the tendency to produce fines under like conditions. The Illinois coals are not so friable as the coking bituminous coals of the Appalachian region, and in freedom from the breakage which occurs during mining, preparation, and shipment, they are perhaps not excelled by coal from any other section of the bituminous fields of America. Taken as a whole the different seams in Illinois show considerable uniformity as regards friability, although some-

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*W. R. Roberts, Black Diamond, November 30, 1912.
†T. E. Savage, Journal of Geology, Vol. 22, No. 8, 1914.

times the same seam in different districts or even in the same district will vary, depending probably on the thickness of the cover and the regularity of the bed. A seam buried under several hundred feet of cover is likely to be firm; a seam which has been tilted or folded is likely to be somewhat friable. At only two places in the state where mining is undertaken have the beds undergone any extensive regional

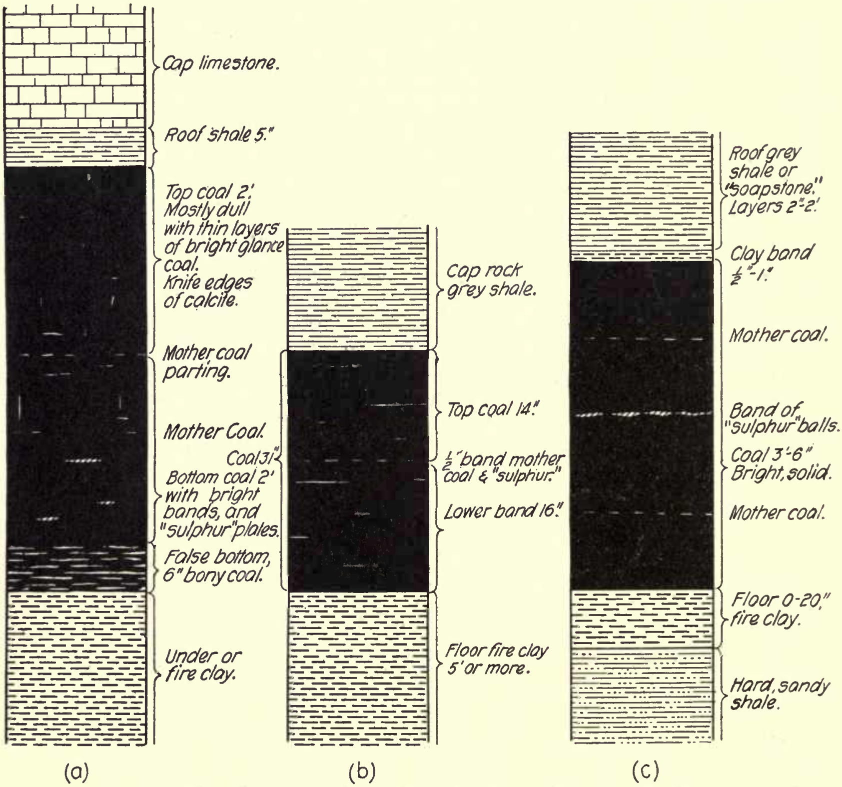

FIG. 13. TYPICAL SECTIONS OF SEAMS NOS. 1 AND 2.

faulting and tilting, all being practically horizontal. This has tended to keep the beds regular in general physical structure over large areas. Since Illinois coal is relatively firm, the preparation of sized coals intended for competition with the domestic sizes of anthracite has recently become a noticeable feature.

The sections shown in Figs. 13 to 16 have been prepared to illustrate the relative occurrence and distribution of impurities in the different coal seams worked in Illinois together with the nature of roof and floor. These in no way reflect on or give prominence to any one seam, since the quality of the merchantable coal is largely affected by

TABLE 5.

AVERAGE ANALYSES* OF COAL IN SEAMS DESCRIBED.

Illustration Fig. No.	Seam	Number of Samples	Proximate analysis of coal: 1st; "as rec'd," with total moisture. 2nd; "Dry," or moisture free				Sulphur	B. t. u.	Unit Coal B. t. u.
			Moisture	Volatile Matter	Fixed Carbon	Ash			
13a	1	11	15.58	39.17	35.80	9.45	4.69	10,673	.....
			Dry	46.40	42.41	11.19	5.55	12,643	14,546
13b	2	3	17.40	33.30	41.48	7.82	2.03	10,811	.....
			Dry	40.32	50.20	9.48	2.45	13,091	14,663
13c	2	33	16.18	38.83	37.89	7.08	2.89	10,981	.....
			Dry	46.34	45.21	8.45	3.45	13,101	14,528
14a, 14b	5	54	15.10	36.79	37.59	10.52	3.52	10,514	.....
			Dry	43.32	44.28	12.40	4.15	12,384	14,447
14c	5	27	6.75	35.49	48.72	9.04	2.92	12,276	.....
			Dry	38.06	52.25	9.69	3.13	13,165	14,812
15a, 15c	6	76	12.56	38.05	39.06	10.33	4.01	9,848	.....
			Dry	43.52	44.67	11.81	4.59	12,406	14,377
15b	6	58	9.21	34.00	48.08	8.71	1.53	11,825	.....
			Dry	37.45	52.96	9.59	1.68	13,025	14,585
16a	2	15	9.28	33.98	51.02	5.72	1.29	12,488	.....
			Dry	37.46	56.24	6.30	1.42	13,765	14,818
16b	6	31	14.45	35.88	40.33	9.34	2.55	10,919	.....
			Dry	41.94	47.14	10.92	2.98	12,764	14,557
16c	7	18	12.99	38.29	38.74	9.98	2.93	11,143	.....
			Dry	44.01	44.52	11.47	3.37	12,807	14,740

*S. O. Andros, "Coal Mining in Illinois," Bulletin 13, Co-operative Agreement, p. 57.

the care and skill exercised in its mining and preparation. These sections and the accompanying analyses of the coal listed in Table 5 are based mainly upon data gathered by the Illinois Coal Mining Co-operative Investigation.

The instructions given the samplers engaged in gathering the face samples for the analyses called for the exclusion of all impurities in the seam more than ⅜ inch thick, or thinner partings or impurities if, in the judgment of the sampler, such are excluded by the miner in loading the coal. The latest directions of the U. S. Bureau of Mines for taking face samples are practically the same, with the addition that "lenses or concretions of 'sulphur' or other impurities more than 2 inches in maximum diameter and one-half inch thick are excluded if, in the judgment of the sampler, they are being excluded by the miner from the coal as loaded out of the mine or as shipped."* It is evidently assumed that these are the maximum sizes the miner would allow to enter the car with the coal. The commercial sizes of prepared coal may be higher or lower in impurities and ash than these face samples, depending largely on the care used in preparation.

Seam No. 1 in Mercer county (Fig. 13a), averages 4 feet in thickness. The coal has weak or incipient cleavage, along which plates and films of pyrite or calcite may be developed, and locally, sulphur bands are interbedded with the coal. Directly over the coal is a shale band 2 to 5 inches thick, which tends to disintegrate and fall on exposure to the air, and which may, therefore, mix with the coal. Below the mineable coal there may be a thin band of bone giving way to a soft fireclay, that swells badly on exposure. This has been likened to bread rising. The output from this seam is scarcely large enough to affect the general market.

Seam No. 2 in McDonough county (Fig. 13b), averages about 30 inches in thickness and consists of a top and a bottom band which are separated as shown. The coal as a whole is built up of fine laminations of bright and dull coal. Irregular bands and lenses of pyrite occur in places. The roof is a grey shale or "soapstone," and the floor fireclay; usually soft.

Seam No. 2 in LaSalle county (Fig. 13c), averages about 3 feet, 6 inches in thickness. The coal is uniformly long grained, hard, bright and firm. It tends to split parallel to the bedding, being aided by the mother coal layers. One or two irregular bands of sulphur balls are found in some places. The roof is a brittle blocky gray shale or soapstone separated from the coal by a clay band ½ inch to 1 inch thick. The floor, in which undercutting is often done, may vary from fireclay to a sandstone. In general, this is a clean seam and little or no picking is necessary to prepare an excellent lump coal for the market. Considerable fire clay, which may be removed by washing, is mixed

*A. C. Fieldner, "Notes on the Sampling and Analysis of Coal." U. S. Bureau of Mines, Technical Paper 76, p. 8.

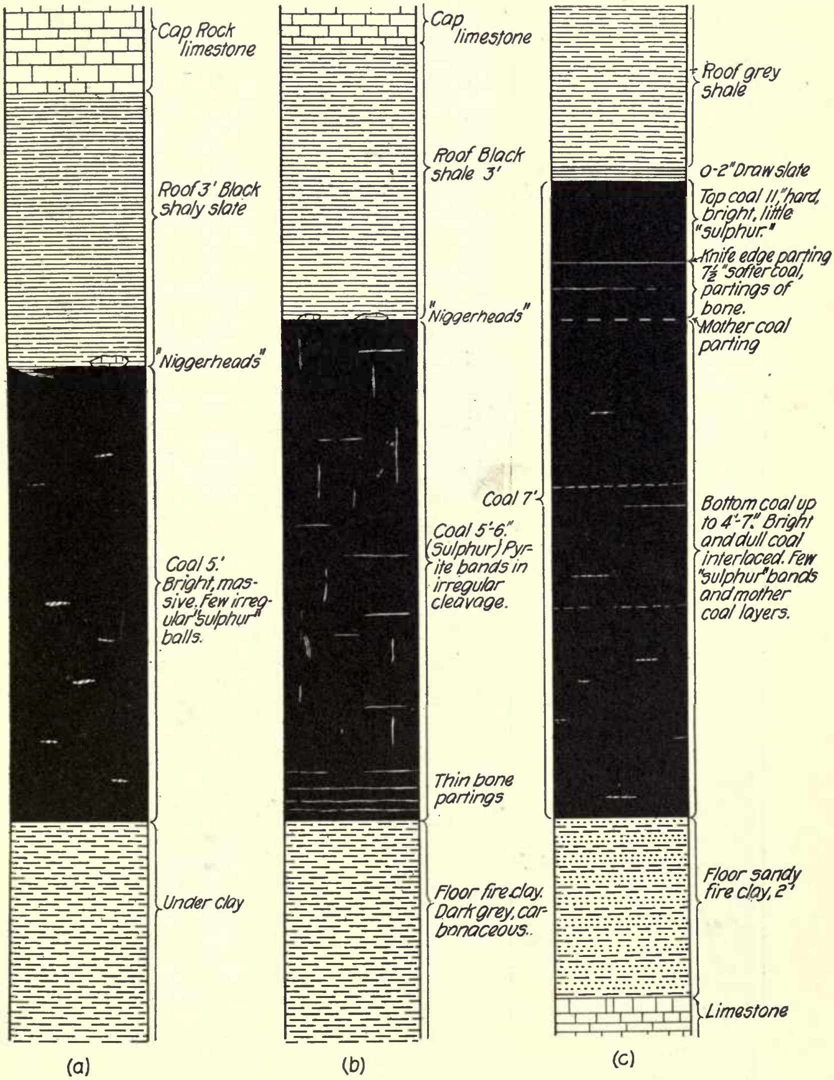

FIG. 14. TYPICAL SECTIONS OF SEAM NO. 5.

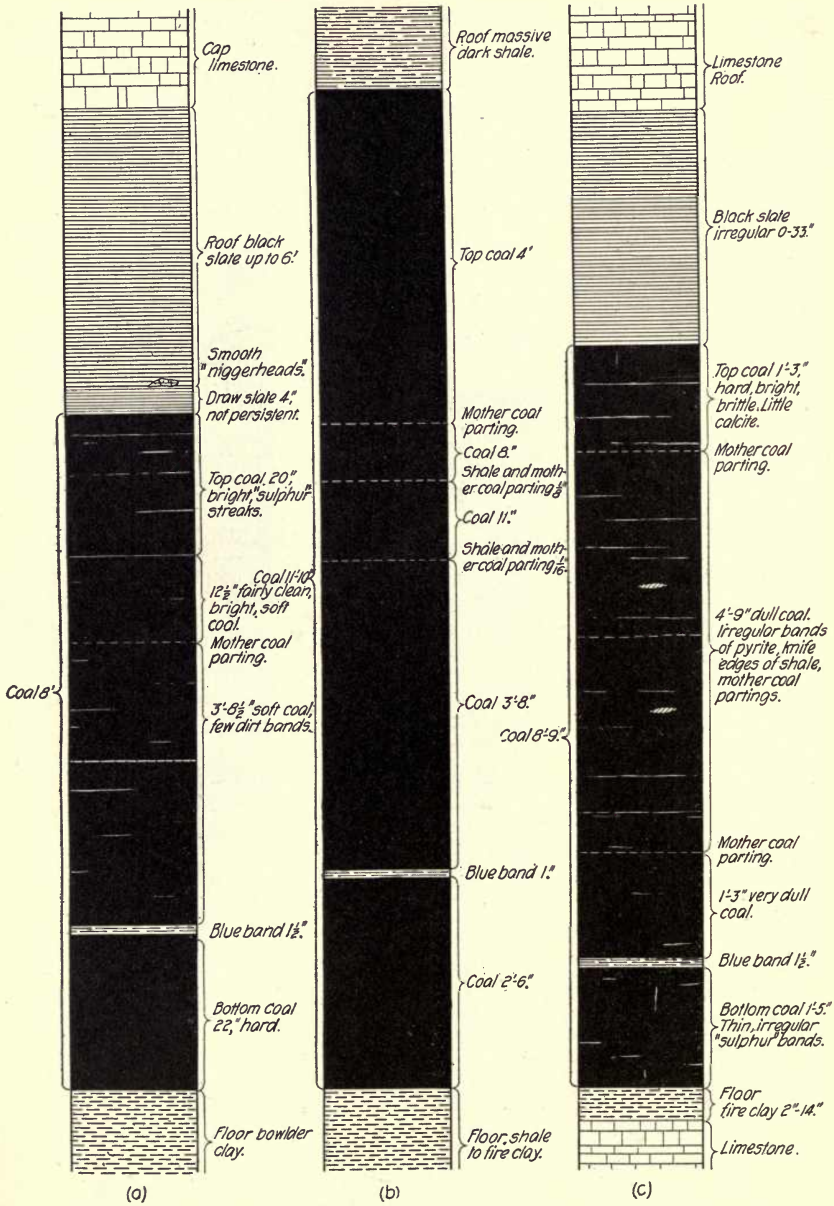

Fig. 15. Typical Sections of Seam No. 6.

with some of the screenings.* As an illustration, raw screenings from this field containing 28.87 per cent ash, are reduced by washing to nut coal containing 8.75 per cent ash and to slack coal containing 9.96 per cent ash.† The top coal is generally harder than the bottom.

Seam No. 5 at Lincoln, Logan county (Fig. 14a), consists of about 5 feet of bright massive coal. There are some irregular balls and bands of sulphur and other impurities present. The roof contains frequent concretions or "niggerheads."

Fig. 14b shows the same seam in the Springfield district. The sulphur here often is irregularly distributed in thin plates in the cleavage planes of the coal. The seam in this district is relatively free from impurities. The chief of these is sulphur in vertical faces. Also, in places a rather high percentage of ash is noted in the lump coal, due to a slight tendency of the coal to be bony. This same tendency, however, results in a coal that is unusually tough, hard and firm, and able to withstand breakage as well as any in the state. Rolls, horsebacks, and clay veins, which are of frequent local occurrence, are often avoided by careful mining. The fact that of these clay veins the large ones are soft, and the small ones are hard, has considerable effect on the cleanness of the adjacent coal.

Fig. 14c shows the seam mined in Saline county, and correlated by the State Geological Survey with seam No. 5. In general it is a bright laminated coal, the hard top coal being succeeded by a much softer coal in the middle of the seam, and this by a harder coal on the bottom. The noticeable feature of this seam here is its low moisture content. This coal has been compared favorably with the famous Hocking Valley coal.‡ Locally, in the roof there are bone and stringers of coal up to 3 feet or more above the true coal. The roof is generally a hard calcareous shale, while the fireclay bottom in places is sandy and heaves badly when wet. Only incipient cleavage is developed, and the coal has a good reputation for hardness.

Seam No. 6 (Fig. 15a) in the Standard district east of East St. Louis is usually divided into several benches by partings, sometimes of mother coal, often by sulphur or by shale bands, which include the blue band. In many places the roof consists of a thin layer of dark drawslate, locally called clod, containing frequent niggerheads. In places in which this drawslate is absent, the cap limestone forms a firm roof. According to A. J. Moorshead,¶ the coal is harder where limestone forms the direct roof. The floor, although a clay shale containing frequent boulders, as a rule does not heave, except when wet. In the mines in which the coal is thick (8 feet) the top coal

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*A. Bement, "Illinois Coal Fields." J. W. S. E., June, 1909.

†F. C. Lincoln, "Coal Washing in Illinois." Bulletin No. 69, Engineering Experiment Station, University of Illinois, p. 90.

‡A. Bement, "The Illinois Coal Field." J. W. S. E., Vol. 14, 1909, p. 319.

¶Colliery Engineer, 1914, p. 435.

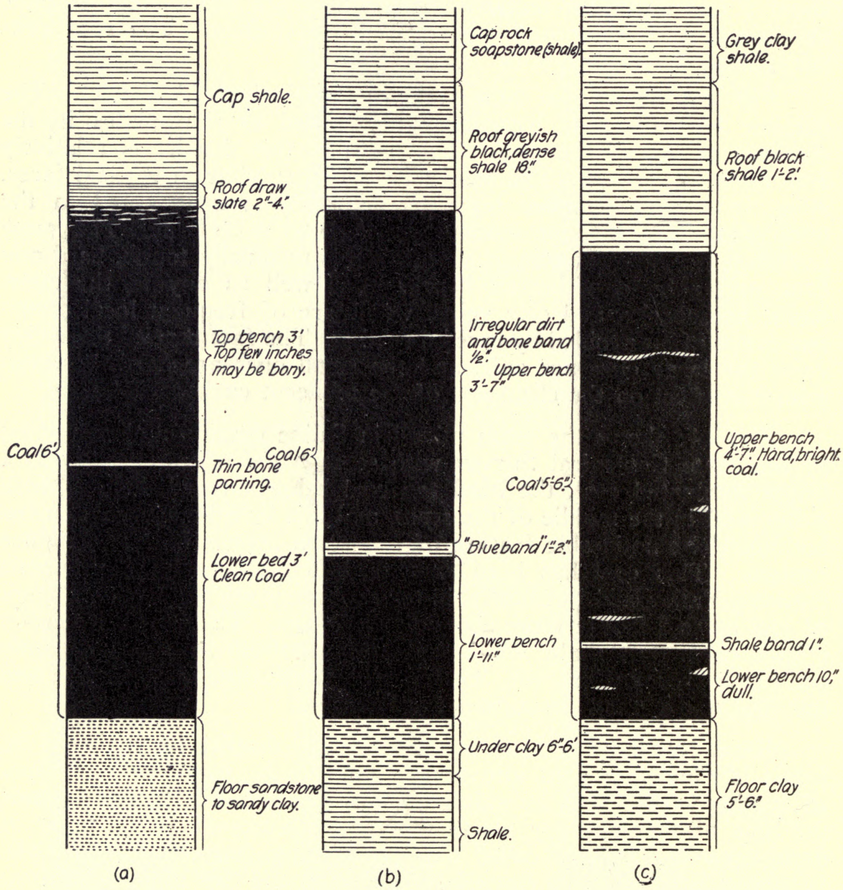

FIG. 16. TYPICAL SECTIONS OF SEAMS NOS. 2, 6, AND 7.

shown is often left in order to hold the roof in place. Since the district covered in the analyses embraces fifteen counties in whole or in part, considerable difference is evident in local physical characteristics. On the whole, the coal contains enough bands of impurities to require care and attention in removing them during its preparation.

Seam No. 6 in Williamson and Franklin counties (Fig. 15b), varies from 7½ to 14 feet in thickness. Excepting for the blue band and locally sulphur in thin, irregular vertical plates, the coal is clean. Although from the standpoint of heating value, it is not the best coal in the state, its toughness, strength and clean glossy appearance make it a favorite, especially for domestic trade and for northwest shipments often requiring several handlings enroute. Also, it withstands storage well. In places a definite east and west vertical cleavage affects to some degree the sharpness of its breakage. The top coal is frequently left in place.

The coal in seam No. 6 in Macoupin county (Fig. 15c), is often more brittle than that in the same seam farther south. This county is included in the average analysis given for seam No. 6, Fig. 15a.

Seam No. 2 in Jackson county (Fig. 16a), is often called Big Muddy or New Kentucky. Its chief characteristics are general freedom from impurities and high fixed carbon, as compared with most other coals of the state. The thin bone parting varies from zero up to 30 feet in thickness, in which case only the lower and better bed is mined. The cleavage is more pronounced than in any other district in the state, the coal breaking freely northeast and southwest, thus making blocky lumps of a bright lustre. As a rule, the floor is more stable than those in the other districts. The former use of this coal for the manufacture of blast furnace coke indicates its generally low sulphur content. A. Bement called this coal the best west of the Appalachian region,* and it is to be regretted that the district is so limited.

Seam No. 6 in the Danville district (Fig. 16b), called the Grape Creek field, consists of two benches, separated by the blue band, the upper bench being usually duller and dirtier than the lower. The roof, varying from a gray to a dark shale with little bedding, breaks away easily and falls, often in conchoidal masses, and thus is mixed more or less with the coal. The underclay swells readily. The bands and nodules of pyrite present are usually thick enough to allow hand separation. Rolls occur in both floor and roof, and frequent horsebacks tend to mix considerable fine impurity with the coal.

Seam No. 7 (Fig. 16c), as it occurs in the Danville district, is the uppermost seam exploited commercially in the state. The feature of the bed is the large lenses and bands of sulphur, which can be easily

*Black Diamond, June 27, 1914, p. 53.

removed in mining and preparation. In general, the lower bench of the seam is hard and dull, overlaid by a softer, cleaner coal near the center of the seam and again by a harder bright coal at the top. The cap rock, a gray clay shale, is soft, and where open cut mining is practiced is dug and removed by steam shovels. The bottom is soft and rolls are frequent.

PART II. IMPURITIES.

Impurities in the Coal Bed.—The diagrams or logs of the various Illinois coal seams (Figs. 13-16), show that they contain various thin bands or streaks of impurities, such as are found in practically all bituminous seams. In order to discuss these impurities, they have been divided by authorities into groups relating either to their origin, position in the seam, or ease of removal. The writer prefers a grouping by origin which divides these coal impurities into three general groups which have been variously named as follows:

Group 1. Innate, Intermixed, Inherent, Normal Ash, or Inseparable Impurities.

Group 2. Sedimentary, Interbedded, Intercalated, or Separable Impurities.

Group 3. Infiltrated, Extraneous, Interstitial, Segregated, Subsequent, or Precipitated Impurities (Sometimes Separable).

Group 1. Innate or Inseparable Impurities.—All the terms listed under this group have been used to describe the true or normal ash of the coal. Since coal is a product of plant remains, it must contain the original mineral matter or ash of such plant. Trees or plants of the present day contain about one per cent ash, but since ancient plant remains have undergone great changes and losses of weight through partial decomposition before arriving at their present stage of coal, and since the mineral matter remains without loss in the decreasing residue, the inherent ash may amount to a much larger percentage in the coal than in the original vegetable matter. Such impurity may be considered a part of the original coal substance. It is present in every piece of coal and cannot be removed or altered by any process of preparation. Certain coals have probably as low as 2½ per cent inherent ash. The author determined approximately by a number of experiments the inseparable or inherent impurities in Illinois coal. Each sample was crushed to pass a ¼-inch mesh screen and then subjected to a "float and sink" test in a solution of 1.35 specific gravity, which allowed the purest coal to float and the separable impurities to sink. The results indicated that the inseparable impurities varied from 3 to 7 per cent, with an average of about 5 per cent.

If the coal bed were formed slowly by accumulations under sheltered and shallow water conditions, and if this water were clear and without sediment, a coal would result containing only inherent ash. If, however, the waters of the marsh contained sediment, such as might arise from the influx of rivers, etc., the slow settlement of this slimy mineral matter simultaneously with the growth of the coal forming bed would produce a coal containing a uniform mixture of this impurity and coal. Such an impurity would increase the ash content, and as it increased in amount would cause the coal to assume more and more a rocklike character, both in appearance and physical characteristics. Since such sediment is, in most cases, a clay-like slime, or clay in a more or less colloidal state, which becomes shale under heat and pressure, its presence in increasing percentages tends to lower rapidly the commercial value of the coal. These impure coals are called bony coal or simply "bone," and by English engineers "bass." Geologically, there may be a range of bone coals containing as much as 50 per cent clayey matter; beyond this point the substance is no longer coal, but a carbonaceous shale, with pure shale as a limit.

If these conditions persisted to a slight degree only during the formation of the coal bed, this admixture of impurity, while increasing slightly the ash content of the coal, would produce through its own cementing tendency a harder and firmer coal than the average. As an illustration, the clean lump from seam No. 5 in the Springfield and Peoria districts is usually slightly higher in ash than the usual clean coal from some other districts, but is of such a recognized hard nature that special provision is made for its mining in the agreement between operators and miners.

If these conditions favoring the formation of bone coal were periodic or infrequent during the growth of the seam, certain benches only of the coal seam would be bony. At many places in this state the bottom bench of the seam is of a higher ash content and is harder than the upper benches, although not bony to a degree which interferes with its commercial value. This is illustrated by seam No. 7 in the Danville district. On the whole, the coal seams of Illinois are unusually free from benches of true high ash bone coal, and trouble is caused by it locally in one or two seams only.

The moisture and oxygen in the coal are also inherent impurities, but since they are removed only by weathering, heating and similar methods, they are not impurities removable in the dry preparation of coal at the mines. S. W. Parr says, "A coal with 14 per cent moisture may reach the consumer with 10 per cent only, therefore the value per ton is greater than when the coal left the mine."* This, however, is probably due to part of the moisture in Illinois coals being held mechanically in the pores and drying out on exposure; therefore, it is not an impurity under control of the operator in the preparation of the coal.

The effect of oxygen in coal is fully discussed by David White, who shows in Bulletin 29, U. S. Bureau of Mines, that oxygen is an inert constituent in coal, and unit for unit of weight takes the place of so much combustible material.

*Bulletin No. 16, Ill. State Geol. Survey, p. 227.

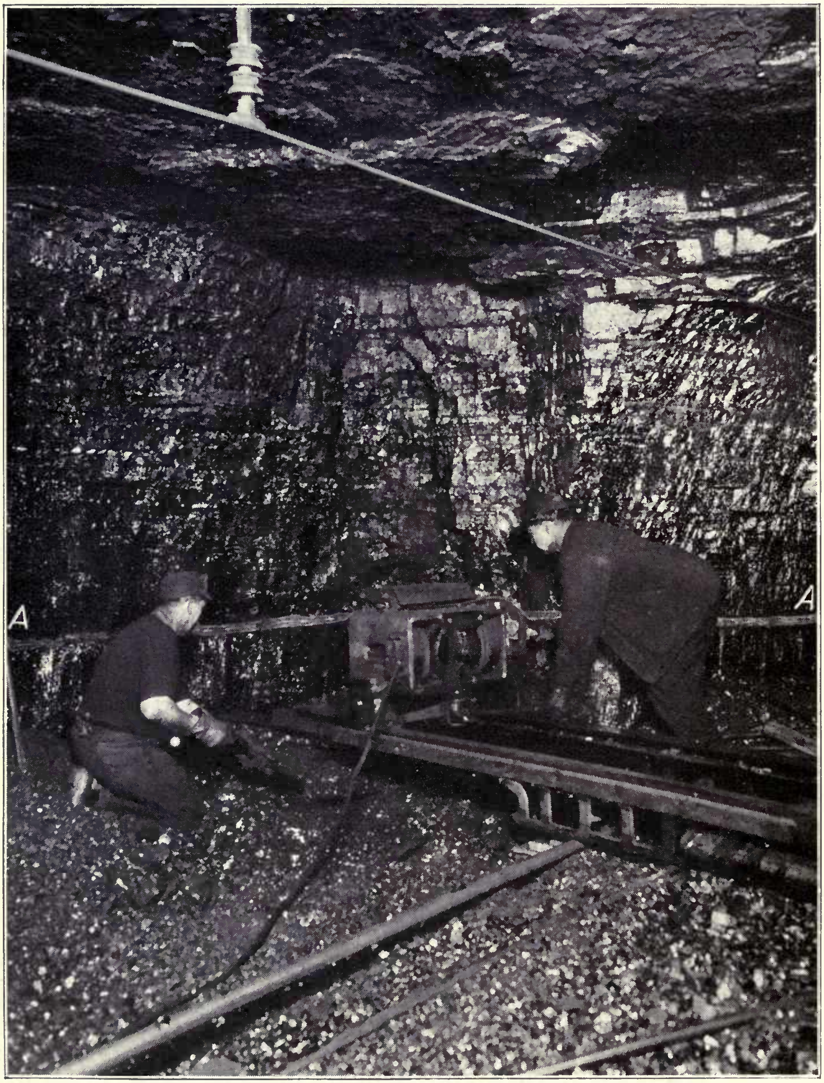

FIG. 17. THE "BLUE BAND."
AA=LINE OF BLUE BAND.

Group 2. Sedimentary or Interbedded Impurities.—Bone coal may be formed in layers or bands intermixed with and separable from the better coal. Such bands may be of any percentage mixture of pure coal and mineral matter and range in thickness from a knife edge to a dimension that separates the coal into two benches. Moreover, such a band may be either flat or lenselike in shape, and either local or of even thickness over a considerable area.

During mining these bands tend to break free from the coal into characteristic flat pieces. As they approach a pure shale in composition ($Al_2O_32H_2O + XSiO_2$) and also containing varying percentages of lime ($CaCO_3$), the color becomes lighter, usually a stony gray, and the specific gravity increases. This makes easy, detection and removal of the coarsest bands by the miner at the face, or by the picker in the better light of the tipple above ground. If these bands are in coal below two or three inches in size and above 5 to 10 per cent in quantity, their removal is accomplished only by some mechanical means, chiefly washing. From the larger sizes of coal, approximately those above three inches, and not exceeding 5 to 10 per cent in quantity, these shale bands can be removed by hand picking, although at the present time the largest percentage of such an impurity hand picked in an Illinois tipple does not exceed 3 per cent of the total coal, or about 4.5 per cent of the sizes above screenings.

Bands of bone coal, containing more than 50 per cent of coal substance, are dark in color and not greatly different from the coal in weight. This renders their removal difficult, whether attempted by hand picking or by washing, which process depends for success upon a considerable difference of specific gravity between coal and impurity.

An examination of the coal sections illustrated on pages 47 to 52 shows that the thinner of these impure bands, those under ¼ or ⅜ inch in thickness, may easily become mixed with the finer coal and not be detected. The thicker ones must be removed at some stage of the preparation, since the appearance and consequently the sale of the coal is injured by their presence, perhaps more than the coal is actually deteriorated chemically. Unfortunately, many of the shale bands in Illinois coal are rather soft and tend to soften, peel, and disintegrate rapidly upon exposure to air and moisture. For this reason, their complete removal from the finer sizes of coal is a problem of some difficulty. In most cases, the purer the shale, the more it tends to soften and disintegrate. The floor shale "fireclay" tends to disintegrate much more rapidly than the interbedded or the roof shale. The miners of the state call these bands of impurities "blue band" (referring to the well known impurity of seam No. 6), "black band," "blackjack," "stone," "grit," "dirt," or "brash." Fig. 17 shows the blue band of Seam No. 6 in Franklin county. Lumps in which coal layers and shale bands are intimately mixed in the same piece are called "intermixed," or "intergrown" coal.

Group 3. Infiltrated or Subsequent Impurities.—This group includes the visible impurities in the coal which were introduced subsequent to the formation of the bed, such as pyrite, calcite, or gypsum.

Underground circulating waters contain considerable amounts of iron, lime, and gypsum salts in solution, which deposit or precipitate under favorable conditions. Such conditions are furnished by the reducing tendencies of the carbonaceous matter of the coal, and by the more porous layers of the seam which furnish easy channels of circulation for the solutions. The firmer bands of the seam tend to define

FIG. 18. PYRITE LENSE IN ILLINOIS COAL.

and limit these channels. Having started deposition around some favorable nucleus, further deposition tends to enlarge the particle. The final result will be nodules, bands or lenses of pyrite (iron sulphide, FeS_2), containing if pure 46.6 per cent iron and 53.4 per cent sulphur. By the miners they are usually called "sulphur balls," "sulphur," "cat faces," "kidney sulphur," or "brasses." The nodules have an irregular maximum thickness of several inches. Less resistance usually has been offered to the growth of these masses along the bedding or lamination planes of the coal; for this reason sulphur bands are horizontal in the bed, and may be either flat or slightly lenticular in shape. Often the bands are quite flat, are as much as one or two inches in vertical thickness, and may have a horizontal extent of many square feet. The lenses are sometimes 5 or 6 inches in vertical dimension and considerably greater in length along the bed. Like interbedded shale the pyrite is rarely pure in composition, an analysis of one lump showing 33.2 per cent of volatile matter and fixed carbon present. Occasionally, lumps of pyrite are seen, the forms of which suggest the replacement of bits of branches or other woody tissue. Fig. 18 illustrates the occurrence of pyrite lenses in Illinois coal.

The sulphur balls or bands, being brassy yellow in color and of high specific gravity (if pure from 4.9 to 5.1) are easily distinguishable by the miner, and are usually thrown into the gob. Frequently the pieces are more or less coated with adhering coal, and if missed by the miner are removed by hand picking in the tipple or on the railroad cars.

At one mine in the Standard (Belleville) district at which seam No. 6 is worked, enough of this lump pyrite is picked in a clean condition from the coal during screening and loading to justify saving and shipping the product to various chemical companies for use in the manufacture of sulphuric acid. At certain mines in the Danville district (seam No. 7), numerous large bands of pyrite are hand picked from the coal by the loaders, or in the tipple by pickers during screening and cleaning. Enough impure pyrite is secured from several mines to justify the erection and operation of a washing or jigging plant in which the raw pyrite or sulphur with its adhering bands or bunches of coal is crushed and washed. After the completion of this process the clean pyrite is shipped, and a quantity of fairly clean small coal is recovered as a by-product. In most other places in the state pyrite is justly regarded as a deleterious impurity, not only harming the appearance of the coal if not removed, but aiding materially through its combustion products FeS and FeO in the formation of clinker when the coal is consumed.

Information obtained by correspondence with various chemical companies indicates that the possible market for such a product as pyrite is limited since pyrite is used in quantities for the manufacture of sulphuric acid only when there is a scarcity of the usual and cheaper raw material—the sulphur in zinc blende. Any attempt on the part of Illinois coal operators to generalize the commercial production of pyrite as a by-product of washing or of picking belt, would result at present in a complete demoralization of the market and in a consequent lack of sale.

If all the sulphur in Illinois coals were in this lumpy form its removal would not present any serious difficulties since it can easily be removed from the smaller sizes by mechanical washing processes. Unfortunately, in many of the districts in this state the pyrite is found adhering to the coal in very thin leaves or plates, often several inches square and of almost infinitesimal thickness. These plates have originated by reason of the incipient vertical cleavage in the coal, such planes of weakness having afforded opportunity for the deposition of pyrite in irregular thin plates. When the coal is mined, it breaks into lumps more or less along these cleavage lines, thus exposing to view the thin brassy plate of pyrite. By actual weight or percentage the amount of sulphur in such a coal may be small, even smaller than in coals which show no sulphur to the naked eye. Coal with these glistening films is at a disadvantage on the market since consumers believe that they are an indication of an inferior fuel.

Such pyrite is difficult to remove from the coal underground; in fact, so many lumps of coal may have one or more glistening sulphur faces that a clean separation would involve the waste of a large percentage of the coal. Unfortunately for miner and operator alike, every fresh break in the coal during preparation is likely to expose fresh brassy faces. Again, these thin films hang closely to the coal, and their removal by any process of breaking and picking involves the loss of much lump coal. Another factor is that coal dust easily sticks to and hides these faces, making them indistinguishable until subsequent drying and jarring again bring them to light.

At one mine as many as fifty tons of coal having blotches of this pyrite are picked out in the tipple each day in an effort to ship coal that looks well. This is about 2½ per cent of the daily production of the mine. The coal thus separated is crushed and used as second grade fuel. At another mine which makes a specialty of sized domestic grades, the egg and nut coal are wetted or rinsed by sprays of water before being hand picked, thus removing any adhering dust and bringing to light the pyrite films. This rejected coal is also used for purposes for which appearance is not a requisite.

The author has not observed any regularity by districts in the distribution of this leaf pyrite, every seam in Illinois containing some of it, at least locally. For instance, at one mine no leaf pyrite is found in seam No. 6, while at another mine only a few miles distant it is present in the same seam. This form of pyrite cannot usually be removed by mechanical washing, because it adds little to the weight of the individual piece of coal to which is it attached. In general, operators troubled by it, though at a disadvantage in the open and domestic markets, should have little difficulty meeting competition based on specifications since the trouble often looks worse than it really is.

The total sulphur content of Illinois coals ranges from 1 to 6 per cent, most of it being held in the forms previously noted.* The remainder, probably from ¼ to ¾ per cent of the coal, is in some not well understood chemical organic combination, probably with the hydrogen and carbon of the coal. Such organic sulphur supposedly is completely burned in the process of combustion. This form of sulphur is present in all coals, and is so intimately combined with the coal substances that it is not apparent to the eye and cannot be mechan-

*S. W. Parr, Bulletin 16, Illinois State Geological Survey, p. 226.

ically separated from it. For this reason, it may be classed with the ash of Group 1. The minute percentages of phosphorus present in coal may be classed with this sulphur. Such organic sulphur does not lessen the value of a coal for combustion.

Only those forms of sulphur, such as pyrite, which occur as a mineral in the coal and which after combustion leave an incombustible basic residue such as iron oxide (FeO), promote the formation of the ash slag known as clinker. However, a complete solution of the clinker problem involves a study of combustion temperature and conditions* and of the proportion in the ash of the basic compounds (iron or lime) to acid compounds† (silica and alumina), and of their relative sizes and admixture. Pyrite alone need not cause trouble.‡

Calcite ($CaCO_3$), and in smaller quantities, gypsum or calcium sulphate ($CaSO_4$. $2H_2O$), and still smaller amounts of other salts occur in much the same way as flake pyrite. Many Illinois coal beds contain these thin flakes of calcium sulphate and of gypsum in the small joints and cleavage planes of the freshly mined coal. If these minerals are present in considerable quantity their whitish color offers an easy means of detection, and removal may be made by hand picking. Seams Nos. 1 and 7 especially contain in places considerable amounts of these impurities. The presence of gypsum adds a percentage of sulphur to the coal. Whether or not these impurities may be removed by washing depends upon their amount, thickness, and tenacity to adhere to the coal. At only a few mines is attention paid to them during preparation, their presence usually being of chemical interest only.

Another probably subsequent impurity is the clay or shale which often fills small vertical fissures through, or in the top or bottom of the coal bed. These are locally called slips, horsebacks, or mud seams. In some districts, for instance around Springfield, these impurities occur frequently in seam No. 5, and are called "clay slips." They are probably caused by the soft floor or roof material having worked, under pressure, into local slips or faults in the coal bed. Local rolls in roof or floor, causing thinning of the seam, together with more or less intermixture of coal and shale often occur. The method of separation of any of these from the coal is similar to that of removing the shales as noted in Group 2. Many such disturbances are avoided in mining and they are not necessarily an impurity.

Niggerheads are sometimes present in or just above the coal bed. In the same way that pyrite through deposition forms sulphur balls, calcium carbonate, or iron carbonate, upon deposition around a favorable nucleus, may form oval concretions or niggerheads often several inches or even feet in diameter. These impurities, readily detected on account of their size and shape, can be easily removed by the miner when shot down with the coal in the mine.

Even the coal part of a seam is not a solid homogenous mass of

*S. W. Parr, Bulletin 16, Illinois State Geological Survey, p. 226.
†F. R. Wadleigh, Coal Age, June 22, 1912, p. 1206.
‡W. B. Phillips, Coal Age, July 27, 1912, p. 111.

pure shining coal. A casual inspection shows that the seam is built up of alternate bands or laminae of bright, shiny coal, and dull, lustreless coal. According to T. E. Savage,* a close examination of much of the Illinois coal shows that these alternating laminae are generally between 1/32 and ½ inch and often more in thickness, and that in places the dull laminae make up nearly one-half of the coal bed. Coal in which the bright bands predominate has in the small sizes a bright appearance approaching anthracite, popularly supposed to be necessary with a good coal.

A powdery dull thin band generally of paper thickness, called mother of coal, mineral charcoal, or carbonized wood, forms a distinct parting between many of these layers or laminae in Illinois coals. On exposure such a band leaves a slight smut when touched with the finger. If of any thickness, it dusts badly when the coal is mined and must in such cases be a definite factor in the formation of fine dust. Although somewhat unlike the other dull coal in appearance, this mother of coal is usually associated with and constitutes a part of such a band.

David White and R. Thiessen,† and James Lomax,‡ have studied microscopically the bright and dull bands in coal and their conclusions are that dull bands may be as truly coal substance as the bright bands with which they are associated. E. C. Jeffrey¶ came to the same conclusions concerning mother of coal or mineral charcoal. These statements do not apply to the definite bone or shale bands which, although dull in color, are entirely different in appearance. An analysis of the dull mother of coal layers from seam No. 6 in Williamson county§ showed them to contain the same amount of ash as the average coal from the seam. Several analyses made recently by M. L. Nebel,** however, showed in every case higher ash values in the dull bands than in the bright bands in the same lump of coal. A sample of mother of coal taken from a band ½ inch in thickness in seam No. 6, Williamson county, and analyzed under the direction of the writer, gave the following proximate analysis: Moisture (as received) 0.16 per cent; volatile matter 9.75 per cent; fixed carbon 87.47 per cent; ash 1.72 per cent; and sulphur 0.90 per cent. This indicates that mother of coal is a high grade coal of different composition than the rest of the seam. Since the presence of the dull laminae and the mother coal are specially prominent in Illinois coals and since coal of a dull appearance is at a disadvantage in the open market, further analytical work concerning the relative purity and composition of these bands is desirable.

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*Journal of Geology, Vol. 22, No. 8, 1914.
†"The Origin of Coal," Bulletin 38, U. S. Bureau of Mines, pp. 29 and 64.
‡"Microscopic Examination of Coal," T. I. M. E., Vol. 42, p. 2.
¶Economic Geology, Vol. 9, No. 8, p. 734.
§T. E. Savage, Journal of Geology, Vol. 22, No. 8, 1914.
**Results of these analyses will appear in Bulletin 89 of the Engineering Experiment Station, University of Illinois.

Impurities Entering the Coal from Roof and Floor.—In a majority of the mines in Illinois the roof directly above the mineable coal is of a soft crumbly nature. In some of the thicker coals, as in seam No. 6 in the southern districts, this roof is protected by leaving the bench of top coal in place. In other districts the shale roof is only a few inches thick, and when it spalls off or is taken down, is found to be overlaid by a firm limestone or other resistant roof. In mines in which the coal is under about six feet in thickness and in which it is necessary to take out the whole seam, excessive use of powder weakens the roof, which frequently breaks off, sometimes in large slabs, but oftener in small scales. When this "drawslate" is removed some of it unavoidably becomes mixed with the coal. Seam No. 6 in the Danville district has a notably crumbly roof. This impurity is more likely to occur in solid shooting mines than in machine worked or in longwall mines. In the longwall field, however, the soapstone or slippy shale roof is weak and brittle, and falls unless closely propped. In the state as a whole there are conditions of roof and customs in the use of powder which tend to introduce portions of this roof into the coal as an impurity. As a rule, this material keeps its structure well enough to make possible its removal at the proper place by picking or by mechanical means unless extra breakage allows it to pass into the screenings.

The different seams in the state generally have a soft weak clay shale or fireclay bottom. Often this floor is extremely hard when first exposed and makes a suitable bottom from which to shovel the coal; in other places it is softer and mixes with the coal. Usually, after exposure for a few weeks to the dry atmospheric conditions in the mine, the top layers of such a floor crumble and become loose and dusty. Sometimes the floor expands, swells, and rises, thus increasing the probability of the presence of impurities in the coal should shoveling be necessary at such places. In most of the cases which come under the writer's observation, the lumps of bottom fireclay, although they may be hard and firm, disintegrate if placed in water even for five minutes. Under like conditions in the mine the bulk of this fireclay passes into the screenings during preparation. In parts of the longwall field hand pick undercutting is practiced in this under shale band, producing considerable amounts of fine shale, which become mixed with the coal and pass into the screenings. Under this condition a clean high grade lump coal and dirty screenings are produced. This practice is not uniform.

In the room and pillar mines floor impurities are generally introduced through three causes:

(1) Careless shoveling.

(2) Excessive disturbance of the floor by heavy shooting.

(3) Undercutting in the bottom clay instead of in the lower bench of coal.

Careless shoveling explains itself. Concerning the second cause, W. R. Coleman* says that long 6 to 7 feet holes in solid shooting mines in Illinois may pick up from 4 to 10 inches of bottom mud, which becomes mixed with the coal during shoveling into the mine car. Although these are extreme cases, they illustrate the possibility of the addition of considerable impurity if such conditions are not kept under control. Little difficulty should be experienced in undercutting if the bottom or floor is fairly level. In some places uneven floors formed by rolls and horsebacks may be cut into.

PART III. REMOVAL OF IMPURITIES.

Removal of Impurities Underground.—Most of the larger pieces of separable impurities which have been mined with the coal may be removed underground by hand sorting during loading, but the time spent in doing this reduces a miner's daily output of loaded cars; consequently, there is an inclination to minimize this work. The regulations pertaining to this subject, as a part of the evolution of present preparation practice, have been outlined in Chapter I, pp. 23 to 29.

The claim has often been made that the most efficient place for inspection of coal for impurities is underground during loading. However, as the miners usually work in pairs only and in separate rooms, continual underground inspection in the dim light is impossible. At several mines in which persistent bands of impurities occur, the assistant mine manager makes regular trips through the mine and by noting the size of the waste or rejected pile, or the character of the coal in a partly loaded car, he is able to estimate rather closely the percentage of rejected impurities. If he detects carelessness, word is sent to the regular coal inspector at the surface plant to watch closely for the cars of the miner in question. It is probable, however, owing to the multiple duties of the assistant mine manager and to the limited number of these officials allowable under the agreement between the operators and miners, that underground inspection is casual rather than systematic.

Once in the mine car further inspection is impossible until the coal is dumped or spread out on the screen in the tipple. One mine only was visited in which inspection was attempted in the loaded cars at the shaft bottom before hoisting. Since the natural tendency is to put clean coal on the top of the car, it is difficult to see how such inspection could be effective. At the particular mine noted, condemned cars were not hoisted into the tipple, but were set off at the surface landing and kept there for the inspection of the interested parties, and in full view of all men entering or leaving the cage. It was explained that the effect of this was noteworthy.

*Proc. 1st Annual Convention, International Railway Fuel Association, 1909, p. 22.

It is necessary to emphasize how closely all the impurities loaded with the coal are within the control of the miner at the face. If he takes pride in his trade, is careful, undercuts with skill, uses powder with judgment, and loads with care, a considerable part of preparation has been accomplished, and he has done his part towards making a good name in the markets for the mine in which he works.

Removal of Impurities in the Tipple.—At practically all mines in Illinois an attempt is made to remove the bulk of impurities loaded underground at one or more of the following places in the surface plant:

(a) In the tipple during screening.

(b) On picking bands or belts after screening.

(c) During the loading of the railroad cars underneath the tipple.

At one of these places a coal inspector, dock boss, or rock man is stationed, who not only watches for impurities and penalizes the miner according to the joint agreement (see page 24), but often has general charge over the men picking and loading the coal. Some companies place an inspector at each tipple, others employ a single inspector who covers two or more of their neighboring surface plants. Large companies frequently have one chief inspector who superintends dock bosses at the individual tipples. In all cases close inspection was reported beneficial in lowering the percentage of ash in the coal. Frequently, the buyer is notified if a railroad car which has been loaded contains defective coal. An economy of 6/10 of one per cent will pay for inspection at the mines.*

At a few tipples in the state the dock boss "rides" the screen; that is, he is seated on a stationary support just above the shaking screen, from which with perhaps one or two assistants, he can bend down and remove the impurities from time to time. If the screen is narrow (7 feet or less), the dock boss and his assistants may stand at the sides and remove impurities; in either case throwing the rejected material into chutes which lead to a refuse car or pile below. Such inspection is not very efficient in the dusty surroundings if a considerable amount of impurities is present, if a large tonnage (perhaps 2,000 tons or more) passes over the screens, or if wide screens (7 to 10 feet) are used. Another factor hindering the detection of impurities is the mixture of sizes from nut to the largest lumps, which must be examined at the same time. In such a mixture of sizes, lumps are bound to hide the impurities of nut size. This difficulty is overcome at several tipples by the use of a patented combined screen and picking table. The screen is horizontal and of sufficient length and movement to separate efficiently the sizes and allow picking on the screen under favorable conditions. This screen will be described later.

*Eugene McAuliffe, Proc. 4th Annual Convention, Int. Ry. Fuel Assoc., p. 280.

The Black Diamond, under date of Feb. 1, 1913, stated that picking tables after screens were new in Illinois. The demand for cleaner coal forced Illinois operators, especially at the large mines, in which from 2,500 to 5,000 tons per day were handled in the tipple, to adopt these picking tables or belts as a method of removing the refuse. The picking tables (Fig. 19), are from 3 to 5 feet wide, often 30 feet long, 30 inches above the floor, and are endless belts either of rubber or of steel links covered with small over-lapping sections of steel plate. The tonnage handled is up to 1,000 tons per day per belt. These belts catch the coal as it falls through or leaves the screen and convey it horizontally at right angles to the screen. Each size of coal may have an individual belt or picking table. Thus the coal, spread out on the belt and traveling at a speed of from 30 to 60 feet per minute, passes before men or boy pickers who can easily pick out the refuse. Dirty coals, of course, require low speed and additional pickers. Speed depends also on the size, on the color, and on the shape of the impurities; that is, the ease with which they can be distinguished.

Fig. 19. Operation of a Picking Table.

In general, picking tables, bands, or belts have the following advantages:

(1) Thorough inspection; all coal being spread out in fixed sizes and moving at a fixed rate.

(2) Decreased length of chutes and height necessary to feed certain tracks.

(3) Loading of coal in a constant stream with minimum velocity and breakage.

(4) Safety and effectiveness of pickers; they are no longer exposed to the dust on the screens or to danger in the loading cars.

(5) Combined with a movable loading boom, they reduce further the breakage and allow easy loading on cars of different heights. The only disadvantages are first cost and maintenance.

At one mine in which pyrite refuse is saved from the tables, six rock pickers, three on lump and three on egg, pick out 50 tons of pyrite per day, or about 8 tons per man per day. On account of the high percentage of refuse, stationary plows are fixed on the tables close above the belt, so that the moving coal may be turned over and thus expose to view any hidden impurity.

At other mines, including some of the largest, inspection and picking are carried on only when the railroad cars are being loaded with the screened coal. The stream of coal filling the car is closely watched by one or two men, who throw overboard from time to time the noticeable pieces of impurities. They often use large rakes to pull the impurities from under the falling stream of coal. In such cases picking is for appearance only, the actual amount of impurities removed being usually under 1 per cent of the size loaded. At some mines only the lump sizes are picked. At other mines the egg and nut sizes as well as lump sizes are picked. At these mines the dock boss usually watches the railroad cars and not the screens for impurities. Fig. 20 illustrates car picking on egg coal.

Car picking is sufficient if the amount of refuse is small or consists of only occasional and accidental pieces, possibly one or two tons per thousand tons loaded. In these cases it is possible to remove all noticeable impurities from the top of the car before shipping. Car picking is not sufficient to clean systematically a dirty coal. A piece of impurity even if detected cannot always be removed from a stream of lump coal falling and rolling into a car without exposing the workman to danger of injury from the large lumps. Consequently such impurities are buried rather than removed. The danger of being injured by the small egg and nut sizes is not so great. In one case as much as 1 per cent of the egg size is thrown out of the car during loading; however, the percentage is usually much smaller. The removal in this way, as refuse, of a noticeable percentage of the coal would probably be commercially impossible. Table 6 shows detail of picking practice at several mines chosen at random.

The chief difficulty with hand picking in any form is that of securing conscientious labor to do the work. At several of the tipples visited the laborers made little pretense at picking unless the dock boss was in constant attendance. Another feature is the amount of good coal going to waste with the shale and sulphur. For instance, if an impure band ½ inch thick is noted in perhaps an 8-inch lump of

FIG. 20. HAND PICKING AN EGG COAL DURING LOADING.

coal, the whole is likely to be discarded. An examination of some of the refuse heaps to which the rejected lumps are hauled, revealed many tons of good coal. It is unfortunate that this waste may be

TABLE 6.

DETAILS OF TIPPLE PICKING PRACTICE IN ILLINOIS MINES.*

Mine No.	Commercial Designation District	Picking Lump Coal: Tons P'k'd per Day	Picking Lump Coal: How Picked	Picking Lump Coal: Tons Wasted per Day	Picking Lump Coal: No. of Men	Picking Egg Coal: Tons P'k'd per Day	Picking Egg Coal: How Picked	Picking Egg Coal: Tons Wasted per Day	Picking Egg Coal: No. of Men	Picking Nut Coal: Tons P'k'd per Day	Picking Nut Coal: How Picked	Picking Nut Coal: Tons Wasted per Day	Picking Nut Coal: No. of Men	Coal Inspector	Remarks
1	Saline county...	375	In R. R. cars only	2	1	...	Not picked.......	–	–	...	Not picked.......	–	–	Part time	
5	Franklin county.	800	In R. R. cars only	1–2	1	800	On picking belt...	8–12	2–3	...	Rescreened	–	–	Yes	
7	Franklin county.	660	In R. R. cars only	–	–	660	R. R. car........	–	–	480	R. R. Car.......	–	–	Yes	Waste: 10 tons per day.
9	Williamson " .	960	In chute and car	7	2	420	On picking table..	3	3	...	Washed	–	–	Yes	8–10 trimmers and pickers.
11	Franklin county.	600	On picking table and loading boom	–	–	600	On picking table..	–	–	400	Rescreened	–	–	No	Total waste: 3 tons per day.
17	Sangamon " .		No picking except occasionally if coal is dirty.........			...	....	–	–	...	....	–	–	Yes	
24	Montgomery " .	450	On picking table and loading boom	11	2–3 boys	400	On picking table..	10	2 boys	...	Not picked.......	–	–	Yes	
32	Longwall field...	360	In R. R. cars....	2 3	1	360	Not picked.......	–	–	...	Not made........	–	–	Yes	Occasional pieces of sulphur.
34	Standard district	650	On screens.......	5	2	650	On screens.......	5	1	390	On screens included in other sizes.	–	–	Yes	3 men pick
35	Standard district	1300	On screens.......	5	–	1300	On screens.......	5	–	...	Not made........	–	–	Yes	2 men and inspector pick on screens.
40	Standard district	1000	In R. R. cars....	2–3	1	...	Not picked.......	–	–	165	Not picked.......	–	–	Yes	
42	Marion county..	550	On screen and table	–	–	440	On screen and table	–	–	440	On screen and table	–	–	Yes	12 pickers; 60 tons waste per day.
43	Marion county..	720	In R. R. cars....	1	1	...	Not picked.......	–	–	...	Not made........	–	–	Yes	Inspector picks.
45	Perry county....	700	On screen and table	–	–	360	On picking table..	–	–	340	On screen and table	–	–	Yes	4 pickers; 6 tons waste per day.
47	Perry county....	700	In R. R. cars....	1	1	420	On picking table..	4	2	420	On picking table..	4	2	Yes	
48	Danville district	150	On picking tables.	–	3	600	On picking table.	–	3	...	No nut made.....	–	–	No	50 tons impurities per day.

*Mines were chosen at random.

a commercial necessity at the present time. At a few mines these lumps are pulled from the picking belt, the impure band split off, and the good coal returned to the belt. This operation is called "skinning" the coal.

Sizing should take place before the picking is begun. If picking is attempted on 1¼-inch lump coal the eye of the picker cannot readily detect the different sizes of impurities mixed with the different sizes of coal. The more uniform the size of the coal that passes the picker, the better the impurities can be removed. A recently built dock cleaning plant sizes the coal for picking purposes, and then reunites the sizes to meet the demands of the market.

Other important questions regarding picking are: How small sizes can be hand picked? How shall the screenings and small sizes be cleaned? Should they be hand picked or washed? In general, what are the limits of refuse today in a commercial Illinois coal?

In European bituminous coal fields hand picking has been practiced for many years. In comparing their practice with our own, it must be kept in mind that cheaper labor and higher priced coal allow a closer and a greater range of work than is possible here. Various authorities treat this problem as follows:

"The process of hand picking can be successfully applied to pieces of coal and shale of 1½ inches to 2 inches in diameter, but not to smaller pieces. Washing can be used from 3 inches to 1/20 inch. There is no known process of separating shale dust from coal dust."*

"Hand picking cannot economically be applied to coal less than 2 inches in diameter, except in exceptional cases as where coal is fairly clean or wages low, in which case picking takes place even at 1 inch. It is usually done by boys, as it requires alertness of hand and eye."†

"On the continent sizes over 4 to 5 centimeters (1.6 to 2 inches) are generally picked by women or boys, sizes smaller than these are frequently washed."‡

In many places in Illinois hand picking is practiced on the lump size only, in others the 3-inch egg is the lower limit. It is probable that unless the refuse in such sizes had some special value it would not pay to mine and hand pick coal in Illinois containing more than from 3 to 5 per cent of refuse in the large sizes. Fortunately, in most districts the bulk of refuse passes into the finer sizes.

At present in Illinois washing is practiced on 3 or 3½-inch coal as a maximum size.¶ This is partly on account of the mechanical difficulties encountered in building jigs for washing larger sizes. The average amount of impurities removed from the washed coals in 35 plants examined was 11 per cent, with a maximum of 36 per cent and

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*W. Galloway, "Lectures on Mining." Subject 8, p. 2.

†W. S. Boulton, "Practical Coal Mining." Vol. 3. p. 315.

‡J. Callon, "Cours d'Exploitation des Mines." Texte 3, p. 152.

¶F. C. Lincoln, "Coal Washing in Illinois," Bul. No. 69, Engineering Experiment Station, University of Illinois.

a minimum of 5 per cent. It is difficult to estimate an exact limit for commercially profitable washing because of the varying character of the refuse and its degree of freedom from contained coal. On the whole 3½ inches is the maximum size, and about 7 per cent refuse, containing at least 60 per cent of ash or its equivalent, represents a possible minimum of removable impurities. Under European conditions this limit has been put at from 4 to 6 per cent impurities.* As a lower limit, coal under ¼-inch in size is benefited little by washing and under from 20 to 50 mesh probably not at all. Considerable doubt exists as to the proper method of handling the small sizes of Illinois coals on account of the frequent occurrence of a high percentage of ash. These sizes are discussed further under Sizing in Chapter IV.

At a considerable number of mines, especially in the southern part of the state where rescreening plants are used for the separation of nut coal and screenings, all sizes below from 2 to 3 inches are divided into as many as five distinct sizes. Most of the impurities generally stay with the finest of these sizes, leaving two or three of the largest sizes of nut coal practically as clean as the lump. At several mines one or two men were noted in these rescreeners picking the largest sizes of nut, perhaps from 3 to 1¾ inches in size. Although no figures of amounts picked were obtainable, it is evident that the large number of pieces of this size that must be picked out of the coal to produce a ton of refuse makes the problem of doubtful economic value. If two men are picking 100 tons per day of such nut, the extra cost is roughly five cents per ton. From the ash standpoint one man must pick one ton per day of this fine material to reduce the ash content one per cent. Does the comparatively small amount picked pay for the better appearance? This question must be solved for each coal and each market condition.

Impurity and Inspection Standards.—Coal inspection is becoming more rigid, and large users, such as railroads, frequently have their own inspectors, even at the mines of the producer. Much coal is inspected by the buyer by a hasty examination of the top of the railroad car; but to secure the best results, more strict examination, such as inspecting the inside of the load while it is being loaded is necessary. If hopper bottom railroad cars are used and delivery is made through these to a bin or to a stock pile, individual car inspection is difficult.

A set of impurity and inspection standards has been proposed for railroads using bituminous coal as follows:

"The seller further agrees that all coal delivered under this contract shall not contain more than....per cent removable noncombustible or nearly noncombustible impurities. The quality of coal furnished....shall be subject to the inspection of the buyer, and the buyer's inspector....has the right to reject any of said coal which.... does not conform to specifications, at whatever point the same may be

*Soc. Min. Ind., Vol. 17, p. 384.

TABLE 7.

MAXIMUM PERCENTAGE OR LIMITS OF REMOVABLE IMPURITIES PERMISSIBLE IN GRADES OF COAL FROM THE DISTRICTS AS LISTED.

Mining District	Lump		Egg		Mine Run	Egg Run†
	Size	Percentage Impurities Allowed	Size	Percentage Impurities Allowed	Percentage Impurities Allowed	Percentage Impurities Allowed
Canton, Ill.	1¼″ R*	2.0	1¼″ x 8″ R	3.0	2.0	...
Virden, Ill.	1½″ R	1.5	1½″ x 6″ R	2.5	1.5	...
Centralia, Ill.	1½″ R	1.5	1½″ x 6″ R	2.5	1.5	...
Herrin, Ill.	2″ R	1.0	2″ x 6″ R	1.5	1.0	...
Oskaloosa and Albia, Iowa	1¼″ bar	4.0	....	...	...	...
Centerville, Iowa	1¼″ bar	1.0	....	...	1.5	...
Bevier, Mo.	¾″ bar	2.0	....	...	3.0	...
Novinger, Mo.	⅞″ bar	3.0	....	...	3.0	...
Walsenburg, Colo.	....	...	....	...	2.0	...
LaFayette, Colo.	....	...	....	...	0.5	...
Cambria, Wy.	¼″ Sq.	4.0	....	...	4.0	...
Sheridan, Wy.	4″ bar	0.2	2½″ x 4″ bar	0.2	0.5	0.7
Kirby, Wy.	....	...	....	...	0.8	1.0

*R = Railroad.
†See p. 104.

found. The buyer's inspectors shall have access to the seller's tipple screens, scales, washer, and yards while the coal is being hoisted and prepared.

"All coal delivered....may be inspected at the mines by the.... (representative) of the buyer....such inspection and refusal to be final and conclusive."*

A further paragraph covers the discovery of inferior coal after shipment when the same was not inspected at the mines.

Besides individual contracts, the most specific standardization of Illinois and other middle west bituminous coals in regard to the percentage of noncombustible or nearly noncombustible impurities allowable has been used by several railroads drawing their supply from mines in the territory mentioned. Through the kindness of C. G. Hall, Secretary-Treasurer, Int. Rwy. Fuel Assoc., figures of the limits or removable impurities as allowed by these railroads have been secured (see Table 7).

Table 8 shows the amounts of different impurities, etc., which are allowed to remain in the coal in the standard preparation of Pennsylvania anthracite,† and is given for comparison with Table 7.

TABLE 8.

IMPURITIES ALLOWED WITH STANDARD ANTHRACITE PRACTICE.

Size of Coal	Allowable Percentage			
	Slate	Bone*	Of Next Size Larger	Of Next Size Smaller
Broken	1.0	2	—	20
Egg	2.0	2	5	50
Stove	2.5	4	5	50
Nut	4.0	5	10	15
Pea	8.0	5	5	{ 15 Buckwheat 15 Rice
Buckwheat	10.0	—	8	15
Rice	15.0	—	8	15
Barley	15.0	—	8	25

†Bone equals product of between 40 to 55 per cent of carbon.

PART IV. BREAKAGE.

Bituminous coals vary from 0.5 to 2.0 on Mohr's scale of hardness.‡ They are, as a rule, decidedly brittle and friable, tending to break into more or less cubical blocks, depending on physical structure, such as frequency of bedding laminae or planes of stratification, and development of cleat or vertical cleavage. Cleat may be defined as

*Inspection Specifications, Proc. 5th Annual Convention, Int. Rwy. Fuel Assoc., 1913, p. 28.

†Paul Sterling, "Preparation of Anthracite." T. A. I. M. E., 1911, p. 757.

‡Henry Lewis, "The Dressing of Minerals." p. 8.

the tendency for the coal to break into more or less cubical blocks along vertical or highly inclined planes either parallel or normal to the face of the coal.

Natural Physical Factors Causing Breakage in Illinois Coal.—Illinois coal may be considered comparatively hard, rather porous, more or less brittle, and friable; tending to break or split easily along definite major bedding laminae 5 to 12 inches apart and somewhat less easily along small or minor bedding planes. Vertical cleavage, prominent in many bituminous coals, is generally lacking or is developed only incipiently. This incipient cleavage is more marked in one direction than in the other, the lump coal usually being rather smooth and regular on the breakage faces in two directions, but tending to be irregular on the third face. This incipient cleavage determines the lines on which the coal frequently breaks into small blocks on first being heated. This cracking, which is probably due to shrinkage caused by the heat expelling the water, is also often more strongly developed in one vertical plane than in the other.

Exceptions to this rule occur in the case of east and west cleavage in parts of seam No. 6 in Franklin county, and in that of a cleavage in seam No. 2 in Jackson county (Big Muddy district). Here the cleavage is developed sufficiently to influence the direction of mining, as the ease of mining when working along the face cleavage here, tends to produce a larger percentage of lump coal with less powder than in the majority of mines. In most districts, however, mining takes place with no thought of cleavage.

There is considerable difference in the natural tendency towards breakage of coal in the different seams and in the different districts in Illinois. The coals of seams No. 1 and No. 2 in the northern field are of average hardness (firmness or cohesion); an example appears in the coal from seam No. 2 in the La Salle district, which breaks into rectangular lumps capable of withstanding much handling before breakage.* The coal from seam No. 5 in the Springfield and Peoria districts is harder and firmer than the average. Seam No. 6 west of the DuQuoin anticline, although covering a large area, is generally regarded as somewhat friable, especially in the northeast and southwest portions and also in those mines just west of the anticline, in which it is close to the surface. Seam No. 6, east of the DuQuoin anticline, and in general wherever it is situated under several hundred feet of cover, consists of a hard firm coal, especially in the smaller sizes. This coal withstands without breakage handling and shipment, and therefore forms a good domestic fuel in markets in which clean coal and close sizing are prerequisites. The coal of seam No. 5 in Saline county is also of a firm texture and well adapted for rescreening. Seam No. 6 in the Danville district contains rather friable coal. Seam No. 2 (Big Muddy), partly by reason of the cleavage noted, produces blocky lumps of a bright lustre. The coal of seam No. 7, Danville district, on the whole

*T. A. I. M. E., Vol. 29, p. 187.

is softer and more brittle than the others, perhaps on account of its nearness to the surface. It cannot undergo transportation as well as the average.* It is interesting to note that in the deepest mine in the state, at Assumption, a coal is produced from seams Nos. 1 and 2, which commands a premium, partly on account of its blocky firm character.

Importance of the Breakage Problem.—Aside from the inherent friability or tendency of the coals to break, as just discussed, the mining and preparation, or in general, any moving, dropping, or handling of a brittle substance like Illinois coal results in more or less breakage with each operation. Breakage, therefore, commences with the first operations of mining, continues with each succeeding operation, and ceases only when the coal is consumed. This gradual breaking of such a material into smaller sizes due to handling, exposure, etc., is called degradation.

None of the problems confronting the Illinois mining industry today is more important commercially than that of breakage. Although this problem, as far as surface preparation is concerned, could be solved so that a considerable increase in value per ton of the whole product would result, yet it has been neglected in all except a few plants recently erected. Breakage constantly reduces the larger sizes to form the smaller. The effect of this sizing on the prices received for the coal by the operator is shown in Fig. 21, prepared from the figures appearing weekly in "Black Diamond" during the years 1913 and 1914 for the average circular price f. o. b. cars at the mine in Franklin county. Although the curves do not represent the true price received in individual contracts, yet taken over such a long period, they represent the average difference in value of the sizes produced. The egg and nut sizes, although ranging with the lump in circular price, are frequently unsalable as such, and must be thrown into the cheaper steam sizes. The average price of lump coal during this period was $1.50 per ton, and the average price of screenings $0.73 per ton. The mere question of size reduces value over 50 per cent. Thus it is advantageous to produce the free burning Illinois coal in as coarse lumps as possible.

If these figures represent the average difference in price between lump coal and screenings, each per cent of lump gained (or each per cent of breakage reduced) is worth 0.77 cents per ton to the operator. At a mine at which three thousand tons per day are produced this means $23.10 per day or nearly $600.00 per month saved.

In the tipple a long, high angle dump chute, a poorly designed weigh box, or a drop of several feet onto the screens may cause the breaking of several per cent of lump coal into the finer sizes. At some mines the sound of the coal when dumped from the car is audible above the rest of the surface noises at a distance of several hundred yards from the tipple. The louder the noise the greater the

*Eng. and Min. Jour., Vol. 63, p. 165.

breakage. In some cases the dumping takes place with such force that the coal actually seems to be thrown from the car through a distance of from twelve to fifteen feet into the bottom of the weigh box, in which it is more or less broken by the rest of the load falling upon it. While the great speed of such apparatus, in some cases three dumps per minute, is a notable achievement, good

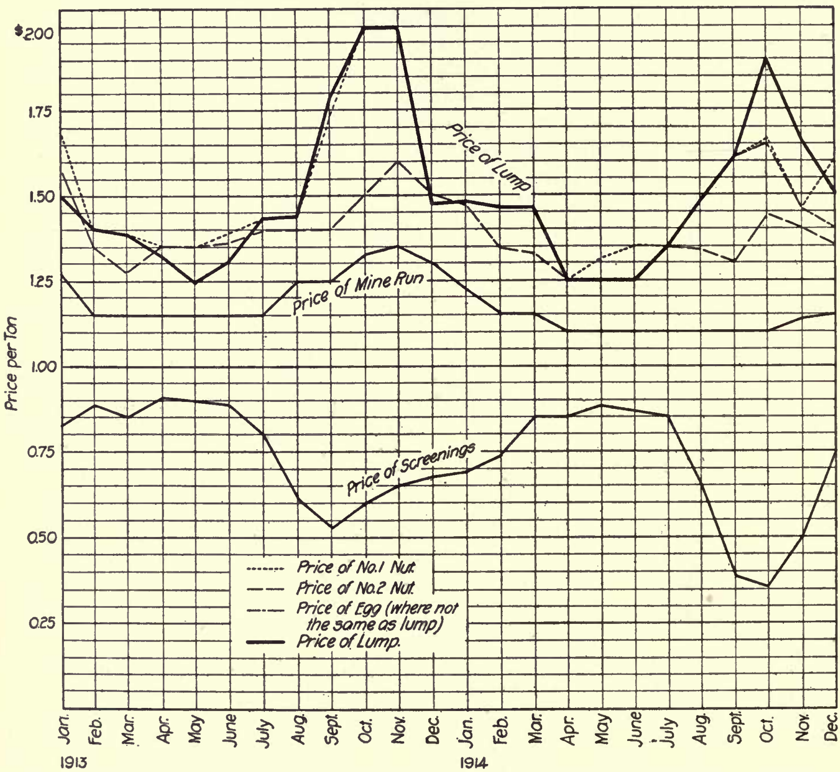

FIG. 21. AVERAGE CIRCULAR PRICE OF THE DIFFERENT SIZES OF COAL. FRANKLIN COUNTY (1913-14).

engineering demands a closer study of the problem of decreasing the breakage during preparation.

Breakage or Degradation Standards.—The adoption of some standard of breakage for Illinois coal is desirable. Especially in making specifications in which close clean sizing is required it would be of advantage to have a standard allowable amount of breakage under fixed conditions with which each coal could be compared, in order that it might be designated as harder or softer (more friable), or as containing more or less fines than the standard. If Illinois coal withstands transportation and handling better than competitive coal from other states, such a standard inserted into specifications, would emphasize a fact that is of great importance to retail dealers, especially to those to whom fine coal represents almost a dead loss. To show the difference in the friability of different bituminous coals, a certain bituminous coal in dock handling on lake shipments degraded from 30 to 35 per cent in two cases, while another bituminous coal under the same treatment degraded only from 12 to 14 per cent.*

While there has been much discussion concerning degradation on various coals no standard of degradation has been introduced into general practice. Attempts have been made by the U. S. Geological Survey† to fix such standard for the purpose of comparing the friability of coal briquets. For illustration, 50 lb. of briquets made from an Illinois coal were dropped five times through a distance of 6½ feet, and then screened on a one-inch wire screen; 35.5 per cent of the material passed through the screen. The briquets were then compared with others in this respect.

The U. S. Bureau of Mines‡ has adopted a similar standard for comparison of cokes. A fixed weight of coke is dropped 6 feet onto a cast iron plate. This operation is repeated four times. Then the sample is screened over a standard screen, and the percentage of fines is determined.

J. B. Porter¶ determines the comparative friability of fine bituminous coal and dust, by taking coal under ¼-inch screen in size and screening it through the following sieves: ¼-inch; ⅛-inch; 14-mesh; 24-mesh; 50-mesh; and 100-mesh, a screen ratio of practically 2. The percentage of each size is then plotted, and the assumption made that the several coals range in friability in the order of their percentage of fine material.

It is evident that in any set of breakage test on bituminous coal the large lumps of such a friable and non-homogenous material may break easily and the smaller sizes not so easily, or vice versa. The position of the coal in the seam, whether in the top, middle, or bottom bench, and the percentage of ash or other impurity in a particular piece have a decided effect on breakage. For these reasons any set of tests must be relative rather than absolute. Tests along the above lines are now being conducted in the Mining Laboratory of the University of Illinois to ascertain if such breakage standards are of any practical value.

Theoretical Considerations of Breakage.—Considered from a theoretical standpoint, breakage of coal takes place by splitting along

*Records of Interstate Joint Conference, Philadelphia, Pa., Feb. 10, 1914, p. 914.

†Bulletin No. 332, p. 44.

‡Technical Paper No. 50.

¶"Coals of Canada." Vol. 1, p. 195.

planes of minimum strength rather than by actual shearing or crushing of the coal substance itself. Thus the actual measure of the force in pounds per square inch required to crush or break coal is extremely variable. The application of Rittinger's theory* that the work necessary to break or crush minerals is proportional to the reduction in diameter, shows, for example, that three times as much power must be expended in breaking 6-inch cubes into 1½-inch cubes as in breaking 6-inch cubes into 3-inch cubes.

The kinetic energy developed in any lump of coal being moved; in other words, the force with which one piece strikes another and causes breakage, is directly proportional to its weight and to the square of its velocity, or if dropping, directly proportional to the distance through which it is dropped. In simpler language a piece thrown or moved with twice the speed of another, has four times as much power to break or to shatter. The practical effects of these laws will become evident when breakage in bins, in chutes, and in other surface plant devices is discussed. Since force is proportional to weight, the general effect of size or weight is that large pieces striking on their own ragged edges sustain breakage from a drop that will not affect the smaller sizes.

If coal is dropped piece by piece from a height of from 10 to 15 feet upon iron or steel it will show from three to four times as much breakage as if dropped onto wood.† It is claimed, in unloading a bin or a car, that the first drop only causes breakage and that after the pile below has started there is little breakage. Probably the breakage is greater in the dumping of large volumes than in the dumping of small volumes of coal. Still another point is the effect of squeezing and rubbing of the particles against one another in a bin from which coal is being drawn from the bottom. If other conditions are equal, the actual breakage is greater in handling or transporting sized coals than in handling or transporting run of mine coal because the fines in run of mine coal form a bed or nest upon which the large sharp pieces of lump may ride without breakage.

Data on Degradation of Bituminous Coals.—There is a practical limit to the freedom of a particular size of coal from smaller sizes, because reduction in the amount of smaller sizes beyond a certain point by rescreening means the making of an additional amount of the large coal into fines. At one mine it was reported that each rescreening of the coal meant 5 per cent was broken into small sizes and passed the screens. Concerning this point, "Experiments show that there is a limit beyond which there is no advantage in attempting to rescreen and further prepare anthracite and bituminous coal. In one instance in which a ton of hand picked coal was used the process of screening furnished 3 per cent undersize which went through the screen, while a larger per cent of undersize formed in the handling

*R. H. Richards, "Text Book of Ore Dressing. p. 167; also, H. von Rittenger, Lehrbuch der Aufbereitungskunde, p. 19.

†Black Diamond, August 29, 1914, p. 165.

still remained in the coarse coal. In repeating the operation, another 3 per cent of undersize was caught, while the (coarse) coal again held a proportion of undersize similar to that previously found. It is believed that the process might be repeated indefinitely without materially benefiting the grade of the coal."*

In one test made by a consumer in Chicago clean Illinois nut coal over ¾-inch screen was shoveled into a wheelbarrow, weighed, dumped, and then rescreened over the same screen. In one lot 4 per cent and in another lot 2 per cent degradation resulted from the shoveling and dumping.

At a mine in the central part of the state, the degradation of clean screened coal of from 3 to 6 inch size, which was rescreened after passing through a bin 20 feet in height was 5 per cent. In a similar case in the southern part of the state 2 per cent degradation was reported.

Another test, made on a car of carefully loaded domestic lump coal by removing clean lumps from the car with a fork, showed 5 per cent of smaller sizes left in the car. J. D. Rogers† states that a breakage of 5 tons per car, or 10 per cent, is common and is even greater if loading is carelessly done.

In elevating and passing an Arkansas bituminous coal through a 50-foot railroad coaling station the increase of slack was 25 per cent.‡ This coal is somewhat softer than Illinois coal.

An English test on bituminous coal falling 10 ft. showed a loss of 1s. 3d. per ton or 15.6 per cent on coal valued at 8s. per ton.¶

At a large Chicago retail yard a degradation of 7 cents per ton is allowed on all sizes of bituminous coal passing through the yard; on an estimated average value of $2.50 per ton this would be a loss of about 3 per cent. J. W. Hardy** records the breakage on bituminous coal as 4 per cent for every 10-foot vertical drop.

Transferring Coal in Railroad Cars.—Considerable discussion has taken place regarding the amount of degradation caused by the transferring of coal from one railroad car to another en route. H. C. McKinney in The American Coal Journal for Dec. 5, 1914, states that the loss of 25 cents per ton (at the point in question this amount represents possibly 10 per cent of the value) conceded by the railroads is insufficient. Since the practice of transferring coal from one car to another en route is common, more data on this point would be valuable.

The random references given show the present day practice in estimating the general breakage on Illinois and other bituminous coals. In every case dropping coal even once causes serious breakage. Considering the treatment that Illinois coal receives in the tipple in prepara-

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*Eng. and Min. Jour., Feb. 16, 1907, p. 339.
†"Preparation of a Domestic Coal." Kentucky Min. Inst., December, 1912.
‡Proc. 5th Annual Convention, Int. Rwy. Fuel Assoc., p. 257.
¶Gillott on Kirkby Colliery. Inst. of C. E. of London, Vol. 127, 1897, p. 177.
**Black Diamond, Aug. 29, 1914, p. 165.

tion, it is doubtful, especially on the prepared sizes, if it pays to strive for tonnage records at the expense of extra breakage of the coal.

As anthracite is essentially a domestic coal prepared under standard practice, the results of tests made to determine its breakage are given for the purpose of comparison.

(1) Test on Dropping.* Sized anthracite dropped 7 feet onto iron plate gave 0.77 per cent breakage into finer sizes, and dropped 7 feet onto wood plate gave 0.34 per cent breakage into finer sizes. In other words, the breakage of anthracite upon striking iron is more than twice as great as upon striking a softer material like wood.

(2) Tests on Handling and Shipping.† The loss by breakage in storage and picking up averages 2 per cent, but varies from ½ per cent with the coal and with the amount of handling. At one plant in which coal is dropped into a hopper beneath the car, though the fall is small, the breakage measures ½ per cent. The breakage in shipping east without rescreening is from 2 to 3 per cent. In shipping west, in which case the anthracite is transferred and rescreened, breakage is from 8½ to 9 per cent. By breakage is meant the actual amount of all sizes smaller than the size specified.

(3) Breakage by Dropping.‡ A summary of tests made both by dropping carefully sized anthracite through measured distances and by dropping carload lots into pockets is given in Table 9.

TABLE 9.

Breakage of Anthracite by Dropping.

Size	Amount of Breakage into Smaller Prepared* Sizes	Amount of Breakage into Sizes Smaller than Nut	Total Amount of Breakage
Broken	3% plus 43/100D†	2% plus 17/100D	5% plus 6/10D
Egg	4% " 43/100D	2% " 17/100D	6% " 6/10D
Stove	2% " 33/100D	2% " 27/100D	4% " 6/10D
Nut	....	4% " 40/100D	4% " 4/10D
Pea	....	2% " 50/100D	2% " 5/10D
Buckwheat	....	1% " 25/100D	1% " 25/100D

*Prepared sizes are broken, egg, stove, and nut.
†D equals drop of coal in feet.

Table 9 shows that not only is the percentage of degradation through fall for a hard coal like anthracite surprisingly large, but also that breakage increases with an increase in size and in height of drop. The breakage in an Illinois coal must be considerably greater.

*Black Diamond, July 12, 1913, p. 16.
†Mines and Minerals, Vol. 25, p. 23.
‡R. V. Norris, "The Storage of Anthracite." T. A. I. M. E., Vol. 42, p. 316.

General Analysis of the Breakage Problem.—In general during mining and preparation of a coal, breakage may occur in any of the following necessary operations:

- A. Breakage in the mine incident to......
  - a. Undercutting.
  - b. Snubbing and drilling.
  - c. Breaking the coal from the face.
    - 1. In longwall mines.
    - 2. Shooting after undercutting and solid shooting.
    - 3. Permissible explosives.
  - d. Handling ..
    - 1. Loading.
    - 2. Haulage.
    - 3. Dumping into a skip at shaft bottom.
- B. Breakage in surface plants incident to...
  - e. Use of self-dumping cage.
  - f. Dumping into weigh box and onto the screen.
  - g. Screening.
  - h. Loading ....
    - 1. Passage over loading chutes, aprons, or booms.
    - 2. Loading and trimming railroad cars.
  - i. Rescreeners and bins.
  - j. Washing (not included in this bulletin).
- C. Breakage in transportation and rehandling (not discussed fully in this bulletin).

Breakage in the Mine.—Undercutting.—About 52 per cent of the tonnage in Illinois is produced in mines in which undercutting is practiced either by hand picks, by machines of the puncher type, or by electric chain machines. The last named type is the most common, and its use is increasing. Contrary to the practice in many bituminous fields, undercutting in Illinois takes place almost entirely in the coal; the exceptions being at several mines in the longwall field, in which hand picks are used to undercut in the clay bottom. At other scattered mines, the line of undercutting follows some thin dirt band in the lower part of the seam, and at others in which the floor rolls or is irregular, accidental undercutting of the floors takes place, in all of which cases the cuttings are high in ash or impurities. In general, however, the miners avoid working in the tough bottom clay. This leads to the reduction into fine sizes of a certain portion of any particular seam, the percentage depending on the height of the undercut; that is, on the particular machine or method used.

The cuttings obtained, called "bug dust" by the miner, are generally assumed to consist only of the finest sizes of coal, and on account of a high percentage of dangerous dust contained, are often loaded out before breaking down the face of the seam undercut. Therefore, cars of bug dust are generally at the foot of the shaft when hoisting begins in the morning; consequently, the first railroad cars of screen-

TABLE 10.

AMOUNTS AND SIZES OF CUTTINGS MADE BY VARIOUS MINING MACHINES.

1	2	3	4	5						6		7	8	9	10	11	12	13
Mine	District	Seam Number	Kind of Undercutting	Screen Analysis Percentage						Chemical Analysis of Cuttings		Total Undercut During Test. Sq. ft.	Total Weight of Cuttings, lb.	Pounds of Cuttings per sq. ft. of Seam Undercut.	Total Per Cent of Cuttings if Seam Were 6 ft. Thick.	Per Cent of Cuttings Under 1¼″ r'nd hole; i.e., 1¼″ Screenings.	Weight of Cuttings per sq. ft. passing 1¼ in. Round Hole Screen.	Per Cent of 6 ft. Seam Made into Screenings by Hand or Machine Mining.
				a	b	c	d	e	f	a	b							
				On 1″	On ½″	On ¼″	On 10 Mesh	On 100 Mesh	Throu 100 Mesh	Per Cent Ash	Per Cent Sulphur							
1	Northern Longwall	2	Hand	33.2	20.2	18.7	17.3	10.3	0.3	17.5	4.7	14	1180	84.3	17.3	66.8	56.3	11.6
2	Southern Room and Pillar	6	Electric	11.2	12.3	13.9	21.4	39.4	1.8	14.0	2.7	129	4075	31.6	6.5	88.8	28.0	5.8
3	Southern Room and Pillar	6	Ch. Mach.	3.7	15.2	23.7	34.5	22.1	0.8	10.2	0.9	166	5290	31.8	6.5	96.3	30.6	6.3
4	Southern Room and Pillar	6	Ch. Mach.	5.9	16.4	20.4	31.0	25.2	1.1	9.2	1.5	130	4393	33.8	6.9	94.1	31.8	6.5
5	Southern Room and Pillar	6	Ch. Mach.	6.6	19.4	22.8	25.6	25.2	0.4	13.0	1.2	94	2935	31.2	6.4	93.4	28.1	5.8
6	South-western Room and Pillar	6	Ch. Mach.	12.8	15.6	19.8	22.4	28.2	1.2	17.1	6.8	64	2150	33.6	6.9	87.2	29.3	6.0

7	South-western Room and Pillar	6	Air Puncher	37.2	13.5	13.8	17.8	17.7	0.0	26.5	5.1	55	3780	68.7	14.1	62.8	43.1	8.9
8	Danville Room and Pillar	7	Air Puncher	35.4	16.4	15.4	17.3	14.8	0.7	17.5	4.1	26.8	2750	103.0	21.2	64.6	66.5	13.7
9	South-western Room and Pillar	6	Air Puncher	45.1	13.2	13.5	15.6	12.0	0.6	27.6	6.7	87	11550	133.0	27.3	54.9	73.0	15.0
10	Southern Room and Pillar	6	Air Puncher	28.5	17.8	16.6	19.9	16.2	1.0	15.8	1.2	32.6	2250	69.0	14.2	71.5	49.3	10.1

ings loaded may contain more than the usual percentage of this fine coal, which is often of lower grade than the regular screenings.

There has been considerable discussion as to which type of machine makes the least cuttings, coarsest cuttings, lowest percentage of dangerous dust, etc. To throw light on these and other pertinent questions in connection with the use of machines in Illinois mines, H. H. Lauer of the Department of Mining Engineering of the University of Illinois, in connection with the Co-operative Investigation of Illinois mining conditions, made a series of ten tests at mines in which undercutting was variously practiced with hand picks, punchers, and electric chain machines of different types. In each test a room or a definite length of face in a mine was carefully cleaned, and then undercut by one of the above methods as in regular practice. The total amount of cuttings produced was carefully collected, weighed, and sampled. One sample was saved for analysis while another was passed through various standard screens, the object being to ascertain the percentages of the various sizes made, and in this way to compare the cuttings produced by the various methods of undercutting. These operations were all carried out underground at the face. The full results have not yet been published, but through the courtesy of the Co-operative Investigation the results regarding amounts and sizes of cuttings, summarized in Table 10, were secured.

The screens used in these tests were of square mesh; the openings, therefore, were slightly greater in area than the corresponding sizes of round holes, which are more convenient as a standard. A screen ratio or sieve scale of ½ inch was used, excepting with the smallest size of screen—100-mesh. The percentage of coarse coal on the 1-inch screen is high in mines in which pick mining or puncher machines were used. The very small percentage of cuttings through a 100-mesh screen is surprising. In other words, machine cuttings are more granular than they are commonly supposed to be, and the percentage of dangerous dust (at least through 100-mesh) is smaller than was anticipated.

Column 6, a and b, shows that, as a general rule, cuttings are of lower grade than the average face sample from the same seam (see Table 5). The presence of a much smaller amount of ash in the top benches of the seam at many mines in the state than in the lower benches influenced unfavorably the results given in Column 6. Column 7 gives the total square feet of the seam undercut during the test, and Column 8 the total weight of cuttings; consequently, dividing Column 8 by Column 7 gives Column 9, which shows the pounds of cuttings made per square foot of the seam undercut.

To standardize the test still further, the seams are assumed to be 6 feet thick, and Column 10 shows the total percentage of a seam made into machine cuttings on the basis of a six-foot seam. The proper percentage to allow for a seam of any other thickness may be easily calculated.

If machine cuttings were large enough to pass into the lump sizes their quantity would be of minor importance. If a 1¼-inch round hole is taken as the standard size over which lump may be prepared (this size is nearly equivalent to a 1-inch square hole opening); Column 11 shows that considerable difference exists in the percentage of the cuttings which are fine enough to pass a 1¼-inch round hole; namely, to be screenings. The percentages in Column 11, recalculated on the basis of weight in Column 12, are reduced to the basis of a standard six-foot seam, and are given in Column 13. Percentages for thicker or thinner seams may be easily figured from this calculation. If there were no other breakage in coal mining and preparation, this percentage of the seam would represent the amount of 1¼-inch screenings made by undercutting.

The tonnage won after undercutting has in each case been assumed to be that part or block of the seam directly over the undercut. The frequent practice of boring holes deeper than the undercut increases the tonnage, and so decreases the percentage of the seam made into screenings by undercutting. The puncher machine and hand pick show more favorably in Column 13 than in Column 10; that is, while these machines make more cuttings than the electric chain machines, the sizes of their cuttings are coarser. An average of the electric chain machines shows 6.08 per cent screenings, and of punchers 11.92 per cent. The writer visited two mines of the same company within four miles of each other at which ½-inch bar screens of the same size were used. At one of these mines 11 per cent screenings was produced with electric mining machines; at the other, 17 per cent screenings was produced with punchers. These facts tend to confirm the reliability of the figures given in Table 10.

The agreement of the electric chain machines in Column 13 is remarkable, five machines in five different mines differing only 7/10 of 1 per cent in total cuttings when reduced to a common basis of measurement. Such a difference or even a greater one might depend upon the nature of the coal cut, upon the number of positions of bits used in the chain, upon the kind of bits; that is, chisel or pick point, and also upon whether the bits were sharp or dull. The height of the cutting opening made, or "kerf," also varies somewhat with different machines.

Excepting special manufacturers' tests, this is believed to represent the first work on this special problem carried out in the central bituminous field. In Mines and Minerals for March, 1908, p. 397, a table is given for similar work carried on in the Westmoreland mine, Pittsburg Seam, Pennsylvania. For purposes of comparison the results are given in Table 11.*

*See also G. S. Rice, "The Explosibility of Coal Dust." U. S. Bureau of Mines, Bul. No. 20, p. 35.

TABLE 11.

AMOUNTS AND SIZES OF CUTTINGS MADE BY VARIOUS MINING MACHINES IN THE PENNSYLVANIA BITUMINOUS DISTRICT.

Method	Total Cuttings		Through 40 Mesh	
	Pounds	Per Cent	Pounds	Per Cent
Puncher	3436	10.95	394	1.250
Chain Machine..	1836	5.86	155	0.494
Hand Pick......	4533	14.45	128	0.408

The percentage of total cuttings here is also reduced to a six-foot seam as a basis of common measurement.

Considering the physical differences between the coals of the two fields and other possible conditions, as noted previously, the general agreement of these results with those of Table 9 is significant.

Snubbing and Drilling.—By snubbing is meant the practice common in some districts before shooting, of cutting a triangular section from 18 inches to 3 feet high from the lower face of the coal above the undercutting. If this is not done the shooting is likely to loosen the coal only enough to fill the space undercut and, unless excessive powder is used, does not break it sufficiently to allow easy loading. Proper snubbing causes the coal to roll and spread out in the room with a minimum of powder.

The amount of snubbings made is less than 3 per cent of the average seam, and since the work is often done with a hand pick and there are two free faces to break to, the relative sizes of the snubbings are large. No determinations of the sizes have been made. Since from only two to five 2-inch drill holes are bored to a depth of from 5 to 8 feet in a single face, the percentage of fine coal made in this way is too small to be considered. These cuttings, however, contain a considerable percentage of fine dust. One per cent or less screenings probably represents the fine coal made by snubbing and drilling.

Breaking the Coal from the Face.—By the method of applying roof pressure or wedging as in longwall mines, the coal breaks slowly and into blocks, governed by the resultant direction of pressure and by the larger incipient cleavage planes, and consequently loosens ready for loading with a minimum of breakage. At certain longwall mines as small an amount as 15 per cent screenings (1¼-inch round hole or ⅞-inch bar) has been reported after loading, hauling, hoisting, and dumping over the screen. "On the whole, the longwall field shows 15 to 20 per cent more lump coal over 1¼-inch screen as compared with the rest of the state."* These figures agree with those gathered by the author at individual mines. Although the question is somewhat complicated by partial hand pick undercutting at some of the longwall mines, the conclusion seems logical that the amount of screenings in the coal at the face need not be greater than from 5 to 10 per cent.

The amount of fines or breakage produced in shooting is largely under the control of the miner (Chapter I). Heavy charges of powder shatter the coal. No conclusive data on this subject are available, and it will be discussed by making a comparison of general results obtained from the practice of two forms of mining; namely, shooting after undercutting vs. solid shooting.

In the bituminous field of Arkansas the change at one mine from undercutting to solid shooting increased the slack coal 14 per cent and the amount of slate from 11 to 23 per cent in three years; in the state as a whole, the change to solid shooting increased the amount of slack coal 50 per cent.† It is also claimed that overshooting weakens the lump coal so that it readily slacks off on standing and is more easily broken by handling. A retail dealer stated that when a car of clean lump made with undercutting was unloaded at destination, from 3 to 5 per cent of degradation was left in the car, while under solid shooting the amount was as great as 15 per cent.‡ A. A. Steel states that Oklahoma has had like experience,¶ and other writers complain that heavy solid shooting not only increases the amount of fines but also jars the coal and breaks the grain, producing incipient shattering, and even though it may hold together until it passes over the screen, it disintegrates more easily afterwards.

A direct comparison of these methods has been made in several cases of Illinois. A. J. Moorshead, in a paper read before the 1913 meeting of the Illinois Mining Institute,** states that from long experience he believes Illinois coal mined by machine has from 3 to 10 per cent less screenings on the average than the same coal shot off the solid, but that some of the harder coal gives as few screenings when shot off the solid as when undercut. Also he states that the percentage of screenings made from the coal from seam No. 6 in Williamson county when shooting off the solid is larger than that made when undercutting is practiced, the difference being probably from 7 to 10 per cent. The difference varies with the manner of shooting. At a mine†† in one district in the state, where shooting off the solid is practiced 55 per cent lump over 1¼ inches is made, while at three mines where undercutting is practiced 70 per cent lump is made over the same size screen. A study was made of 100 typical mines throughout

*S. O. Andros, Co-op. Bul. No. 5, p. 40.
†A. H. Perdue, Proc. American Mining Congress, 1909 to 1911, p. 227.
‡J. E. Turney, Ibid., p. 233.
¶Proc. 3rd Annual Convention, Int. Rwy. Fuel Assoc., p. 56.
**From reprint in Colliery Engineer, 1914, p. 435.
††S. O. Andros, Co-op. Bul. No. 6, p. 23.

the state;* at 33 mines where shooting off the solid is practiced an average of 65 per cent of the coal produced is larger than 1¼ inches, while at 43 mines where undercutting is practiced 67 per cent of the coal is larger than this size.

A personal communication to H. H. Stoek gives the following test made at an unnamed Illinois mine:

TABLE 12.
COMPARISON OF SIZES PRODUCED, SOLID SHOOTING VS. UNDERCUTTING.

Test	Per Cent of Lump	Per Cent of Nut	Per Cent of Slack
Solid Shooting.......	35	30	35
Undercut by Electric Machine	60	20	20

Generally, the amount of screenings made by either process of shooting is measured by screening through the tipple screens. Since the amount of breakage in handling, in weighing, and in screening the coal, varies for different mines, a direct comparison of breakage by shooting in sometimes impossible. Figures gathered by the writer concerning these two classes of mines in the same districts, show in every case as great or a greater percentage of screenings at solid shooting mines than at undercutting mines. Of two neighboring mines in the southern part of the state, one at which solid shooting is used, 35 per cent of screenings through an 1¼-inch round hole are produced. At the other, where electric machines are used, the same percentage of 1½-inch round hole screenings are produced. At a third mine in this district, where electric machines are used, 33 per cent 1½-inch round hole screenings are produced.

Permissible Explosives.—Since the amount of permissible explosives used in the state in 1915 amounted to 1,342,334 pounds, their influence on the coal is of considerable importance. Concerning permissible explosives vs. black powder, S. O. Andros† doubts that permissibles make more slack if properly used.

J. J. Rutledge and Clarence Hall state, "Permissible explosives have come into use so recently that it is not easy to get reliable figures showing the increased proportion of fine coal they make as compared with black blasting powder. The estimates of this increase given by mine superintendents run from no increase to 10 per cent. Some superintendents maintain that although smaller lumps of coal may be made by using permissible explosives, yet changing from black blasting powder to these explosives does not increase the proportion of fine coal. Some persons state that the lumps of coal produced by using permissible explosives are not so easily broken up during trans-

*S. O. Andros, "Coal Mining in Illinois," Co-op. Bul. No. 13.
†Co-operative Bul. No. 8, p. 34.

portation or exposure to the air as are those made by using black blasting powder, whereas other persons maintain the reverse. However, if the coal is undercut or sheared and the blasting is done with judgment, the permissible explosives make as good coal as black blasting powder and at approximately the same cost."*

J. R. Fleming, Assistant Engineer of the U. S. Bureau of Mines, has gathered data for a bulletin on "Use of Explosives in Illinois with Special Reference to Permissibles." These data show that the percentages of fines made by the use of permissibles at several mines are less than when black blasting powder is used; in other cases little difference is noted, while in still others an increased amount of fines in recorded when permissibles are used. Following are summaries from several mines:

Mine No. 1. The extreme case reported in which permissibles made more fines than black blasting powder.

Size of Coal	Year 1910 Black Blasting Powder	Year 1912 Permissibles
6 in. lump	24.19 per cent	20.41 per cent
6 in. x 3 in. egg	19.28 per cent	21.29 per cent
3 in. x 2 in. nut	16.50 per cent	12.88 per cent
2 in. screenings	40.03 per cent	45.72 per cent
Total	100.00 per cent	100.00 per cent

Mine No. 2. A more favorable case.

Size of Coal	Black Blasting Powder	Permissibles
6 in. lump	15.2 per cent	13.5 per cent
1¼ in. x 6 in. egg	49.5 per cent	51.0 per cent
1¼ in. screenings	35.3 per cent	35.5 per cent
Total	100.0 per cent	100.0 per cent

Mine No. 3. A very favorable case.

Size of Coal	Black Blasting Powder	Permissibles
2 in. lump	47.4 per cent	50.0 per cent
2 in. screenings	52.6 per cent	50.0 per cent
Total	100.0 per cent	100.0 per cent

The conclusion is that if permissibles are used with judgment no material increase of fines results.

Handling the Coal.—Loading.—Loading the broken coal into the mine car in Illinois is done with a hand shovel. The only exception to this rule occurs in the case of two stripping mines at which the broken coal is loaded with small steam shovels. At only one mine, near La

*"The Use of Permissible Explosives." U. S. Bureau of Mines, Bul. No. 10, 1912.

Salle, is the seam inclined enough to necessitate the use of chutes or other rehandling devices. Breakage from this cause, which is often a serious question in other states in which the seams are highly inclined, is therefore at a minimum. Whether or not the miner loads his coal in the largest possible lumps or rebreaks it, either by more powder, by pick, or by the back of a shovel into sizes convenient for shoveling, is a somewhat disputed point. It is not uncommon, however, to see mine cars containing lumps possibly as large as 12 inches by 18 inches, 2½ feet long, and weighing 300 pounds; as large in fact as the two men in the room can lift into the car.

Haulage.—The coal, having been loaded into mine cars, is moved to the foot of the shaft by mule or electric locomotive, or both. At times the writer has heard complaint about breakage caused by such transit, especially if in making up a trip the locomotive bumps the loaded cars, jarring the contents considerably and even breaking the top load.

Probably the custom of excessive topping, or loading the coal to too great a height above the top of the car, is responsible for most of the breakage in haulage. Bumping easily knocks off lumps from a poorly topped car which fall on the roadway and become broken. At comparatively few mines in the state is the load on the car limited; these few, however, have a maximum limit. As an illustration, at one mine the car is supposed to hold 4,000 pounds and if any carload weighs over 4,500 pounds, the excess weight goes to the check weighman fund. Such a rule is intended to prevent loss and breakage caused by excessive topping of cars. It is probable that breakage from actual car transportation, whether below ground or in railroad cars, has been rather overestimated.

Breakage Through Dumping into a Skip at the Shaft Bottom.—At nearly all the mines in the state coal is hoisted to the surface and into the tipple in the mine cars. Attempts have been made to dump the coal from the mine car at the bottom of the shaft into skips which are hoisted into the tipple and there dumped automatically. A similar arrangement is common at ore mines and is used at some coal mines in the Appalachian districts in which the coal is used for coking, and in which extra breakage is a benefit.

When a mine in the southern part of this state abandoned this system for the ordinary self-dumping cage, an estimated gain of 10 per cent in the coarser sizes resulted. A mine in the longwall field using skips produces 15 per cent more screenings over the same size of screen than the average of six other mines in the district using cages. In Franklin county a mine operating 7-ton skips reports 6 per cent more 1¼-inch screenings than the average of thirteen other mines in the district, and only 12 per cent of 6-inch lump against an average of 22 per cent for the other mines mentioned which hoist the mine car in self-dumping cages.*

*S. O. Andros, Co-op. Bul. No. 8, p. 48.

If, however, as in one or two cases in the state, the output of a mine is used for special purposes not affected by the general commercial market requirements for large lumps, skips may be the best solution of the engineering problem of a small shaft and high tonnage requirement.

Breakage in Surface Plants.—Final preparation and sizing in the tipple are carried on under the advantages of daylight and easy access to all parts of the plant. Underground the coal is subjected to a series of movements causing breakage, some necessary and some unnecessary, but all more or less under the control of the operator and miner. In the surface plant the success attained depends largely upon the design and erection of the tipple building, chutes, screens, conveyors, loading devices, etc. The operator usually feels that this part of his mine plant is distinct from the rest, and its design and erection is usually entrusted to some engineering firm which makes a specialty of distinctive and often patented designs of headframes, weigh boxes, screens, chutes, and other equipment.

The general types of Illinois coal mine tipples or surface plants have been described in Chapter II. While special engineering features of tipples are reserved for future discussion, several features causing breakage should be mentioned at this point.

Breakage from Use of the Self-Dumping Cage.—In older designs, the cage, after being brought to a quick stop is tipped suddenly with considerable throw and jerk, throwing the coal out of the tipped car. At the required angle for dumping, the coal at the top end of the car is frequently from 6 to 8 feet above the dump shoe, thus giving a considerable momentum to the outgoing load. If the shape of the dump shoe and connecting chutes is carefully designed, the coal will slide out with a minimum of breakage and danger.

In the interests of safety as well as breakage more care should be taken to prevent the coal being dumped from missing its proper chute and falling either down the shaft or to the surface around the headframe. It is not unusual to see considerable coal falling when dumping takes place.

Dumping into Weigh Box and onto the Screen.—The coal on being dumped from the car slides down a short dump chute into the weigh box. In one of the older tipples a dump chute, 6 feet long and set at an angle of 75 degrees, gives an additional falling height to the coal of about 5 feet. At this mine 4 per cent more screenings are produced than at a neighboring one with a modern tipple. The increase in screenings can be attributed to such defects. The tipple breakage is even apparent to the eye.

The slope of the bottom of the type of weigh box, pan, hopper, or basket illustrated in Fig. 22 is usually 35 to 40 degrees, and since the upper end may be from 10 to 12 feet above the lower end, the distance moved and the speed acquired by the coal may cause considerable breakage before it comes to rest and is ready to be weighed.

This is evident from the flying bits of coal noticeable in the usual type. The weigh box or basket is usually made large enough to hold two or even three loads from the mine car, and although this means waste space, lost headroom, and chance for extra breakage if used for single weighings only, the large capacity allows the hoisting to proceed continuously even though the screens below may be stopped.

Weigh boxes with a more gentle slope or at least a changing and decreasing slope, which would bring the coal to rest without a shock and then would deliver it on the screens below in a more gradual manner, would be an improvement. Weigh boxes of this type have been

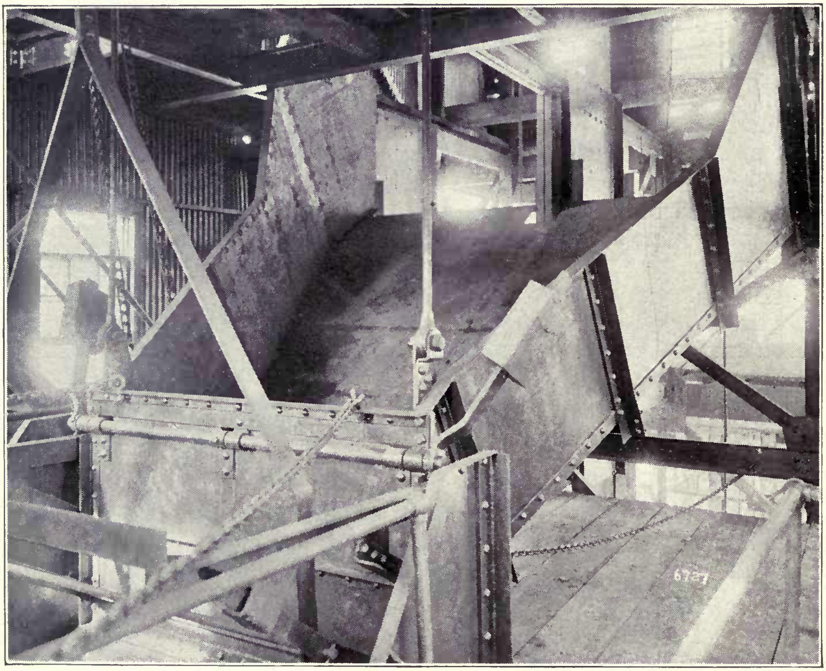

Fig. 22. Weigh Box.

designed, but complaint is made that they tend to decrease the speed of operation. A weigh box having a bottom sloping at a low enough angle to allow a car of dry lump to slide gently may not be steep enough to handle a car of moist or of fine coal, and if the angle is great enough to allow wet coal or slack to run, lump coal usually acquires considerable velocity in passing down the incline.

Use of Screen Feed Hoppers.—The custom of allowing coal from the weigh box to discharge, either at the end or bottom, direct to the shaking screen, is meeting with disfavor for the following reasons:

(1) A drop between the weigh box and screen is a factor in the amount of breakage; in certain tipples a drop of 3½ feet has been noted.

(2) Coal is weighed in from 2 to 5-ton lots, and when this amount is dumped suddenly on the upper screen, it throws an extra weight upon it, which seriously affects the balance of weight that should be maintained between the upper and lower screens, and gives additional vibration to the screen structure.

(3) The sudden rush of material from the weigh box frequently chokes the fine screens (which usually come first), and allows considerable fine coal to be carried into the coarser sizes, damaging their appearance.

(4) The sudden load thrown on the screen puts an undue strain on the driving belt, causing slipping unless it is laced to a considerable and often damaging tension. At one mine two engines are used to drive the screens, thus avoiding the dead center troubles and lessening the strains just mentioned. This scheme has not been adopted generally.

(5) Any stoppage of the screens for the purposes of repair or to shift railroad cars causes the cessation of hoisting after one or two dumps have filled the weigh box; that is, there is no storage capacity between weigh box and screen.

For these reasons, steel feed hoppers (Fig. 23), with sloping sides and holding from two to four mine cars of coal are, in many of the newer installations, placed under the weigh box and at the head of the screen. The bottoms of these hoppers have a reciprocating motion, due to an adjustable crank arm, the full stroke being from 8 to 12 inches, and the speed from 40 to 60 revolutions per minute. The lower part of the end of the box next to the screen is cut away, thus allowing coal to fall on the screen gently and regularly with each back stroke of the bottom. The partial load of coal usually in these hoppers reduces the breakage since a new load from the weigh basket falls gently onto coal instead of striking steel. If such a feed hopper cannot be used on account of a lack of sufficient headroom some form of conveyor with sides may accomplish the same purpose.*

The most serious objection to the use of a feed hopper is that when two or three mine cars of coal are in it at the same time, and the coal is being mixed and fed continuously onto the screen, it is impossible for a coal inspector to properly single out individual cars of dirty coal. Some companies claim that by good engineering design of the various tipple appliances these feed hoppers may be dispensed with.

Screen Breakage.—Gravity Bar Screens.—Usually there is a dead or blank plate at the top and bottom of the bar screen, the former to spread out the coal before screening, the latter to collect it into the loading chute to the railroad car. Since at certain times the coal

*Coal Age, Vol. 1, p. 1143.

may be damp or extra fine, or weather conditions unfavorable, a considerably greater slope is given the screens than is necessary to allow dry lump to screen by gravity. The result is that a lump attains considerable velocity on the screens and suffers breakage when allowed to shoot directly into a railroad car. It is difficult to see how a car of commercial lump of good size and appearance can be made under such conditions, unless a simple steel adjustable chute is installed

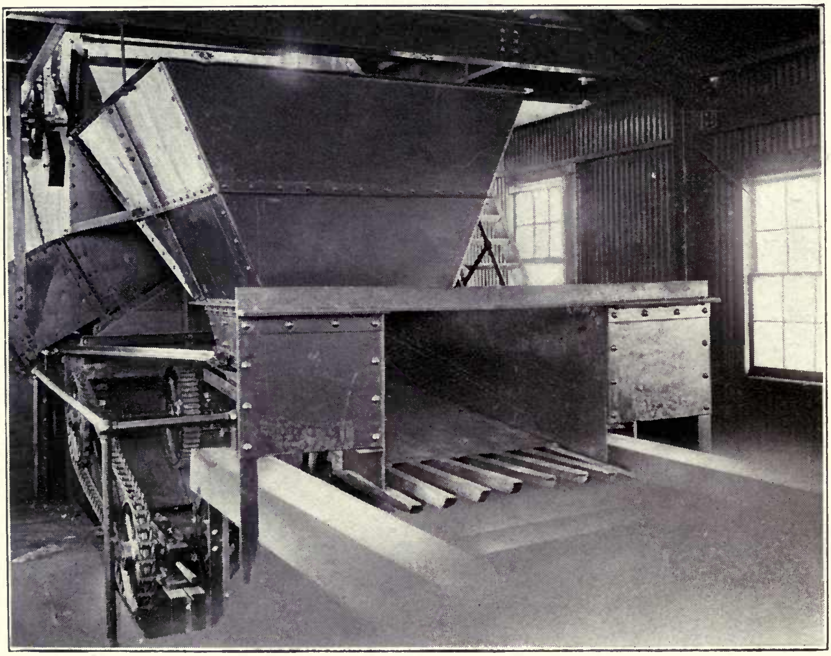

FIG. 23. A STEEL FEED HOPPER.

between bar screen and railroad car to slow up the coal and allow it to fall more gently into the car. The breakage is frequently increased by the chains, car wheels, or short logs of wood which are hung above and about halfway down the screen for the purpose of checking the flight of the coal or of turning the lumps in order to free them from adhering fines. Also lumps frequently become wedged in the bars, and upon being struck by succeeding lumps are broken and drop into the screenings. At many tipples at which bar screens are used to prepare coal for special purposes not in commercial competition with lump coal from adjoining mines, breakage is of secondary importance; the bar screen being used to free the lump from the impurities in the slack rather than from the slack coal itself.

Shaking Screens.—The great variance in speed, in slope, and in size of holes, found in the different designs of shaker screens, cause differences in breakage and freedom of one size from another. In most designs the small holes come first, and often become clogged by sudden rushes of coal. The best results are obtained at the mines at which this fine screen is protected by a false one of larger opening placed about a foot above it, for the purpose of providing against overloading and crushing by the bulk of the lump coal. Where drops of more than one foot are allowed in passing from upper to lower screen some splintering of large lumps can generally be detected.

On a number of screens, lumps of coal fall into the larger screen holes and are not dislodged until worn or broken enough to pass into the undersize. This fault may be remedied by increasing the slope, speed, or length of throw of the screen, or by a combination of these points.

Revolving, Trommel, or Roller Screen Breakage.—On account of the breakage caused by roller screens they are not used in Illinois tipples for the screening of lump coal. They are, however, commonly used, especially in the southern part of the state, for producing the smaller sizes of coal, and indeed they were the only kind of screens used in rescreening plants till about 1910. Now, they are being replaced in the newest rescreeners by the Parrish screen or other approved shakers designed especially for small coal. Roller screened coal can often be distinguished by the rounded corners of the individual pieces, showing that attrition has taken place in the screen, with a consequent production of the dust sizes.

The severest criticism of the roller screen is that in shape and in general principle of action it is similar to the Bradford disintegrator, an efficient machine built for breaking coal. At the Joliet plant of the Illinois Steel Company a Bradford disintegrator 11 feet in diameter and 25 feet long with screen openings of 1⅝-inch diameter breaks Illinois lump coal so completely that less than 3 per cent oversize is discharged, and this is mostly hard refuse. Practically all the coal is broken during its passage through the screen. Although the diameter of the disintegrator is 5 feet greater than that of the ordinary roller screen, and although ribs are placed inside to lift the coal and secure extra height of drop, the general parallelism of action holds.

Breakage in Loading—Passage Over Loading Chutes, Aprons, or Booms.—In England the loading of clean lump coal is assured often by loading from the screen or belt by hand. Two men and a boy can load 60 tons per 8 hours in this way. Because of the price of labor and low value of the coal at Illinois mines coal must be loaded mechanically or automatically, even at the expense of slight breakage. Since most tipple screens have considerable slope, inclined chutes are constructed to lower the various screened products into the railroad cars. Such chutes may be fixed, hinged, shaking, or movable, or may consist of a moving or travelling adjustable steel loading boom, belt or apron (Fig. 24), with which is often combined the picking belt (Fig. 19). Most of the tipples built within the last five years have been equipped for loading the lump and egg sizes of coal with these travelling adjustable loading booms, or with some other form of movable

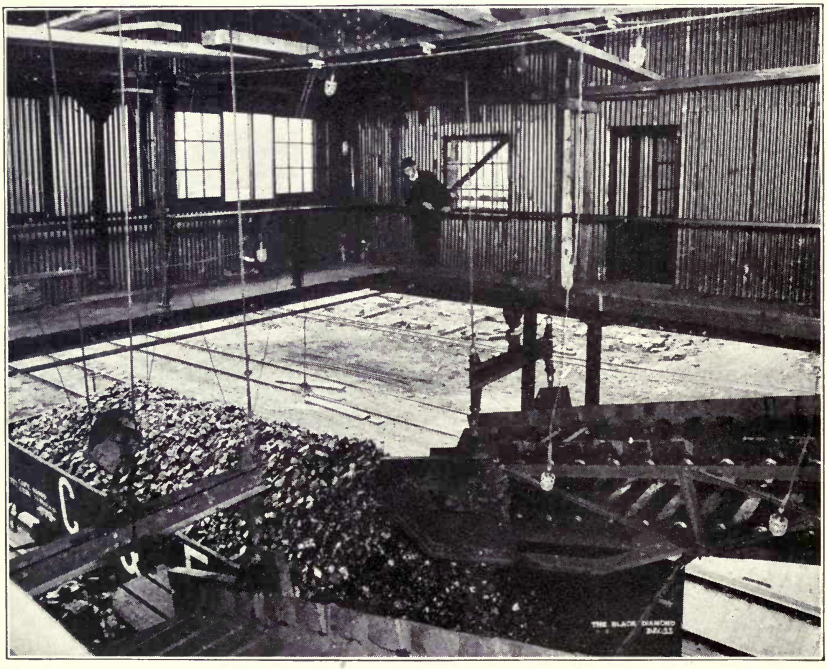

Fig. 24. Loading Boom.

loading chute which can be lowered into the empty car and raised again when that end of the car fills.

Loading chutes may lead directly into the car at right angles to the track or if they have bends or right angle turns or drops they may lead into the car in a direction parallel with its length. Chutes which discharge straight into the car at right angles to the track, unless flat and shaking, shoot the coal into the car. At one or two of the older mines in which these chutes are still in use, a sheet steel buffer is hung over the opposite side of the car in order to prevent spilling, and since the coal comes with considerable force, even trimming and hand picking are rendered difficult. In a chute with curved bottom the lumps slide down only in the lowest part and one at a time, so that a swiftly moving piece may overtake and break the piece ahead. Otherwise, these chutes give good results, especially if bends are necessary, because they turn the direction of the coal gradually.

At most new installations the loading chutes are placed parallel with the track since from this position the coal can be loaded with less breakage, the chutes can be lowered into the cars, spilling of the coal over the sides of the car can be eliminated to a great extent, hand picking can be conducted efficiently and with greater safety, and the coal can be trimmed more uniformly. Whether or not the flow of coal in such a chute should be with or against the direction in which the loading car is moving is open to argument. Most chutes in Illinois are placed so that the coal moves in the same direction as the car. Advocates of this system claim:

(a) If movable loading booms are used, it is possible to get them well down into the empty car.

(b) Lumps can be examined and picked with safety.

Those in favor of the other system claim:

(a) More regular trimming is possible, especially if the cars are moved by hand or by gravity.

(b) Less breakage occurs, since the coal is always moving in the direction of the slope of the coal in the car. The only reference noted on this subject favors this design.*

Breakage in the loading of the smaller prepared sizes—egg and nut—is not so severe on account of their smaller size, lighter weight, and greater uniformity. In order to meet the demands of domestic trade, these sizes must be unusually free from degradation products. A number of mines have recognized this fact and have installed small degradation or secondary screens in the bottom of the loading chutes for these sizes. These screens, bar, round hole, wire screen hole, or lip, are usually stationary and form the bottom of the chute for their length. They usually have less than 1-inch openings, but they remove the last trace of accidental fines and allow only the clean, sized coal to enter the car. The undersize usually passes into the screenings car or to the boiler room.

The perforations in the lip screens (Fig. 25) are long in comparison with their width, and they become slightly wider at the lower or discharge end. A slight drop in the screen at the end of each series of slots allows wedged pieces to be released at these points. This screen also aids in removing small flat impurities which have been sized on the round hole shaker with the more cubical pieces of coal.

Loading and Trimming Railroad Cars.—If all railroad cars were of the same dimensions as regards height, it would be a simple matter to regulate a chute so that loading might take place with a minimum of breakage. Coal cars differ greatly in design, in height, and in

*A. J. Reef, Coal Age, Dec. 14, 1912.

capacity. They consist of three classes: (a) Gondola cars, with or without dumping devices. (b) Hopper bottom cars. (c) Box cars. The special loaders of the box cars will be treated later. Open gondolas and hoppers are the common classes, and at present range in capacity from 25 to 50 tons, and in height or clearance of sides above the rails they vary from about 7 to more than 11 feet in the newer "high sides" or "battleships," as they are often called at the mines. Such a range of clearance seriously affects the successful loading and trimming of the cars, especially if the chutes are not easily and quickly adjustable, since in "spotting" the cars one with steel sides is likely to be followed by a low wooden gondola. At some of the old mines, screens and chutes are so low that the highest cars cannot be loaded on the lump track. In such a case, they are usually switched under the screenings chute, where more headroom is available and breakage not so important. Also, by this practice, excessive shifting of the loading devices is avoided.

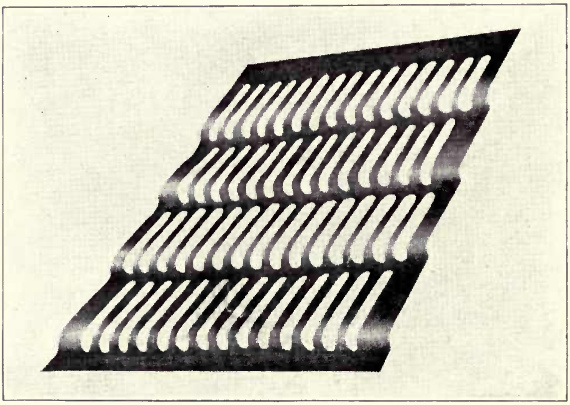

Fig. 25. Lip Screen (Cut Loaned by Cross Engineering Co., Carbondale, Pa.)

There is a wide difference in the inside height of coal cars. They range from 3 feet 6 inches in the smaller flat bottom gondolas to 9 feet in the deepest part of a modern steel hopper car. The difference in breakage in loading two such cars from a chute of the same height is evident. At one mine the loading chute had been raised to a height of about 14 feet above the tracks in order to load properly and trim a high side car. The next car was only 8 feet in height and, therefore, the coal dropped about 10 feet before striking the bottom of the car. Another measurement showed that the end of the lump coal chute had a clearance of 8 feet above the car being loaded at the time.

In general, car loading without breakage is an engineering problem which has been practically solved. Frequently the loaders do not take advantage of the adjustable features of the chutes by following the loading closely, and often no attempt whatever is made to use them. In some cases bad balancing makes the shifting of the automatic loading devices laborious. The newer inclined loading belts or booms are generally controlled by small electric hoists which make adjustment easy.

When loading a car under the tipple, first the end should be filled to the full height of the car, and then the car gradually and slowly moved along, preferably only a few inches at a time. In this way the coal coming from the loading chute strikes near the top of the loaded pile, and after dropping a minimum distance, rolls gently down the slope of the pile into the car. Sometimes the cars are pinched by hand while being loaded, along a grade which has become somewhat irregular by reason of long service, while on other tracks the grade is sufficient to start the car on releasing the brakes; in either case, there is danger of excessive breakage from lumps dropping the full distance to the floor if the car is allowed to move too far. At the more modern and larger mines the cars are retarded and moved either by means of a car puller, which is simply a wire rope attached to a power driven drum, or by a patented car retarder, which consists of a rope attached to a small friction drum under control of an operator. This allows the car to be moved forward as desired and insures a uniform unbroken lump.

While it may be argued that car breakage as discussed has no effect on the percentage of sizes made, the following illustration gives an idea of its effect on the buyer. A large retail dealer gives an average figure of 5 per cent degradation on Illinois lump coal after careful loading, transporting to Chicago, and then unloading with a fork. Other cars, which he thinks must be carelessly loaded, frequently contain up to 15 per cent fines. A saving of 10 per cent breakage in carefully loaded coal is shown by these figures.

Box cars are loaded at many Illinois mines for the following reasons:

(1) General shortage of regular coal cars.

(2) To avoid wetting and possible freezing of the coal in winter.

(3) Prevention of theft in distant shipments.

(4) To prevent box cars returning empty to the states west of Illinois.

(5) Less shrinkage in weight of the coal en route.

(6) Railroads sometimes require box cars to be used for shipments to Texas in order that they may be available there for reshipping cotton.

According to J. J. Rutledge,* twenty years ago in Illinois it was common to see from six to twenty laborers shoveling and carrying lump coal from the center doors of the car and piling it in the ends. Since that time a number of mechanical devices have been perfected, called box car loaders, which load the coal evenly in the car, or where desired.

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*Min. Mag., March, 1906.

A modern box car loader in the tipple should fulfill the following requirements: (a) A capacity equal to that of the shaker screen. (b) Ready adaption to the regular coal chutes. (c) Mobility.—Can be moved in and out of the cars quickly. (d) Freedom of injury to the car ends. (e) Freedom from breakage in conveying and depositing the lump coal in the ends of the cars. The first four requirements will come properly in the discussion of the engineering features of the tipple. The fifth feature, breakage, is being overcome in the newer designs.

At a number of the tipples the box car loaders, which had been installed several years previously and were of older designs, were rusty and unused. Inquiry revealed that the main reason for this was "too much breakage of coal," although it is fair to say that other reasons were, "we don't get the box cars we used to," and "the trade don't call for it loaded that way." Another objection to their use is that no inspection or picking is possible in the car. At many mines, however, the loaders are used constantly, and the fact that some of the newest plants have installed them is proof that they fill a need.

Much of the breakage in connection with a box car loader is due to sliding the coal from the shaker screen down the steep chute necessary to bring the lump coal to the box car loader. Mr. A. J. Reef describes the difficulty as follows: "It has been the universal practice to feed box car loaders over stationary chutes, and even when shaking screens are used, the oscillating portion is at such height as to load open cars, and for the loading of box cars, a long and rather steep chute is always employed. The coal necessarily attains such speed in passing through this latter that it is certain to splinter more or less on striking the loader."* Recent installations in Illinois have improved this obvious defect.

Railroad cars are usually loaded to the limit of 110 per cent of their rated capacity, and the railroads require loading at least to their rated capacity. Several devices have been put on the market to make the top or exposed portion of the carload of coal appear free from small coal. A well appearing and nicely trimmed car is attractive and calls the purchaser's attention to the fact that preparation is receiving due attention.†

The St. Louis and San Francisco Railroad Company has published a bulletin on the proper way to load a railroad car with coal.‡ This states that steel cars should not be loaded more than 4 inches above or below the top of the car against the sides and ends. The top load should not be over 26 inches high. The same rules apply to wooden cars, excepting that the top load should not be over 20 inches high. Cars are properly loaded according to the rules if they contain 10 per cent in excess of the marked capacity. This saves one car in ten, which is important when difficulty is experienced in get-

*Coal Age, Dec. 14, 1912, p. 830.

†B. S. Thym, Coal Age, Vol. 2, p. 248.

‡For abstract see Black Diamond, Dec. 6, 1914, p. 21.

ting cars spotted. Further, they note that the above advantage should more than pay for careful trimming. These rules also reduce loss and breakage to a minimum.

Rescreener and Bin Breakage.—These have been considered briefly under Date on Degradation of Bituminous Coal, p. 76. Further data concerning this subject are not available for this bulletin.

Attention has been called to every possibility of breakage because it is believed that the great care taken at the face to avoid the production of fines can be rendered useless by carelessness in handling below and especially above ground, from the time the coal is hoisted until it is shipped. A single illustration, chosen from a reliable source, shows the importance of modern engineering devices in the tipple in preventing breakage.

At a mine in southern Illinois a new tipple was recently installed in which particular attention was given to the question of breakage. Comparative data given in Table 13 show the percentages of sizes made in the old and new tipples, together with a probable realizable value per ton of coal produced. The prices per ton are an average of the circular prices for the Franklin county field for the years 1913 and 1914.

TABLE 13.

RELATIVE PERCENTAGES AND PRICES RECEIVED FOR COAL WITH OLD AND NEW TIPPLE EQUIPMENT.

Sizes	Old Tipple Equipment			New Tipple Equipment		
	Percentage of Output	Value per Ton	Percentage times Value or Value of Each Size in a Ton	Percentage of Output	Value per Ton	Percentage times Value or Value of Each Size in a Ton
Screenings	37	$0.73	$0.2701	33	$0.73	$0.2409
Small Nut	6	1.38	0.0828	7	1.38	0.0966
2x3-in. Nut	12	1.50	0.1800	11	1.50	0.1650
3x6-in. Egg	24	1.47	0.3528	23	1.47	0.3381
6-in. Lump	21	1.50	0.3150	26	1.50	0.3900
Total	100	....	$1.2007	100	....	$1.2306

Without changing underground methods and by tipple improvements alone the value of the coal was increased 3 cents per ton. At a 2,000-ton mine this is an added income of sixty dollars per day; enough to yield considerable profit after covering the extra fixed charges. Another benefit not apparent from an inspection of the table is that with the new tipple the percentage of domestic sizes is somewhat less than with the old. Although about the same prices are quoted for these sizes as for lump, it is well known that they are at times a drug on the market and must be sold at a lower price.

CHAPTER IV.

Sizing and Sizes of Illinois Coal.

STATEMENT OF PROBLEM.

No feature of coal preparation in Illinois has caused so much discussion as the question of sizing coal in the mine tipple for the various markets. The tendency during the past few years undoubtedly has been towards a multiplication in the number of sizes with a consequent increase of mechanical equipment and preparation cost for each ton produced. The introduction of a new size for a particular purpose at one mine has forced producers at competing mines to introduce a like or even greater refinement in order to hold their trade. Such competition has been severe especially among the smaller mines at which the limited tonnage produced makes difficult the disposal of small amounts of special sizes made as a by-product during the production of the more salable special sizes. The domestic trade today demands the larger coal;* thus the considerable amount of fines produced in its preparation must be absorbed by the steam trade. At times this causes demoralization of the steam coal market.

The coal mining industry is seriously asking the question, "Are too many, enough, or too few sizes of coal being made in Illinois today?" A majority of the operators have expressed themselves in favor of a simplification of sizing and of sizes made, contending that (a) formerly the trade was satisfied with fewer sizes, (b) present sizing tends to cause undue loss through the production of considerable amounts of fines during screening and preparation, (c) at certain periods of the year such carefully prepared sizes are not in demand and must be sacrificed with the smaller and cheaper coal, and (d) consumers do not receive sufficient benefit from sized coals to warrant their paying the increased price per ton which careful preparation demands. They also claim that retail dealers do not like to handle so many sizes in their yards. Some even favor shipping run of mine coal only, since the lumps in such coal, having a cushion of fines to ride on, ship with minimum breakage. If sizes are needed for domestic trade, the retail yard could prepare them as needed in a perfect condition. This plan has been adopted at one Chicago coal yard.†

Others contend that (a) the present sizing practice is the legitimate evolution of an increased knowledge and consequent demand on the part of the consumer, (b) much capital expense has been incurred by mining companies in the erection of special screening and rescreening plants to meet this demand, and (c) having won satisfied customers in this way, a change would be folly. Still others contend that the benefits resulting from very closely sized coals are great, and

*Black Diamond, Oct. 10, 1914, p. 281.
†Black Diamond, March 8, 1913.

that even closer sizing is in demand. They favor the multiplication of sizes as fast as the market will absorb them.

Many of the arguments over the above questions fail to consider the basic question: namely, "Have the correct sizes been made?" Is not the present practice in sizing, although complex, based on custom and convenience, rather than on accurate knowledge of what sizes or range of sizes are most efficient for the consumer and consequently of greatest potential value to the producer?

Necessity for Close Sizing.—In discussing the question of sizing Illinois bituminous coal, care should be taken to differentiate it from Pennsylvania anthracite and from the Appalachian bituminous coal with which it competes.

No doubt, close sizing is necessary for the successful burning of anthracite coal. One of the best summaries on this question is given by J. Callon,* who says that Pennsylvania anthracite will not decrepitate enough in the fire to burn without sizing; that it cannot be in too large sizes because the cold mass would be in too great proportion to the incandescent surface; that all the fragments must be of nearly the same size so that all the particles will be under the action of the flame at the same time; that little pieces must not be so numerous as to fill up the space between the large; and that these little particles are useless because they do not coke. Moreover, he states that the hard nature of anthracite permits close sizing without excessive breakage.

In burning the friable Appalachian bituminous coal, a new set of conditions arises. The coal, whether large or small, when introduced into the fire, heats, gives off its volatile combustible matter, swells, becomes pasty, and fuses or cokes into a more or less coherent mass. In hand fired furnaces this coke must sometimes be broken with a slice bar in order to give the air free access to the fixed carbon or coke remaining, although the coke is in itself porous, and usually admits air, causing combustion to take place throughout the whole mass. Much of the value of close sizing is lost through this coking of the pieces, whether large or small.

Illinois coals are essentially free burning or non-coking in an open fire, are higher in volatile matter than either of the two coals just discussed, and in point of hardness lie between them. On account of its lack of coking properties it might be well to imitate the close sizing used with anthracite; at least to size enough to prevent fines from falling through the grate bars, although in some cases wetting of the coal is said to cause this fine material to adhere to the larger lumps long enough for it to be burned with success. On the other hand, its property of decrepitating readily in the fire into more or less rectangular blocks, allowing free admission of air would seem to refute

*Cours d'Exploitation des Mines, Texte 3, p. 153.

the general claim that increased furnace efficiency is a result of close preliminary sizing.

The following reasons have been advanced for closely sizing Illinois coal:*

(1) Increased furnace and boiler efficiency.
(2) Less loss of fuel in ash.
(3) Less smoke.
(4) Uniformity in quality better assured.
(5) Uniform combustion insuring great capacity.
(6) Less clinker and cinders.†
(7) Less draft needed.
(8) Longer life of grates.
(9) Less cleaning of fires and tubes.
(10) Greater efficiency of fireman, through handling evenly sized lumps.
(11) Furnace under better control; steam can be increased more rapidly.
(12) Sized coal may be stored with little danger of spontaneous combustion.
(13) Increased capacity of furnace through more rapid combustion.
(14) Even and regular air supply encircling each piece being burned.
(15) Sizing allows depth of fire to be adjusted so as to give each size its proper draft.
(16) Quicker fire on account of great number of surfaces in proportion to the weight immediately exposed to the fire.
(17) Less dirt and dust.

It is not province of this bulletin to discuss all of these reasons. Some which are true in the case of anthracite, coking bituminous, or even briquetted coal, are not necessarily true in the case of Illinois coal, or may be true when the coal is used for a particular purpose only. In general, the size of coal which can evaporate the most water for a dollar under the conditions imposed will ultimately determine which sizing practice will be adopted. Until tests have settled this point, a universally acceptable standardization, at least of steam coal, is not feasible.

Another view point is the following: "From an engineering standpoint, exact sizing is right for effective combustion, but consumers for whom sizing is done do not want to pay for it, therefore in a commercial sense sizing is wrong."‡

Sizes Prepared in Illinois.—In order to bring out present sizing practices in Illinois a list of the various sizes of coal prepared has been

*Partly after C. T. Malcolmson. "Briquetted Coal." Proc. 1st Annual Convent., Int. Rwy. Fuel Assoc., 1909.

†Bul. 325, U. S. G. S., p. 40, gives a table showing that size has no effect on clinkering.

‡Black Diamond, December 5, 1914, p. 455.

compiled and is given below, together with trade names and general use or significance of these sizes. The screen in each case is understood to be a standard round hole plate, unless otherwise stated.

(1) Run of Mine.—Coal sold as mined without preparation, and including all sizes mixed together.

(2) Lump Coal.—The larger sizes, from which the finer have been removed. Lump may be made by screening over any one of a variety of sizes of holes. In different parts of the state the size of perforation varies from ½ inch to 8 inches. A few sizes, however, are so common that special names have been given to the lump coal made over them. They are:

(3) Big Lump or Fancy Lump.—Made over a screen with 8-inch holes.

(4) Standard Lump or Chunk.—Made over a screen with 5-inch, 6-inch, or even 8-inch holes. This is the common large size made for the retail trade, and is a favorite, especially if coal must stand considerable handling before using, as in the northwestern trade. In one district a mixture of egg and lump mixed is called standard lump.

(5) Domestic Lump.—Usually a lump made over a screen having 3-inch or 4-inch holes; or it may be identical with (4).

(6) Steam Lump or Ordinary Lump.—Usually made over a screen with 1¼-inch or frequently 1½-inch or 2-inch holes; at some mines the holes may be 1⅛ inches or smaller. Bar screens are also used to prepare this product.

(7) Three Quarters Coal.—Lump and nut coal mixed. (A term adopted from the Pittsburgh district in which bar screens are used.)

(8) Modified Lump.—Made by taking only part of the screenings from run of mine coal. (More frequently used in the Kansas districts, and is made by taking 25 per cent screenings from run of mine containing about 40 per cent screenings.)

(9) Railroad Lump or Standard Railroad Lump.—About the same size as No. 6. In places this is dumped over a bar screen with 8 to 10-inch spaces for the purpose of reducing the largest lumps in order that they may be fired without the necessity of breaking. In this case it may be called Engine Coal or Locomotive Coal.

(10) Engine Coal or Locomotive Coal.—(See (9).) These terms may also refer to run of mine coal broken to pass bars from 8 to 10 inches apart, placed over the receiving hopper or pockets of the coaling station. Locomotives burn other sizes of coal and at least locally, the terms defined may refer to almost any size.

(11) Chute Coal.—A coal containing all sizes under about 6 inches, including screenings, which is frequently sold for local uses. Railroad Chute Coal may be any size used in locomotives.

(12) Local Trade or Wagon Coal.—At many of the mines situated in or near towns there is an auxiliary chute leading from below the weigh box to the ground at a place convenient for loading wagons. This chute usually contains a bar screen with as small as ¾-inch or as large as 2-inch spaces, over which this size is prepared.

(13) Egg Coal.—If screens with from 4 to 8-inch holes are used in preparing a lump, the largest of the sizes below this limit is called egg. Thus egg coal may be as small as 1¼-inch or as large as 8 inches in diameter. If a wide range is included in the egg size, as from 1¼ to 6 inches, it is frequently called Railroad Egg or Railroad Coal. The most common egg coal, however, is that made through a 6-inch and over a 3-inch hole. In retail trade this is sometimes called Furnace Coal.

(14) Egg Run.—Made by leaving all the smaller sizes in the egg coal. May be all coal passing a screen with 5, 6, or even 8-inch holes. Used mostly by locomotives.

(15) Nut Coal.—The sizes smaller than egg and from which the smallest coal has been removed. Nut is made as large as 3½ inches and as small as ¼ inch in diameter. The usual size, however, is through a 3-inch and over a 1¼-inch screen.

(16) Nut Run.—Includes nut coal and all smaller sizes. If nut run is rescreened, it may be divided into any combinations of five sizes, the usual dimensions of which are as follows:

(17) No. 1 Nut.—Through 3-inch and over 2-inch. (May be called Small Egg.)

(18) No. 2 Nut.—Through 2-inch and over 1¼-inch. (May be called Stove.)

(19) No. 3 Nut.—Through 1¼-inch and over ¾-inch. (May be called Chestnut.)

(20) No. 4 Nut.—Through ¾-inch and over ¼-inch. (May be called Pea, Buckshot, or the smaller sizes, Buckwheat.)

(21) No. 5 Nut.—Through ¼-inch and over 0-inch. (May be called Dust or Slack.)

Nut coal is frequently washed, in which case sizes may be prepared, ranging as follows:*

(22) No. 1 Extra Washed.—Always under 3¾-inches and always over 2½-inches.

(23) No. 1 Washed.—Always under 3½-inches and always over 1¾-inches.

(24) No. 2 Extra Washed.—Always under 2¼-inches and always over 1⅜-inches.

(25) No. 2 Washed.—Always under 2¼-inches and always over ⅞-inches.

(26) No. 3 Washed.—Always under 1½-inches and always over ⅝-inches.

(27) No. 4 Washed.—Always under ⅞-inch and always over 3/16-inch.

(28) No. 5 Washed.—Always under 7/16-inch and always over 0-inch.

If only two sizes are made at a washery, the larger is designated "washed nut" and the smaller "washed slack."

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*F. C. Lincoln, "Coal Washing in Illinois." Bul. No. 69, Engineering Experiment Station, University of Illinois, p. 44.

(29) Pea Coal.—In Illinois this term refers to the intermediate sizes of nut. (See (20).) Coal ranging in any of the sizes between 2 inches and ¼ inch has been called pea. Generally this term refers to some size of coal made with less than 1¼ inch as a maximum dimension and with greater than ¼ inch as a minimum.

(30) Screenings or Raw Screenings.—The general term for the fines made in the tipple, if they are not rescreened, includes all sizes passing 2-inch holes or more generally 1¼-inch holes, although screenings are made with larger or smaller maximum limits than these. It is the standard chain grate stoker coal.

(31) Slack.—Refers to screenings from which the larger sizes have been taken. It may be from ¾ inch (plus or minus) to zero in size. The term is frequently used interchangeably with screenings.

(32) Coarse Slack or Stoker Coal.—A combination of Slack, Pea, and Nut.

(33) Fancy Screenings.—Refers to Pea and Slack sizes not separated, and is sometimes called Pea Run.

(34) Duff.—The smaller sizes of rescreened coal. It may be ½ inch (plus or minus) to zero, or may refer to the same sizes as Slack or as Dust Coal.

(35) Dust Coal.—Usually refers to the smallest coal. Thus No. 5 Nut (See (28)) of a size ¼ inch to zero may be called Dust Coal. This coal is also referred to as Culm.

(31), (34), and (35) are sometimes called Waste Coal, especially if they are so dirty that they have little market value.

(36) Pulverized or Powdered Coal.—Coal used in metallurgical furnaces or cement kilns is frequently ground before burning so that 92 per cent or more passes a 100-mesh screen. This is usually done at the plants in which it is used.*

Common terms used in connection with prepared Illinois coal, although not restricted to any special sizes are the following:

Secondary Coal.—Coal in general not of the first grade. It may be a product from the picking belts in the tipple or from the second compartment of a washing jig.

Bug Dust.—Machine cuttings.

Clean Coal.—A coal properly prepared without visible impurities; and not one free from small sizes, as sometimes thought.†

Dirty Coal.—A term ordinarily used when fines or degradation products are visible in the coal; should be used only to designate the presence of visible foreign matter or impurities.†

Conditions Affecting the Sizes Produced.—Considerable differences exist in the actual sizes of the coals just defined, due to differences in the screening surface and to the conditions under which screening is carried on. The screening surface may be composed of

*For a symposium on powdered fuel see: Journal American Society of Mechanical Engineers, October, 1914.

†Black Diamond, May 11, 1912.

bars, of screen plate with round or oblong holes, or of wire screens with square or rectangular openings. The latter are used only on roller sceens in rescreening plants. Also, the steeper the angle at which the screen is placed, the smaller is the maximum piece which will just pass the holes.

Round and Square Hole Screens.—The round hole screen is by far the most common in Illinois, and is generally taken as a standard. No tests are available showing the width of bar screen or the diameter of square opening which will pass the same percentage of an Illinois coal as will a round hole of given diameter.

Tests on other bituminous coals show that a ⅝-inch bar screen will pass the same percentage of run of mine coal as a 1-inch round hole.* Another test shows that a square hole screen will pass as much material as a round hole screen with a diameter 1.23 times as large.† Thus, a 1-inch square hole may be equivalent to about a 1¼-inch round hole, and a 1¼-inch bar screen equivalent to a 2-inch round hole screen. The largest pieces made on a round hole screen are more nearly of uniform dimensions in two directions. For these reasons, if exact sizes are desired, specifications should state not only the sizes of coal desired, but also the kind of screen over which they are to be made, since an operator using a 1¼-inch bar screen produces a considerably coarser screenings than one using a 1¼-inch round hole screen.

Sizes in Competing Districts.—The market for Illinois coal covers at least parts of eighteen states. In different portions of the territory this coal comes into competition chiefly with the bituminous coal from West Virginia, Kentucky, Ohio, and Indiana on the east, and from Iowa, Missouri, Kansas, Oklahoma, etc., on the west. Multiplication of sizes in all of these districts has been rapid during the past few years, and many mines formerly producing only lump and screenings, now ship two or more prepared sizes.

Until recently the initial preparation of coal in much of the eastern territory mentioned was governed by an agreement between the coal operators and the United Mine Workers of America, which specified as follows:

"Screens hereby adopted for the State of Ohio, Western Pennsylvania, and the bituminous district of Indiana shall be uniform in size, six feet wide by twelve feet long, built of flat or Akron‡ shaped bar of not less than ⅝ of an inch surface with 1¼ inches between bars, free from obstructions, and that such screen will rest upon a sufficient number of bearings to hold the bars in proper position."

Frequently, the slack or screenings made through this standard screen are rescreened over a bar screen having ½ or ¾-inch spaces, making pea and slack. In other cases this second screening is over

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*Henry Louis, "The Dressing of Mineral," p. 12.

†Eng. and Min. Jour., March 13, 1915, p. 493.

‡The name Akron bar refers to a bar of particular cross section, taking its name from the city of Akron, Ohio, where it originated, and not from the resemblance of the cross section of the bar to an acorn, as has been suggested.

a rotary screen with square or round holes. As has been stated, Ohio has recently passed to the mine run basis which will lead to a change in preparation and possibly to a multiplication of sizes to meet competing districts.

In districts of West Virginia in which coking coal is mined not so much attention is paid to sizing as in districts in which splint and gas coals are mined. Thus, in the New River field 3-inch bar lump, 1 or 1½-inch bar to 3-inch bar egg, and 1 or ½-inch bar screenings are prepared. From the Fairmont region of northern West Virginia the following sizes are shipped:*

(a) Lump.—Four inches, 3 inches, 2½ inches, 2 inches, 1½ inches, 1¼ inches, and ¾ inch.

(b) Egg and Nut.—The sizes depend upon the size of lump.

(c) Pea.—Through ¾-inch and over ½-inch.

(d) Slack.—Through ½-inch. This district has been sizing its coal closely since 1900. The recent tendency is towards a simplification in the number of sizes.

In Indiana 1¼-inch bar screenings are prepared which may be rescreened into pea or slack. The 1¼-inch bar lump is frequently made into nut, egg, and lump which competes with Illinois sizing.

In Kentucky the practice varies greatly, but in many of the newer tipples, especially in the eastern part of the state, and in several cases in the western part, shaker and other screens have been installed to prepare the domestic and other sizes common in Illinois.

In Iowa, Missouri, and Kansas, although payment to the miner is on the run of mine basis, preparation is generally more simple than in Illinois. One, two, or three sets of bar screens are often used, making at the most four sizes; through 1¼-inch, through 2½-inch, then through 4, 5, or 6-inch, and a large lump over this size. Round hole shaker screens, however, are not uncommon in these fields. For example, Kansas coal for general domestic trade is prepared over round hole shaker screens into 3-inch lump, 2-inch to 3-inch egg, ¾-inch to 2-inch nut, and a ¾-inch slack.

Oklahoma. (For Oklahoma sizes see p. 109.)

Standardization of Sizes.—Such a multitude of sizes and names of bituminous coal must be a cause of uncertainty, trouble, and annoyance to producer and consumer alike; to the producer in endeavoring to adjust his own screens to meet the extremely varying market, and to the consumer from lack of information regarding the nature and real worth of the many sizes. Aside from the question as to whether more or fewer sizes are advantageous, Illinois and the rest of the bituminous field are badly in need of some standardization of sizes.

In November, 1914, a radical change, proposing to do away with the many sizes now made and to return to the old methods of producing 1¼-inch screenings and 1¼-inch lump coal only, was advocated

*H. H. Stoek, "Mechanical Preparation of Coal." Proc. 2nd Annual Convention, Int. Rwy. Fuel Assoc., 1910.

in the present method of preparing bituminous coal at the mines in Illinois and in the eastern competing region. This plan contained a provision for producing a domestic nut size when necessary.* The plan was not to be adopted until accepted by enough operators to represent 90 per cent of the tonnage in the field.

Mr. H. C. Adams, the originator of the plan, states that Ohio, Indiana, West Virginia, and western Kentucky appeared to be favorable to the change, but that Illinois and the southeastern Kentucky did not give sufficient support to make it successful.† Figures given for Illinois show that operators representing about two-thirds of the tonnage were willing to standardize if competing districts would do likewise, and that over 14 per cent of the remainder represented mines not entering the general market. It is remarkable that such a percentage of the operators were willing to return to the simplest of all preparation,—two sizes, and of course run of mine. Further opposition to the plan was made by the railroads which in some cases were afraid the change would mean forced sizing in their own chutes, especially if they had been accustomed to burn lump.‡

Standard Practice in Various Districts.—Standardization has been accomplished in several districts, as is shown by the following:

TABLE 14.

COMMERCIAL SIZES OF ANTHRACITE.

Name of Size	Diameter of Ring		Uses
	Over inches	Through inches	
Lump	6½	...	Locomotive Steam Coal. (Very little now made.)
Steamboat	4½	6½	Blast Furnace Coal. Smith's Forge Coal. (Very little now made.)
Broken	3¼	4½	Domestic Furnace Coal.
Egg	2 5/16	3¼	" " "
Stove	1⅝	2 5/16	Domestic Range Coal.
Nut	15/16	1⅝	" " "
Pea	⅝	15/16	Domestic Furnace Coal.
Buckwheat	7/16	⅝	Steam Boiler Coal.
Rice	¼	7/16	" " "
Barley	3/32	¼	" " "

In 1916 the standard sizes of anthracite were changed and a reduction made in the number.¶

*The Coal Trade Journal, November 14, 1914.
†Black Diamond, February 20, 1915.
‡Coal Age, March 6, 1915.
¶Coal Age, p. 839, May 13, 1916.

TABLE 15.

STANDARD SIZES OF BITUMINOUS COAL. (OKLAHOMA.)

Name of Size	Diameter of Round Perforations in the Shaker Screen Used	
	Through, inches	Over, inches
Domestic Lump	...	2½
Screened Nut	2½	1¼
Chestnut or Pea	1¼	¾
Slack	¾	...

In the anthracite districts of Pennsylvania the commercial sizes given in Table 14 are produced,* and the standardized sizes adopted by the producers in the Oklahoma bituminous fields are given in Table 15. This standardization has been in force since about 1912, and is used at practically all mines in Oklahoma, irrespective of district or seam. Five sizes cover the entire range of these bituminous coals. They are probably somewhat softer than Illinois coals and, with the exception of one seam, are non-coking. It has proved satisfactory to both producers and consumers.

A committee on standard form of contract covering purchase of railroad fuel reported in favor of a standard for bituminous coal as follows:† (See Table 16.)

TABLE 16.

STANDARD SIZES OF BITUMINOUS COAL FOR RAILROADS.

Kind of Coal	Screen Made Over			Screen Made Through		
	Round Inches	Square Inches	Bar Inches	Round Inches	Square Inches	Bar Inches
Pea	...	⅜	...	...	1¼	... or
Pea	½	...	...	...	1¼	... or
Pea	...	¾	...	1¼	...	... or
Pea	½	...	...	2	...	...
Nut	1¼	...	...	2½	...	...
Egg	2½	...	...	7	...	... or
Egg	3½	...	...	6	...	... or
Lump	7	...	...	...	...	... or
Lump	...	...	4	...	...	...
Pea Run	...	...	...	1¼	...	...
Nut Run	...	...	...	2½	...	...
Egg Run	...	...	...	...	...	5 (not less than)
7″ Round Egg Run	...	...	...	7	...	...

*Paul Sterling, "The Preparation of Anthracite." T. A. I. M. E., Vol. 42, 1911, p. 264.

†Proc. 5th Annual Convent., Int. Rwy. Fuel Assoc., 1913, p. 31.

Mine Run Coal shall not contain more than 30 per cent screenings through 1-inch diamond bar screen, but shall contain more than 30 per cent of 5-inch bar screen lump or more than 40 per cent of 7-inch round hole screen lump.

The recommendations also included the use of relief screens to prevent overcrowding of the fine screens, and specified a minimum area for screens making the different sizes. Although favored by the convention in question the provisions have not been adopted by the railroads.

"In 1903 the operators in Williamson county, Illinois, adopted the following standard of sizes for washed coal. The numbers used refer to screens with round perforations."* This standardization has not been maintained in all cases.

Designation	Through	Over
No. 1	3 in.	1¾ in.
No. 2	1¾ in.	1 in.
No. 3	1 in.	¾ in.
No. 4	¾ in.	¼ in.
No. 5	¼ in.	......

Standardization means little to the small consumer, whose aggregate consumption, however, forms a considerable percentage of the coal produced. The general ignorance on this subject is well brought out in a report of a committee of the Boston Chamber of Commerce on Buying and General Handling of Steam Coal (November, 1909), wherein it is stated that of 225 manufacturing firms using steam coal, 25 per cent did not even know the particular kind of coal they were using.

The recent trend of public opinion towards some form of standardization for coal is significant. In 1913 the United Improvement Association of Boston voted to present three bills to the legislature:

(1) To establish a standard of quality for coal sold for domestic purposes.

(2) To establish a standard for sizes of meshes in sieves used in screening coal sold for domestic purposes.

(3) To require that a list of prices and notices of change of the same be filed with the state police.

Requirements for Standardization.—In considering the standardization of Illinois coal several viewpoints may be taken: (1) That of the producer, who desires to make only the largest percentage of the sizes of greatest market value. (2) That of the dealer who must furnish the coal which customers demand and are accustomed to.

*C. S. McGovney, "Tests of Washed Grades of Illinois Coal." Bul. No. 39, Engineering Experiment Station, University of Illinois.

(3) That of the fuel agent, or purchaser for the larger consumers, who generally wants the most heat units for a dollar. (4) That of the consumer, each class of whom, for various reasons, demands a different fuel. It would appear that his viewpoint must be the final judgment as to what coal may be produced.

Consumers of Illinois coal may be subdivided into seven groups as follows:

(1) Railroads using coal for locomotives.

(2) Stationary power plants in which coal is used to produce steam.

(3) Domestic, retail, or household users.

(4) Large heating plants (as brick kilns and metallurgical plants).

(5) Those using pulverized coal. (Generally as a fuel for cement kilns and for certain metallurgical purposes.)

(6) Coke oven operators. (Ovens operated primarily for manufacture of metallurgical coke.)

(7) Gas Manufacturers using (a) gas producers for power purposes, and (b) retorts.

Many consumers in the last four classes obtain their coal from mines operated for their particular demand, or if buying in the general market they consume only a small fraction of the total production; therefore, they will not be given detailed consideration. Pulverization (5) has been referred to (p. 105). It is noteworthy that recently considerable Illinois coal has been used to produce metallurgical coke in the by-product ovens in northern Illinois and Indiana, 25 per cent and even more of the high volatile coal of Illinois having been mixed with low volatile eastern coals with success. Low ash and sulphur contents are the prerequisites for the coal used for this purpose, and since the coal is crushed to ¼ inch and smaller before using, size is of minor importance.

The first three classes noted—railroads, power plants, and domestic users—enter most strongly into the general market, the railroads alone buying 18 per cent of the total production of Illinois coal in 1914.* There is doubt that these three users, with their widely varying demands, can be satisfied with the same coal.

Railroad Fuel for Locomotive Use.—The railroads have and can use almost any size of fuel produced in Illinois today. The type of locomotive, class of service, grate and fire box design, draft and load (whether light or heavy) may render one size of fuel more efficient than another. Ease of firing, kind of fuel to which the fireman is accustomed, desire to assist a mine being served by the railroad, and relative price converted into ton miles under the conditions imposed, also influence the sizing or lack of sizing favored.

*Illinois Coal Report, 1914.

It has been stated that Illinois run of mine coal under present conditions is the most economical coal per ton mile obtainable.*

The sizes listed on p. 103 as railroad fuel are the ones frequently used, although a number of companies, considering the difference in price, prefer run of mine; and recently the automatic stoker, burning the lower priced screenings, has been successfully introduced for this work. Most authorities agree that the ideal fuel for hand fired locomotives would be one with lumps of a maximum size of from 3 to 5 inches,† which would allow the fireman to shovel without taking his time to break lumps; and of a minimum size of about ½ inch, which would lessen losses through the grates and prevent the draft drawing the fine fuel out of the stack. Large lumps generally necessitate breaking in the railroad chutes or coaling stations.

From the standpoint of absolute efficiency, a number of railroad tests made with run of mine vs. variously sized coals, do not show conclusively that it is cheaper to use a closely sized fuel for this work.

Domestic, Retail, or Household Fuel.—Individual fuel users burn only a few tons per year and usually buy the size of fuel recommended by their dealer as best suited to their needs. The standard domestic fuel, anthracite, is sized closely, and until recently most stoves and heating furnaces were designed for this fuel; consequently a domestic bituminous coal, to sell well, should resemble anthracite in appearance. Absence of dirt and dust are important factors which make closely sized fuel a favorite. In discussing this subject, J. D. Rogers states that in grading a bituminous coal for domestic use three points must be noted: (a) absence of slack in the prepared grades, (b) absence of impurities in all grades, and (c) uniformity of size of the smaller grades.‡ For interstate shipments designed for house heating furnaces, or for threshing engine boilers and similar uses, where the coal must be handled several times, often with excessive breakage, it seems essential that a large lump should be shipped. Many householders favor a sized coal because it is said to sustain better a mild, steady combustion.

Tests by J. M. Snodgrass¶ conducted for the Engineering Experiment Station of the University of Illinois, have shown that with Illinois coal as a fuel, water can be evaporated in house heating boilers at about 50 per cent of the fuel cost of anthracite, and at about 75 per cent of the fuel cost of Pocahontas coal or coke. The relative worth of the different sizes in use for this purpose is not discussed.

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*Proc. International Rwy. Fuel Assoc., 2nd Annual Convention, p. 88.

†Proc. International Rwy. Fuel Assoc., 2nd Annual Convention, pp. 19 and 21.

‡"Preparation of a Domestic Coal." Kentucky Mining Institute, December, 1912.

¶Proc. Illinois Fuel Conference, Urbana, Ill., 1909.

Whatever the comparative effective heating power of unsized vs. sized coal for domestic trade, it is outweighed by appearance, freedom from dust and cleanliness in handling of the prepared sizes. These demands must be met by the producers furnishing this trade.

Stationary Power Plants Using Coal to Produce Steam.—The selection of coal for steam boilers depends on five things; namely, (a) relative price per ton, (b) total heating value, (c) relative percentage of the heating value that can be utilized in the boiler (d) maximum capacity which may be developed in the boiler, and (e) cost of handling different coals and the ashes produced by them.*

The results obtained by this selection depend in turn on: (a) the nature and condition of the coal, (b) character of the furnace, and (c) conditions of firing and furnace control.†

Effect of Size of Fuel.—The great number of variables thus introduced into any boiler test have tended somewhat to obscure the effects of sizing or of the range of sizes to be used under any particular condition. Regarding sizes of Illinois coal for a steam boiler fuel the following data are available.

"Tests made with different sizes were negative in results, and emphasize the statement—that the study of the effects of the various elements of size of coal has not been made in sufficient detail."‡

"The size of coal influences the capacity of any given equipment owing to its effect on the draft. . . . When dust and fine coal are fed into the furnace they either check the flow of air or are taken up by the draft and after being only partly burned are deposited back of the bridge walls. . . . Coal of uniform size forms the most satisfactory fuel, as it does not pack so closely as coal of different sizes mixed. The furnace design may be changed to suit the coal in view."¶ In the same bulletin (p. 6) it is stated that almost any fuel may be burned with reasonable efficiency in a properly designed apparatus.

L. P. Breckenridge states, "When coal fed into a furnace is fairly uniform in size it is much easier to burn it without smoke than when it is of different sizes. . . . Just to what extent it will pay to size coal for regular use is not yet clear."** Still another investigator states, "The size of the interstices between the coal particles increases with the size of the coal particles. Consequently with lower grades (meaning smaller sizes) of uniform coal a large proportion of the total air passes through the fuel bed. . . . For each size a depth of fuel bed will be found for which a minimum excess (of air) occurs."††

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*Colliery Engineer, Vol. 19, p. 64.

†Colliery Engineer, Vol. 10, p. 114.

‡U. S. G. S., Bul. No. 325, p. 49.

¶U. S. G. S., Bul. No. 428, p. 8.

**"How to Burn Illinois Coal Without Smoke." University of Illinois, Engineering Experiment Station, Bul. No. 15, p. 43.

††C. S. McGovney, "Tests of Washed Grades of Illinois Coal." University of Illinois, Engineering Experiment Station, Bul. No. 39, p. 55.

In general none of the references quoted give information specific enough to aid the operator of a hand fired stationary grate power plant in choosing among a variety of roughly or more closely sized coal. Such a consumer demands a coal large enough to avoid losses through the grate and to burn freely under the weak draft conditions existing in these plants. The tendency of fines to produce smoke may be an added factor, although "any fuel may be burned economically and without smoke if it is mixed with the proper amount of air and at the proper temperature."*

The ordinary coal sold for this purpose is steam lump with more or less screenings removed as demanded. Certain types of automatic stokers also are run with such lump coal.

Use of Screenings.—Most of the automatic stokers in power plants using Illinois coal today are designed for burning the sizes of coal under two inches, usually raw screenings. A favorite type is the chain grate stoker. In 1914 Illinois mines produced 19,740,000 tons of screenings size, or 32.5 per cent of their coal output, and although considerable of this was rescreened, a larger part was burned in automatic stoker boiler plants for the generation of steam. At the power houses of one public service corporation in Chicago, over 1,500,000 tons of coal were burned in 1914. This was mostly Illinois screenings, the cost of which represented about three-fourths of the total cost of each kilowatt of electricity generated.

"During the past twenty years the price of screenings has risen from practically nothing to a figure that in 1913 threatened for a time to make possible the crushing of larger prepared sizes for use in this work."† Normally, however, screenings are of lower value. Considerable success has been attained by rescreening this raw product, the average circular price of the different sizes so produced being higher than that of the raw screenings. A market for these sizes must necessarily be limited and unable to absorb the major tonnage of the raw screenings, unless some such separation is proved to be of added benefit in those sizes used in automatic stoker steam plants.

Because of this great production and market any proposed standardization of coal sizes should take into account the following questions: What size of screenings, if any, is best adapted for chain grate work? Will 1¼-inch or 2-inch or even some larger or smaller sizes or range of sizes give the coal for the most economic combustion? Other factors being equal, 2-inch screenings bring a higher price than 1¼-inch. Is this justified? Another point concerns the occurrence, distribution, and effect of the ash and impurities in the various sizes of screenings. Unlike many eastern bituminous coals, Illinois screenings are uniformly higher in ash than the larger sizes of coal and are not available for coking purposes, which throws practically the entire output into the steam trade.

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*University of Illinois, Engineering Experiment Station, Bul. No. 15, p. 16. p. 16.

†H. W. Weeks, Black Diamond, March 20, 1915, p. 233.

Mr. H. W. Weeks, in discussing the general subject, says of the standard 1¼-inch screenings, "Screenings of this size are not satisfactory when used on many different kinds of equipment, the nature and amount of the load having an important bearing on their efficient use."* On the whole he favors larger screenings than these, especially if heavy loads are frequent.

To show the general effect of size on the efficiency with which Illinois screenings can be burned, the following are quoted: "Coals ranging in size from ¼ inch to 1½ inch burn much more rapidly than either very small or very large sizes."† (They must therefore give a greater capacity for any given equipment.) "Many Illinois screenings contain 40 per cent or over of material under ¼ inch."‡ "A coal with evaporative efficiency of 66 per cent when 10 per cent of it is under ¼ inch diameter, will give an efficiency of only 62 per cent when 60 per cent of it is under ¼ inch in diameter."¶ "Small sizes of coal burned with less smoke than large sizes, but developed lower capacities;"§ however, "31 tests on coal with an average diameter of 0.39 inches give an average efficiency of 66.88 per cent and 53 tests on coal with an average diameter of 1.46 inches give an average of 65.97 per cent."**

A. P. Kratz made a number of boiler tests with 1¼-inch round hole Illinois screenings from which the following is abstracted.†† In test No. 6 using 1¼-inch screenings of which 19.6 per cent were smaller than ¼-inch round hole opening, the overall efficiency of the boiler was 68.09 per cent; while in test No. 8, with 50.5 per cent passing the ¼-inch screen, the overall efficiency was 61.08 per cent. He states (personal interview) that draft and thickness of fuel bed are factors in high efficiency as well as any particular sizing of the coal.

Recent specifications frequently limit the amount of the screenings under ¼ inch in diameter, one examined limiting the amount to 40 per cent.

Tests made by the Commonwealth Edison Company of Chicago in 1906 ‡‡ show that for their chain gate stoker work with a constant thickness of fire, maximum efficiency was obtained when using sized coal of an average diameter of ¾ inch, and that especially below this size efficiency decreases rapidly and is very low for screenings under ¼ inch in size. This view has been somewhat modified since

*"Influence of Size on the Cost of Making Steam." Black Diamond, March 20, 1915, p. 233.

†U. S. G. S., Bul. 325, p. 176.

‡U. S. G. S., Bul. 290 (Tables).

¶University of Illinois, Engineering Experiment Station, Circular No. 3, p. 37.

§U. S. G. S., Bul. 373, p. 10.

**U. S. G. S., Bul. 373, p. 148, Table 37.

††"A Study of Boiler Losses," University of Illinois, Engineering Experiment Station, Bul. No. 78.

‡‡W. L. Abbott, "Some Characteristics of Coal as Affecting Performance with Steam Boilers." J. W. S. E., Vol. 11, 1906.

that time. Recently the above company have conducted a great number of boiler tests with Illinois screenings to ascertain among other points the size or combination of sizes best adapted for their work. Through the courtesy of W. L. Abbott, Chief Operating Engineer of the company, the writer was able to examine the results of many of these tests, which throw considerable new light on the whole subject of screenings. They point towards the following conclusions:

(1) There is a great difference in ash content among the various raw screenings produced in Illinois today, car samples received showing a minimum of 10.1 per cent and a maximum of 29.7 per cent, with an average of 17.4 per cent for thirty-two samples examined (dry basis).

(2) Screenings made through the same size of screen and coming from different mines or even from the same mine at different times show great differences in the percentages of relatively coarse and fine coal contained. Certain cars showed as much as 50 per cent and others as little as 17.8 per cent of coal under ¼-inch round hole in size. A large percentage of this fine coal in screenings greatly lowers the efficiency of the boiler under test.

(3) The company has placed a maximum limit to the amount of screenings they will buy of 55 per cent under ¼ inch in size. With such material, combustion is slow because the air will not go through it. Most of the trouble comes from the part of this fine material which is smaller than ⅛ inch in size. There is no objection to pieces of ⅛ inch size.

(4) Three per cent moisture added to screenings containing high duff greatly aids combustion.

(5) By removing all material below ⅛ inch from an Illinois screenings in one test the engineers were able to raise the furnace temperature from 2,500° F. to 2,800° F.

(6) On the other hand, coal sized with an entire absence of the sizes under ¼ inch does not show increased efficiency, probably due to difficulty in securing uniform air admission. The engineers report crushing an egg coal to stoker sizes and obtaining indifferent results because of a lack of a certain necessary amount of fine material. Ten per cent of the material under ¼ inch probably represents roughly a minimum desirable.

(7) Screenings with a maximum size of 1 inch are as efficient for these conditions as larger sizes.

Briefly, the best screenings for these and similar conditions are those with a maximum size of 1 inch and containing a limited amount only (15 or 20 per cent) of sizes under ¼ inch. (It is evident that a sized coal would produce this amount of fines as a degradation product if it received two or three handlings before being burned.)

The effect of a variation of ash in the screenings is to reduce the capacity and efficiency of the particular size of coal slowly until 15 to 20 per cent is reached and then more rapidly, until with about 40 per cent ash the efficiency of that size of coal is zero.*

Other references state, "Ash in dry coal has little effect on efficiency up to 15 per cent, above this point efficiency drops rapidly;"† and "overall efficiency of coal decreases only 2 to 3 per cent until ash content rises above 20 per cent when efficiency falls rapidly. In general, ash increase of 1 per cent causes a drop in efficiency of about 2 per cent."‡ In other cases this was less. U. S. government specifications for coal also recognize the greater decrease in efficiency with an increase of ash than would be expected by the actual decrease in combustible matter shown by such added percentage of ash.¶

Tests Made with Illinois Screenings at the Mining Laboratory of the University of Illinois.—Believing that ash and possibly sulphur were unevenly distributed among the various small sizes of coal which compose Illinois screenings, and that the location of certain sizes containing uniformly a high percentage of ash might be of assistance in solving the problem of how to make screenings more valuable, tests were undertaken in the Mining Laboratory of the University of Illinois. It was thought that screening tests, followed by analysis of the separate sizes, might reveal sizes the removal of which might pay both operator and consumer if cost, freight, and comparative boiler efficiency were considered. An outline of these tests follows:

(1) Requests were sent to ten mines in the state, asking that a barrel of screenings be collected from under the tipple at random during loading and be shipped to the laboratory. The mines were chosen with a view of representing all the seams mined in the state and widely separated districts.

Such a sample in no way represents an average of the screenings being made at any of the mines, and does not reflect on or bring credit to any mine or district. It was believed, however, that such samples would give a preliminary guide as to the relative percentages present in the different sizes, how impurities occurred in the screenings, and a hint as to their possible removal.

(2) In any set of sizing tests a standard set of screens must be chosen. Unfortunately many sizing tests are made with no idea of uniformity in the succession of screens used, either regarding shape or relative sizes of the holes. The round hole screens were adopted in each case as conforming to the usual commercial conditions. A 1-inch diameter hole was taken as a standard, and with screens below this size, a ratio of ½ was used; thus the diameter of each hole is ½ the diameter of the hole of next greater size. The screens used were 1 inch, ½ inch, ¼ inch, and ⅛ inch in diameters. For sizes above an inch a 2-inch screen would be the next in the ratio; this was used when the size of the screenings tested warranted it, but

*W. L. Abbott, Jour. West. Soc. Eng., Vol. 11, 1906.
†U. S. G. S. Bul. 325, p. 176.
‡U. S. G. S., p. 38.
¶U. S. G. S. Bul. 339, p. 13.

since some of the screenings were of smaller size, as 1¼ inch, this size of intermediate screen was also used.

(3) Upon receipt, the whole barrel of screenings was carefully weighed, sampled, and a portion saved for analysis.

(4) Another portion was subjected to a float and sink test to determine the relative amounts of high grade and low grade coal present. In this test a solution was brought up to a specific gravity of 1.35 by the additions of zinc chloride. A representative lot of the screenings was stirred into the solution, the light weight purer coal

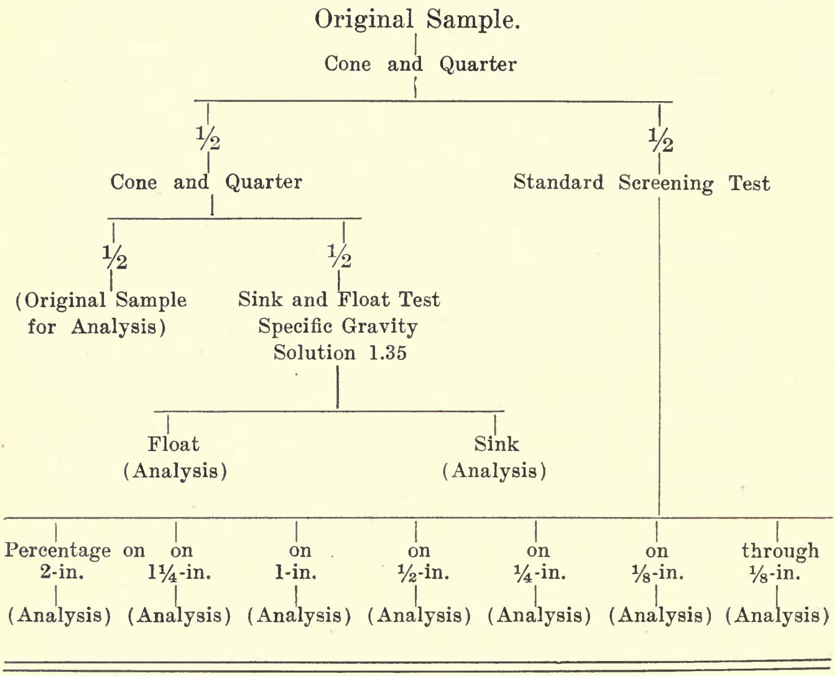

FIGURE 26. OUTLINE OF WORK. SCREENINGS INVESTIGATION.

floating, and the heavier bone coal and refuse sinking. The two products were carefully separated and analysed. The results appear in the tests under the heading "Float and Sink Tests." These results are relative only, as another standard of specific gravity of the test solution would produce different results.

(5) Half of the original sample was carefully screened in succession through the standard set of screens mentioned under (2), effort being made to prevent breakage.

Fig. 26 shows an outline of the work just described.

As received, the eleven samples varied in ash from 6.72 to 24.88 per cent and in sulphur from 0.90 per cent to 7.16 per cent. The float and sink tests show that the greatest part of the screenings is a rather pure coal of from 4.22 to 8.74 per cent ash and of low sulphur, and that on the average 23.2 per cent of the screenings is represented by a separable coal having an average ash content of 36 per cent and correspondingly high sulphur.

Test (1) was made with a 1-inch bar screenings, the other tests were upon screenings through round holes of the sizes indicated. When test (1) was subjected to screening on round hole screens, 23.5 per cent of the material was over 1 inch, showing the relatively large coal produced by bar screens. The presence of 1.47 per cent of coal on a 2-inch round hole in this test, and an ash content of 49.2 per cent and sulphur of 10.78 per cent show how these impurities, by breaking into flat pieces, pass a bar screen when they would not pass a round hole screen.

The largest amount of coal under ¼ inch was in test (4), the total being 30.1 per cent. The largest amount of dust under ⅛ inch occurred in test (5), 21 per cent, and this test had an average ash content of 17.81 per cent or 40 per cent more than the coarsest sizes in the same screenings.

In every test excepting (1) the largest sizes of the screenings show the least ash; this ash increases slightly until the dust coal under ⅛ inch is reached, when it shows in every case a decided increase, tending to confirm the opinion that the universal high ash content of this finest coal may be one cause of its low efficiency. In test (1) this fine material had an ash content of 40.9 per cent, enough to render it practically useless as an efficient fuel. Several others show striking increases measured on a percentage basis.

Contrary to the usual opinion, sulphur showed no increase in the fine sizes; a decrease even being noted in several cases. This tends towards the opinion that a large percentage of the separable sulphur is contained in the lump or ball form rather than in the brittle leaf form as is the case in many coals.

Regarding moisture, the results were irregular, and for this reason they are not included in the table. This may have been partly due to working with considerable quantities of the samples in a steam heated laboratory. It is significant, however, that in no case did the moisture vary greatly among the different sizes or show any tendency to increase in the finer sizes.

The percentage of the total ash was obtained by multiplying per cent weight by per cent ash. It shows the percentage of the total ash in the screenings in any particular size. As an illustration, in test (1) 18.7 per cent of the screenings which passed ⅛ inch, contained over 32 per cent of the total ash.

Calculated on an efficiency basis, if the screenings in tests (1), (2), and (11) were to stand any considerable freight rate, there is

TABLE 17.
SIZING TESTS ON ILLINOIS SCREENINGS.

No. of Test	Origin of Sample	Size of Coal	Outline of Work (See Fig. 26)	Original Sample	Float and Sink Tests		Sizing Tests: Sizes of Round Hole Screens Used						
					Float	Sink	On 2-in.	On 1¼-in.	On 1-in.	On ½-in.	On ¼-in.	On ⅛-in.	Through ⅛-in.
1	Seam No. 1 North	1-in. bar screenings	Per cent of weight	100.00	69.37	30.63	1.47	11.55	10.50	29.22	18.28	10.30	18.70
			" " " ash	24.88	8.72	46.53	49.20	19.17	16.15	16.10	21.21	25.70	49.90
			" " " total ash	100.00	29.75	70.25	3.01	9.44	7.21	20.02	16.50	11.27	32.55
			" " " sulphur	7.16	3.03	10.75	10.78	6.47	5.42	5.74	6.78	6.91	8.39
2	Seam No. 2 North	1⅛-in. round hole screenings	Per cent of weight	100.00	74.25	24.75	.....	.....	6.93	42.54	26.31	12.53	11.87
			" " " ash	19.95	6.62	46.41	.....	.....	14.78	16.18	18.25	20.88	29.21
			" " " total ash	100.00	30.00	70.00	.....	.....	5.43	36.62	25.50	13.90	18.55
			" " " sulphur	4.30	2.58	10.53	.....	.....	4.32	4.32	4.29	4.59	4.22
3	Seam No. 2 South	2-in. round hole screenings	Per cent of weight	100.00	92.50	7.50	5.82	23.60	10.25	25.90	14.85	7.63	12.05
			" " " ash	6.72	4.22	30.91	8.14	5.24	5.67	6.03	7.20	8.82	12.68
			" " " total ash	100.00	62.80	37.20	6.60	17.41	8.15	21.92	15.04	9.41	21.50
			" " " sulphur	0.90	0.60	6.19	3.48	0.97	0.89	1.03	1.15	1.23	1.85
4	Seam No. 5 Central	1¼-in. round hole screenings	Per cent of weight	100.00	73.07	26.93	.....	.....	11.11	36.50	22.30	13.00	17.10
			" " " ash	15.28	8.07	30.62	.....	.....	12.85	16.02	14.82	16.20	19.75
			" " " total ash	100.00	41.70	58.30	.....	.....	9.31	33.33	21.61	13.75	22.00
			" " " sulphur	5.08	3.18	7.42	.....	.....	4.92	4.56	4.86	5.60	4.17
5	Seam No. 5 South	1¼-in. round hole screenings	Per cent of weight	100.00	63.70	36.30	.....	.....	13.01	32.10	20.80	13.18	21.00
			" " " ash	14.73	6.60	31.03	.....	.....	12.70	14.65	15.65	16.52	17.81
			" " " total ash	100.00	27.89	72.11	.....	.....	10.62	30.26	20.99	14.03	24.08
			" " " sulphur	2.46	1.50	4.60	.....	.....	2.08	2.36	2.28	2.44	2.35
6	Seam No. 5 South	2-in. round hole screenings	Per cent of weight	100.00	81.20	18.80	.....	13.55	11.65	27.90	17.70	11.65	17.50
			" " " ash	11.28	6.86	26.79	.....	7.99	9.78	10.10	11.12	11.50	17.38
			" " " total ash	100.00	52.46	47.54	.....	9.48	10.00	24.75	17.32	11.79	26.75
			" " " sulphur	3.49	2.70	9.85	.....	3.28	3.92	4.23	4.47	4.69	4.84
7	Seam No. 6 Benton	2-in. round hole screenings	Per cent of weight	100.00	81.32	18.68	.....	14.50	15.35	38.52	15.40	6.45	9.84
			" " " ash	9.85	5.41	29.89	.....	10.08	9.85	9.25	9.10	9.25	12.40
			" " " total ash	100.00	52.46	47.54	.....	14.61	15.11	38.02	14.00	6.01	12.21
			" " " sulphur	1.63	1.15	4.73	.....	2.23	1.83	1.49	1.37	1.13	1.02
8	Seam No. 6 DuQuoin	2-in. round hole screenings	Per cent of weight	100.00	86.80	13.20	.....	19.75	13.50	23.50	15.68	9.93	17.76
			" " " ash	10.88	6.48	40.14	.....	9.15	9.35	9.87	11.60	12.60	16.00
			" " " total ash	100.00	51.51	48.49	.....	16.03	11.17	20.52	16.13	11.08	25.14
			" " " sulphur	1.70	1.41	2.90	.....	1.51	1.41	1.33	1.77	1.56	1.77

9	Seam No. 6 Livingston	2-in. round hole screenings	Per cent of weight	100.00	71.85	28.15	.....	18.75	11.10	27.18	15.88	10.53	16.60
			" " " ash	16.38	6.65	42.20	.....	13.80	13.31	14.95	17.92	19.01	22.45
			" " " total ash	100.00	28.74	71.26	.....	15.50	8.85	24.28	17.05	12.01	22.30
			" " " sulphur	4.42	1.59	9.50	.....	4.84	4.73	4.39	4.61	4.21	4.26
10	Seam No. 6 Nakomis	2-in. round hole screenings	Per cent of weight	100.00	74.10	25.90	.....	18.40	12.55	28.70	18.70	9.67	12.00
			" " " ash	16.18	7.08	30.64	.....	14.90	14.95	15.15	14.00	14.00	17.80
			" " " total ash	100.00	39.78	60.22	.....	18.16	12.47	28.85	7.38	9.02	14.19
			" " " sulphur	5.20	3.47	6.81	.....	5.65	5.16	5.02	4.93	5.21	4.58
11	Seam No. 7 Danville	1¼-in. round hole screenings	Per cent of weight	100.00	75.75	24.25	.....	.....	17.35	43.45	17.20	7.85	14.05
			" " " ash	15.65	8.74	40.62	.....	.....	13.95	14.80	15.50	17.50	26.35
			" " " total ash	100.00	31.46	68.54	.....	.....	14.62	38.80	16.00	8.35	22.35
			" " " sulphur	3.92	2.90	6.80	.....	.....	3.77	3.86	3.97	4.13	4.30

no doubt that the removal of the material under 1/8 inch would prove of benefit to producer and consumer alike.

Résumé.—This chapter leads to the conclusion that Illinois coal is badly in need of some standardization. As a possible guide, the essential differences of Illinois coal compared to certain others have been mentioned, and relative sizing has been discussed. It seems possible that the different markets, with their own needs, customs, and prejudices may always require particular coals. Furnace efficiency and relative price of any particular size will influence the final decision. It is to be regretted that in most boiler tests so many other variables have obscured the effect of sizing the various coals.

In regard to screenings, it has been shown that in the few tests available this important and often neglected product has a surprising individuality among its own sizes. So far as its standardization is concerned, further investigation is necessary before fixing a definite size or range of sizes. Its efficiency when sized may have a close relationship to the ash content of any sizes removed.

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