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PERCENTAGE OF EXTRACTION OF BITUMINOUS COAL WITH SPECIAL REFERENCE TO ILLINOIS CONDITIONS

BY

C. M. YOUNG

ILLINOIS COAL MINING INVESTIGATIONS
COOPERATIVE AGREEMENT

(This Report was prepared under a Cooperative Agreement between the Engineering Experiment Station of the University of Illinois, the Illinois State Geological Survey, and the U. S., Bureau of Mines)

BULLETIN No. 100

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BY

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ASSISTANT PROFESSOR OF MINING RESEARCH

ENGINEERING EXPERIMENT STATION
PUBLISHED BY THE UNIVERSITY OF ILLINOIS, URBANA
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PERCENTAGE OF EXTRACTION OF BITUMINOUS COAL WITH SPECIAL REFERENCE TO ILLINOIS CONDITIONS

INTRODUCTION

1. Preliminary Statement.—The purpose of the discussion presented in this bulletin is to record the results now being obtained in recovering coal in the mines in Illinois and in other bituminous coal mining districts of the United States. A brief discussion is also presented with reference to recovery in the principal European countries. Where the methods employed are now producing an unusually good percentage of extraction, the conditions under which the mining is carried on are described in considerable detail with the belief that they may suggest changes in practice which will be helpful to those who are now endeavoring to recover a greater percentage of the coal in the ground.

Most of the data presented were obtained from those operating the mines, and represent, therefore, calculations or estimates based upon thorough familiarity with conditions. Some of the methods by which high extraction is attained in other districts are described with the hope that the coal producers of Illinois may find herein suggestions which will prove helpful in their efforts to attain higher recovery.

It has been impossible to include in a single publication all the material available concerning the physical conditions encountered and the methods adopted in the various coal fields, but there will be found in the bibliography a list of books and articles in which these subjects are covered in greater detail. It is the present purpose to begin at an early date a more extended investigation of the plans and dimensions of mine workings in Illinois with reference to the cost of production and the percentage of extraction.

2. Acknowledgments.—The writer wishes to acknowledge his indebtedness to Professor H. H. Stoeck, head of the Department of Mining Engineering, University of Illinois, and to Mr. F. W. Dewolf, Director of the Illinois State Geological Survey, and also to Mr. G. S. Rice, Chief Mining Engineer, United States Bureau of Mines, under whose direction the work of the Illinois Coal Mining
Investigations is being carried on. Professor Stock has been especially helpful in the collection of material for the present bulletin. Many operators and engineers throughout the country have contributed statements concerning the districts with which they are familiar. The state mine inspectors have assisted in the work by suggesting mines at which particularly good records of extraction have been made and also mines at which new methods are being tried with a view of increasing the percentage.

3. Summary.—The facts and information presented in this bulletin include:

(1) A general statement of the importance of the problem of increasing the percentage of extraction of the coal in the ground in order to utilize the coal resources to a greater extent than at present, and, if possible, to decrease the cost of producing coal; also an account of previous efforts made to compile data upon this subject.

(2) A statement with reference to the conditions which have influenced the development of American coal mining methods and which must be considered in changing these methods in order to obtain more nearly complete recovery.

(3) A record of the recovery of coal in Illinois in the past, and a discussion of the efforts now being made to increase the percentage of extraction.

(4) An account of methods adopted in other states and in certain European countries by which higher percentages of extraction are being obtained.

(5) A brief history of the development of English mining practice, upon which American practice is founded.

(6) A short bibliography with reference to the subject of coal mining methods.

4. Conclusions.—A summary of conclusions suggested by a study of the data and information contained herein is presented as follows:

(1) In general in America probably one ton of coal has been left in the mine for every ton brought to the surface.

(2) An effort is being made in many sections of the United States and in a number of Illinois mines to decrease this loss of coal.
The low percentage of recovery in the United States is largely due to economic conditions and to efforts to produce cheap coal.

Where economic conditions have been favorable, percentages of recovery have been obtained in the United States quite as high as in any of the foreign countries in which usually the economic conditions have not been such as to make the production of cheap coal the determining element in the choice of a method.

The low price at which much of the coal land in the United States has been bought has not offered an inducement to save the coal.

The best results in recovery are now being obtained in districts where the value of coal land is high.

As a general rule better extraction is being obtained in West Virginia and Pennsylvania than in the Middle West.

In view of the results being obtained in some other districts, under conditions no more favorable than those in Illinois, the percentage of extraction in Illinois should be increased.

The best results are being obtained by the larger and stronger companies which can afford to plan for the future.

The low value of the smaller sizes of coal in the past has been a drawback to pillar drawing, because very often pillar coal has contained more of the small sizes than room coal. With the increasing use of small sizes in mechanical stokers, the price will undoubtedly advance to nearly the same level as that of the larger sizes; thus this drawback to greater recovery will gradually disappear.

One of the reasons why newer methods have not been generally tried is to be found in the prejudice, too common in coal mining practice, against innovations, and in the fact that mining methods have been based largely upon previous practice in other countries or in other states.

Many of the attempts to draw pillars have been unsystematic. Upon such unsystematic work are based many of the opinions concerning the technical and commercial practicability of pillar drawing and the prejudices against it.

Subsidence of the surface must be regarded as a necessary accompaniment of mining. Instead of trying to prevent
subsidence, the pillars should be removed systematically so that the surface subsidence will occur uniformly and not in isolated spots. Although there may be a temporary disturbance of the surface, after a short time its condition will be as good or nearly as good as before the mining.

(14) In Illinois, at the present time, more than fifty per cent of the coal is frequently left in the ground in an effort to prevent squeezes and subsidence; even then it is not at all certain that the desired result is accomplished.

(15) The best results may be obtained by driving room entries to their full length, then by beginning the rooms at the inby end of the entry, in order that pillar drawing may begin as soon as the inby room is finished.

(16) To be effective, pillar drawing must begin as promptly as possible after the rooms are worked out.

(17) Where pillars are left to be drawn subsequently, the coal is usually lost, because the pillars are crushed through squeezes, or because it is not found economical or convenient to take the coal out and at the same time to keep up the output of the mine with the comparatively small amount of coal left. In other words, unless pillar drawing follows very closely after the first working, very little pillar coal is obtainable.

(18) In many districts poor top has prevented taking out the full thickness of the coal, and one of the great losses is that due to coal left in the roof. This loss has been overcome in some cases very successfully, and should be carefully studied.

(19) The reported percentages of extraction are usually too high because, in estimating, often only the section mined is considered and no account is taken of top or bottom coal left unmined. Also frequently only limited areas of the mine are considered instead of the mine as a whole.

(20) At different mines in the same region where physical conditions are practically the same, the mining methods vary widely with regard to length of rooms, number of rooms in a panel, thickness of barrier pillars, etc. This variation in practice suggests the advisability of a detailed study to determine, if possible, a standard method for a given set of conditions.
CHAPTER I
MINING METHODS AND CONDITIONS IN RELATION TO EXTRACTION

5. Introduction.—The subject of the percentage of coal extracted from the mines in the United States has received very meager attention, except in the case of individual mines or companies. The only comprehensive official study of an extended coal mining area has been in the anthracite district of Pennsylvania, where the high value of the coal and the knowledge that the supply is limited early stimulated an interest in the subject. This interest led to the appointment of the Coal Waste Commission which reported in 1893.*

In 1905 H. H. Stocke† published a table of coal pillar data which contained percentages of extraction gathered largely by correspondence. See Table 1, page 23.

In 1914 A. W. Hess‡ collected as much information as possible on this subject, which is summarized in Table 2, page 24.

In previous bulletins of the Cooperative Coal Mining Investigations tables of pillar data and percentages of extraction were given. These are summarized in Table 3, pages 25, 26, 27.

Doubtless many of the figures in these tables and others on the percentage of recovery are open to question, but they represented the best and most nearly complete information available when they were published. There are several reasons for questioning the accuracy of the figures on extraction. Chief among them is the fact that estimates are usually based upon areas which are too small or upon insufficient data. A single panel or a single lease is sometimes used as a unit upon which to base estimates, and often the areas thus selected are favorably located. While the estimates may represent results obtained with the given method of mining, they by no means represent the average results for the mine as a whole. The panel selected for measurement is usually one in which there has been no squeeze, while all about it there may be squeezed areas in which large amounts of coal have been lost. Many estimates are

*Report of Commission Appointed to Investigate the Waste of Coal Mining with the View to the Utilizing of the Waste, 1893.
based upon possible future recovery from pillars, which may or may not be obtained.

Estimates covering extraction frequently do not take account of top and bottom coal left in the mine, and the values reported often refer only to the section of the coal actually mined. In mining a coal bed ten feet thick, for instance, two feet of top coal may be left unmined. The maximum percentage of extraction from mining eight feet, in this case, would be eighty per cent of the total coal in the bed. If, then, fifty per cent of the eight feet mined is obtained, only forty per cent of the total coal in the bed is recovered.

The only accurate method of estimation is to divide the actual amount of coal mined, as determined by the tonnage for which the miner is paid, by the amount of coal in the ground as determined by multiplying a given area by the average thickness shown in a large number of sections of the bed.

Even where great care is exercised, results are often subject to errors. The causes for these have been outlined by Smyth* as follows: Inaccuracies in railroad weights of possibly five to ten per cent, inaccuracies in estimation of coal used at the mines frequently amounting to ten per cent, inaccuracies in estimating the mean thickness of the bed amounting, even in very uniform beds, probably to five per cent, difficulties of obtaining final figures until a mine is worked out.

The present condition of the coal mining industry in this country is a natural result of the course and character of its development. In general, only those beds and even parts of beds have been worked, the exploitation of which would result in the largest immediate profits. Those methods of mining which were cheapest and which promised the largest profit on the coal produced have been followed, often without regard to the possible injury of the mine or the resulting loss of coal. There has been, moreover, no restriction of market, and in many cases districts have been opened when there has been very little demand for coal in the surrounding territory, but when conditions of operation and transportation have been such as to make it possible for coal from these districts to enter markets already supplied. The result has been cheap coal, produced by wasteful methods.

Another result has been over-development of the industry. The opening in nearly all districts of too many mines has resulted in the

* Smyth, John G., Personal Communication.
idleness of many mines during a large part of each year with the accompanying increase in the cost of production. In dull periods coal has frequently been sold for less than the cost of production in order that mines might be kept in operation and certain fixed charges met. This subject was taken up by Bush and Moorshead in 1911 in a paper* before the American Mining Congress in which it was said that the production in this country exceeded the consumption first in 1891, and that the difference between consumption and capacity for production had steadily increased. The strike of 1910 in Illinois, Indiana, and the Southwest emphasized the over-capacity of the mines of that region. Though the mines of Illinois were idle during six months of the year, the production of 45,900,246 tons was only ten per cent less than the production of the previous year. The mines of Oklahoma, Arkansas, and Missouri were also idle during six months of 1910 because of the strike, but the production showed an average decrease of only twenty per cent. It was also said that the possible capacity of West Virginia mines was seventy-five per cent more than the total production, that the output in the Pittsburgh and the No. 8 Ohio districts was reduced to thirty per cent of the normal production during the three or four months of each year when navigation on the lakes was closed, and that few properties during the three preceding years—1909, 1910, and 1911—had been operated more than 225 working days per year.

This over-production, with its small profit or even loss in the operation of mines, results in a natural tendency to employ only those methods which will insure cheap coal. It is natural, also, that under these conditions there should exist an attitude of hesitancy with regard to the adoption of new or different methods. Neither the coal producer nor the public has as yet become aroused to the full realization of the fact that the natural resources of the country are not inexhaustible. The coal mining engineer of America accordingly, has not had as his problem the development of methods of extraction which would result in the largest percentage of ultimate recovery, but rather the development of methods which would result in the lowest cost of production. In many cases, however, as is shown by the detailed descriptions given later, where economic conditions have seemed to warrant it, methods have been developed by

American engineers and coal producers which have given a percentage of recovery equal to that secured in any European country.

The fact should be borne in mind, when comparisons are made between mining methods in different countries, that, while it is true that the percentage of extraction is less in this country than in most of the European countries, the cost of coal to the consumer and the profit to the producer are also less.

The subject of the comparative cost of production of coal and of the comparative profits realized in Great Britain and in the United States was taken up by Rice* substantially as follows: the average value of coal in the United States on cars at the mine in 1913 is reported as $1.18 per short ton for bituminous coal and $2.13 per short ton for anthracite. In Wales, in 1913, the average value per short ton at the mines for all kinds of coal was $2.55, and in Great Britain as a whole, $2.21. In the German Empire the average value for all kinds was $2.27, and for Westphalia it was $2.37 per short ton. Net mining profits in Great Britain and in Germany are between twenty-five and fifty cents per ton, while profits in the United States for bituminous coal are probably not more than five cents per ton.

It is a matter of course that more expensive methods of mining cannot be adopted without increasing the cost of the coal, and under the conditions which have prevailed in the coal industry for many years there could be no material increase in the cost of coal to the producer without a corresponding increase in the selling price. The prevailing opinion, however, that the percentage of recovery cannot be greatly increased without an increase in the cost of production is questionable, and certainly this increase in cost would not be as great as is generally believed. This is a matter which can be conclusively determined only by actual trial of new methods extending over a sufficient period to insure the reliability of the results. The fact that the adoption of methods which result in an increase in the percentage of extraction has been possible in some districts with little or no increase in cost at least furnishes a reason for thinking that similar changes could be made in other districts with similar results.

Careful planning of operations over long periods and steady working are necessary in order to obtain a high percentage of ex-

*Rice, G. S., "Mining Costs and Selling Prices of Coal in the United States and Europe, with Special Reference to Export Trade," Second Pan-American Scientific Congress.
traction. At present these conditions are impossible in many districts and can be attained only by centralized control of production and selling price, which will provide against alternation of idle and rush periods with the disorganization which accompanies them. Under existing conditions it is feared by operators that the necessary cooperation would be interpreted and attacked as a violation of antitrust laws. In some of the European countries syndicates working in cooperation with the governments regulate the output of the mines and the selling price of coal with results which are said to be highly satisfactory and conducive to a high recovery.*

One of the chief commercial factors affecting the choice of a method has been the cost of coal in the ground. This has generally been very low, and the loss of coal, therefore, has not been considered a serious matter. Even at the present time the value of coal rights in the southern Illinois field, where the No. 6 bed is worked, is estimated at not more than $100 to $150 an acre, and it has been only a very short time since such coal rights could be purchased for less than $50 an acre. The thickness of this coal is somewhat variable, being in some places fourteen feet or more, but, if we assume that only about seven feet is worked, the output will amount to about 12,000 tons per acre and the cost of coal in the ground will be about one cent per ton. A great deal of the coal in the state, however, has been bought at a very much lower figure. In some cases also there is a second bed of coal which will be available later, and when this is considered, the cost of coal in the ground will be much less than one cent per ton.

This phase of the subject was discussed by Rice,† in 1909, as follows:

"The influencing conditions causing the great losses that are at present incurred are:

1. Cheapness of 'coal in place'; that is, in the seam.
2. Low market prices, resulting from extreme competition.
3. Character of the seam, roof, and floor as determining the method of mining.
4. Surface subsidence due to mining.
5. Interlaced boundary ownerships.

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6. Carelessness in mining operations.

The first two factors, taken together, are the controlling ones in most mining operations in influencing the choice of a mining system. The majority of Illinois operators are sufficiently progressive to find ways and means to take out practically all the coal under a given area if it could be made evident that it paid to do so. That many do not do all that can be done in this direction is apparent; but if, without unusual investment, a profit of operation could be shown in taking out all the coal over the profit made by present methods, the industry could undoubtedly find men to accomplish the task. In other words, from an engineering standpoint practically all the coal under a given area can be taken out. It is a question of cost.

"Cheapness of Coal in Place.—This is chiefly due to the great abundance of coal. Except in the barren northern one-fourth of the State, lying north of the outcrop of the coal-basin, the development of a tract depends primarily not on the possibility of finding coal in that particular locality, but on the question whether it is a suitable place, from a market standpoint, to open a mine, the thickness of seam and the quality of the coal being considered.

"The price of coal rights varies from $10 per superficial acre in the middle part of Illinois, away from the mining centers to $100 per acre near developed mines. Or, in the case of leasing, from 2 cents per ton run-of-mine hoisted, in the southern part of the State, to 5 cents in the northern part. The cost of the fee is relatively so much cheaper per ton than leasing that the latter system is not much used. The ownership of the coal by the operator is conducive to better mining, but relative to other items that go to make up the total, the cost of the ‘coal in place’ is so low as to be almost negligible. In central Illinois, in some cases, at a cost of only $10 per acre, two workable seams, from 6 to 8 ft. thick, are obtained. Allowing only 50 per cent yield of the two seams, 13,000 tons would be produced per acre, the purchase cost thus being 1/13 of a cent per ton, or about 1/1000 of the total cost of production in central Illinois. In the Wilmington long-wall field the average cost of the coal rights is about $50 per acre. The seam there, although it averages a trifle less than 3 ft. in thickness, produces about 5,000 tons per acre. The cost is therefore about 1 cent per ton in place, which is 1/130 of the total cost of production. Hence, it may be seen that there is little incentive, from the standpoint of the purchase price of the coal, to save the latter in mining operations."
The cost of coal rights has very greatly increased since Rice's discussion, and there is every reason to believe that the value of coal in the ground will be much greater in the future than it has been in the past. During most of the productive period, however, the coal in the ground over a considerable part of the State has been worth not more than one-tenth of a cent per ton, and under these circumstances the loss of coal has, naturally, not been considered a serious matter. What has been important, and still is, is the extraction of coal at low cost, and the subject of high recovery is one of increasing importance at the present time.

Every ton of coal left in the ground represents the loss of a possible profit. Every ton of such coal represents a loss in increased value. An acre of coal left in the ground at any time means the extraction of another acre at some later time when the value of coal in the ground will be greater. In other words, producers are now extracting coal, worth possibly $150 an acre, which might be left until it would reach even a greater value if it were not for the fact that coal was wasted in the ground when it was worth only fifty dollars an acre.

A low percentage of extraction increases the cost of production, because, for a given output, the workings must cover a larger area. This involves longer haulage roads, and, consequently, a greater investment in rails and trolley wire, greater maintenance expense, greater consumption of power, lower output per unit of equipment, and lower output per man. With long haulage roads there is greater chance for derangements of the track or for falls of roof, which may cause the stopping of haulage until the trouble is removed or may result in wrecks if the trouble is not discovered in time. Another source of danger lies in the greater haulage speed which must be employed on long roads if the output is to be maintained.

The cost of ventilation is also higher, because these larger workings require a larger quantity of air to maintain safe conditions, and more power is required to circulate air through the longer passages. There is, moreover, a greater loss of power because of the more numerous stoppings, which are often inefficient.

Another difficulty accompanying the spreading of the workings over a large area is that of providing the intensive supervision which is highly desirable in coal mining, particularly where skilled workmen have been replaced by comparatively unskilled laborers, and
the pick has been replaced by explosives and mining machines. Unless the cost of operation is to be increased by the employment of a larger number of foremen or face bosses, this intensive supervision can be obtained only by concentration of the workings.

6. Subsidence.—One reason for the use of methods involving low extraction is the desire to maintain the original surface of the ground. Rice* discussed surface subsidence as follows:

"The influence of this factor upon the yield results from the high value of Illinois lands for agricultural purposes. . . . If the long-wall system were applied to the thick seams, when applicable at all, it would cause a considerable derangement of the surface, and when the latter is so nearly level as the prairie-land of Central Illinois, it makes the question of subsidence a serious one. . . . However, until the agricultural land in the United States becomes insufficient to fill the needs of the population, which would be reflected in a continual increase of price for farming land, the money-loss from temporarily destroying the surface in places is relatively small, as compared with the selling price of the coal mined from the seam. Taking the average value of the surface at $125 per acre, if 80 per cent be rendered worthless the immediate money-loss would be $100 per acre. A seam 6 ft. thick would contain per acre 11,000 tons of coal in place, yielding, at 90 per cent, 9,900 tons. The damage done by practically destroying the surface would be only 1 cent per ton. If the land-prices should rise to an amount two or three times as great as the value stated, this loss would still not prohibit mining.''

As far as the long-wall district is concerned, very little if any damage has resulted from subsidence, and little attention has been given to the subject. The most noticeable effects are generally temporary, and farm operations are not hindered.

The subject of the relation of surface values to subsidence in Illinois has been considered by L. E. Young in Bulletin 17 of this series.† Fig. 1 is a map reproduced from this bulletin, on which the approximate values of farm lands are shown. Table 4, page 28, shows the relation between coal values and surface values. The land values indicated on the map and set forth in the table suggest that it might be possible, at least in many cases, to mine coal at a small profit even if the value of the surface were totally destroyed. There is no need, however, for assuming the permanent destruction of the surface or even its serious permanent injury. Generally any damage resulting from subsidence could be largely or wholly re-

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Fig. 1. Map showing thicknesses of coal and values of farm lands, as given by the 1910 Census Reports.
paired, especially if it were accepted that mining is certain to result in subsidence and operations were so planned as to reduce the surface damage and the cost of restoration to the lowest possible amount.

When the coal producer owns nothing but the coal rights, unreasonable damages for surface subsidence are sometimes imposed. The measure of the damages is not always merely the decreased productive value of the land, nor the cost of restoring it to its former condition by artificial drainage; the formation of a small pond has often been claimed to lower the market value of a farm to a considerable extent, simply because it made the farm less sightly. Under these circumstances, operators naturally desire to avoid disturbing the surface for they know that an attempt will be made to recover damages and that, even if they escape the payment of exorbitant amounts, they will incur considerable expense in defending the suits. An effort, accordingly, is often made to conduct the mining operations in a manner which will not result in surface subsidence. The result is that the loss in the ground represents an important percentage of the coal, in many cases more than half that contained in the area worked.

It is very important that the allowable damages for surface subsidence be regulated by some law. This law should fix the damage payable by the coal producer, in case he is legally responsible, upon the basis of the actual damage done to the surface. Under such a law the operators would know the extent and character of their responsibility and could, without fear of excessive or unreasonable damages, proceed according to methods which would yield the highest possible percentage of extraction justifiable under such conditions.

7. Squeezes.—Closely related to, but not identical with, the subject of surface subsidence is that of squeezes. There may be subsidence without a squeeze, but with the conditions in Illinois a squeeze is usually followed by subsidence. The removal of a portion of a deposit throws additional weight upon the pillars left and if these pillars are not strong enough to support this additional weight, they will crack and crush, causing a movement of the overlying material. This movement is called a "squeeze," or sometimes a "creep." Large quantities of coal are often left in the mine in the form of pillars in an effort to prevent a squeeze, which may not only interfere with the operation of the mine and entail a loss of
the coal in the squeezed area, but large areas of the mine may become inaccessible for future economical working. A more nearly complete extraction of the coal properly carried out should, however, result in less damage from squeezes.

There are two ways in which a squeeze may be prevented or stopped; first, by the use of a support strong enough to prevent any movement of the overlying rock, and secondly, by a fracture of the rock above the excavated portion so that the weight on the pillars will not be sufficient to crush them.

The first method may be employed by either leaving natural supports (coal pillars) of sufficient size and strength to hold the roof without any movement, or by the use of artificial supports, such as timber or iron columns, or sand or culm filling. The cost of timber or iron would prohibit their use if a large percentage of coal was to be extracted. Filling is not generally non-compressible, but it occupies most of the space from which coal has been removed, prevents any scaling off of pillars, and eliminates any possibility of movement of pillars. The filling method, however, is hardly to be considered feasible in Illinois because of the cost. In the Upper Silesian coal field where this method is most extensively used, the cost is from twelve to eighteen cents per ton.*

Another difficulty arises from the fact that the material would have to be flushed into the mine with water, and then the water would have to be pumped out. This water would probably have an injurious effect on the clay bottom. The material, moreover, would have to be brought from a distance unless the value of the land should be so small as to permit the use of material from the neighboring surface, and this condition would rarely prevail in Illinois.

In the leaving of coal pillars of sufficient strength to prevent roof movement, the amount of coal which must be left varies with local conditions. It is difficult, if not impossible, to determine this factor in advance, and in attempting to approach as closely as possible the limit of safety, it often occurs that too much coal is removed. Even if the limit is not passed so far as immediate movement is concerned, it may be passed with reference to ultimate movement and the crushing of the pillars.

Apparently, so far as a large part of the State of Illinois is con-

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cerned, it is necessary to leave in the ground about one-half of the area of the coal if movement of the overlying beds is to be prevented.

The desirable dimensions of the rooms and the pillars vary widely from wide pillars between wide rooms to narrow pillars between narrow rooms. One company had squeezes when it drove 25-foot rooms on 50-foot centers, but it has had no trouble with 30-foot rooms with 60-foot centers. This is a question not simply of the crushing strength of the coal nor of the ability of the bottom to withstand pressure, but of the effect on the pillars of scaling at the sides. In other words, the strength of the pillar is not determined merely by its original size but by its effective size after the scaling action, which may follow the extraction of the room coal, has occurred. This scaling action is increased by the shattering effect of explosives.

The use of coal in the ground to prevent squeezes and subsidence, which is what abandoning of pillar coal amounts to, ought to be considered only as a last resort. It has been found that squeezes can be prevented by the removal of so little coal on the advance as to leave a solid support, and by the complete removal on the retreat so that the roof is left entirely without support. This process prevents the gradual settling which occurs when some support is left and produces a sharp bending, or localization of stress, sufficient to cause a rupture of the overlying rock and prevent the transference of weight from the mined-out area to the standing coal. This is the only certain method which has been found for the prevention of squeezes unless an absurdly large quantity of coal is abandoned. The means by which squeezes may be prevented vary under different conditions, but the essential consideration is that the roof of the mined-out area shall be left absolutely without support either from coal or from timber, so that it must fall.
The widths of rooms and room-pillars given in Table 1 show that there were few cases in which plans were made for the extraction of more coal from pillars than from the advance workings.
<table>
<thead>
<tr>
<th>Operating District and State</th>
<th>Ultimate Recovery of Entire Seam in Per Cent</th>
<th>Per Cent of Ultimate Recovery of Top Coal Carried by Drawers</th>
<th>Nature of Top Drawings</th>
<th>Nature of Bottom Drawings</th>
<th>Per Cent of Ultimate Recovery of Bottom Coal Carried</th>
<th>Average Height Period of Operation in Feet</th>
<th>Date</th>
<th>Clay Vains Encountered</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Colorado, Southern</td>
<td>80-90</td>
<td>Same</td>
<td>Same as top</td>
<td>Same</td>
<td>None</td>
<td>30-34 in.</td>
<td>Dikes</td>
<td>None</td>
</tr>
<tr>
<td>2 Colorado, Southern</td>
<td>69-75</td>
<td>Same</td>
<td>Same as top</td>
<td>Same</td>
<td>None</td>
<td>30-34 in.</td>
<td>Dikes</td>
<td>None</td>
</tr>
<tr>
<td>3 Colorado, Southern</td>
<td>69-75</td>
<td>Same</td>
<td>Same as top</td>
<td>Same</td>
<td>None</td>
<td>30-34 in.</td>
<td>Dikes</td>
<td>None</td>
</tr>
<tr>
<td>4 Missouri, Southern</td>
<td>75-80</td>
<td>Same</td>
<td>Same as top</td>
<td>Same</td>
<td>None</td>
<td>30-34 in.</td>
<td>Dikes</td>
<td>None</td>
</tr>
<tr>
<td>5 Illinois, Southern</td>
<td>69-75</td>
<td>Same</td>
<td>Same as top</td>
<td>Same</td>
<td>None</td>
<td>30-34 in.</td>
<td>Dikes</td>
<td>None</td>
</tr>
<tr>
<td>6 Illinois, Southern</td>
<td>69-75</td>
<td>Same</td>
<td>Same as top</td>
<td>Same</td>
<td>None</td>
<td>30-34 in.</td>
<td>Dikes</td>
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<td>7 Illinois, Southern</td>
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<td>Same as top</td>
<td>Same</td>
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<td>30-34 in.</td>
<td>Dikes</td>
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<td>8 Illinois, Southern</td>
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<td>Same as top</td>
<td>Same</td>
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<td>30-34 in.</td>
<td>Dikes</td>
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<td>9 Illinois, Southern</td>
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<td>Same as top</td>
<td>Same</td>
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<td>30-34 in.</td>
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</tr>
<tr>
<td>10 Illinois, Southern</td>
<td>69-75</td>
<td>Same</td>
<td>Same as top</td>
<td>Same</td>
<td>None</td>
<td>30-34 in.</td>
<td>Dikes</td>
<td>None</td>
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<td>11 Illinois, Southern</td>
<td>69-75</td>
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<td>Same as top</td>
<td>Same</td>
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<td>30-34 in.</td>
<td>Dikes</td>
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<td>12 Illinois, Southern</td>
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<td>13 Maryland, southern</td>
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<td>Same as top</td>
<td>Same</td>
<td>None</td>
<td>30-34 in.</td>
<td>Dikes</td>
<td>None</td>
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<tr>
<td>14 Maryland, southern</td>
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<td>Same</td>
<td>Same as top</td>
<td>Same</td>
<td>None</td>
<td>30-34 in.</td>
<td>Dikes</td>
<td>None</td>
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<tr>
<td>15 Maryland, southern</td>
<td>80</td>
<td>Same</td>
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<td>Same</td>
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<td>30-34 in.</td>
<td>Dikes</td>
<td>None</td>
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<td>16 Maryland, southern</td>
<td>80</td>
<td>Same</td>
<td>Same as top</td>
<td>Same</td>
<td>None</td>
<td>30-34 in.</td>
<td>Dikes</td>
<td>None</td>
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<td>17 Maryland, southern</td>
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<td>Same as top</td>
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<td>None</td>
<td>30-34 in.</td>
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<td>Same</td>
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<td>Dikes</td>
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<td>19 Maryland, southern</td>
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<td>Dikes</td>
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<td>20 Maryland, southern</td>
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<td>Same</td>
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<td>21 Maryland, southern</td>
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<td>None</td>
<td>30-34 in.</td>
<td>Dikes</td>
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Table 2: Principal factors governing recovery of coal in different districts.

Note: Opinions by panel members on others by remote judgment.

### PERCENTAGE OF EXTRACTION OF BITUMINOUS COAL

<table>
<thead>
<tr>
<th>District</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
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<tbody>
<tr>
<td>Area (sq mi)</td>
<td>14</td>
<td>14</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td>Coal Bed</td>
<td>II</td>
<td>III</td>
<td>IV</td>
<td>V</td>
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### Table 3

<table>
<thead>
<tr>
<th>Dimension of Workings and Estimated Percentages of Extraction in Illinois Mines</th>
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<tr>
<td><strong>Name of Mine</strong></td>
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<td>------------------</td>
</tr>
<tr>
<td><strong>Square feet</strong></td>
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<tr>
<td><strong>Room length</strong></td>
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<tr>
<td><strong>Room width</strong></td>
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<tr>
<td><strong>Room height</strong></td>
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### Table 3 (Continued)

<table>
<thead>
<tr>
<th>District</th>
<th>No. of mine (Coal Bed)</th>
<th>Depth of investigation (feet)</th>
<th>Method</th>
<th>Entry width</th>
<th>Entry type</th>
<th>Barrier pillar width</th>
<th>Room width</th>
<th>Length of room</th>
<th>Length of neck</th>
<th>Room neck distance from entrance (feet)</th>
<th>Dist. between room centers (feet)</th>
<th>Width of cross-cut (feet)</th>
<th>Home had</th>
<th>Operator's estimate of percentage extracted</th>
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### Table 3 (Concluded)

#### PERCENTAGE OF EXTRACTION OF BITUMINOUS COAL

<table>
<thead>
<tr>
<th>Room, Level</th>
<th>Pillar width</th>
<th>% Room</th>
<th>% Entry with Pillar width</th>
</tr>
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<tbody>
<tr>
<td>Lower</td>
<td>8.5</td>
<td>12.5</td>
<td>48</td>
</tr>
<tr>
<td>Middle</td>
<td>9.0</td>
<td>15.0</td>
<td>24</td>
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<tr>
<td>Upper</td>
<td>9.5</td>
<td>17.5</td>
<td>12</td>
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</tbody>
</table>

#### Method

- Room-and-Pillar
- Panel, Door, and Exit
- Deviation, Good

#### No. of Coal Field

- Aver. of 30 panel mines...
- Aver. of 18 room-and-piller mines...

#### District

<table>
<thead>
<tr>
<th>Coal Bed</th>
<th>VIII</th>
<th>IX</th>
<th>X</th>
<th>XI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aver. by districts</td>
<td>2</td>
<td>1 &amp; 2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I</td>
<td>2</td>
<td>5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>II</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>III</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>IV</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>9</td>
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<td>6</td>
<td>6 &amp; 7</td>
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</tr>
<tr>
<td>VI</td>
<td>7</td>
<td>7 &amp; 8</td>
<td>9 &amp; 10</td>
<td>11</td>
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</tbody>
</table>

#### Dimensions of Workings and Estimated Percentages of Extraction in Illinois Mines

- Upper Room
- Middle Room
- Lower Room
- Pillar width
- % Room
- % Entry with Pillar width
- Method
- No. of Coal Field
- District
- Aver. by districts
- Aver. of 30 panel mines...
- Aver. of 18 room-and-pillar mines...
TABLE 41
VALUES\(^2\) OF SURFACE AND OF COAL RIGHTS BY COUNTIES IN ILLINOIS

<table>
<thead>
<tr>
<th>County</th>
<th>Value of Coal per Acre</th>
<th>Number of Coal Bed</th>
<th>Average Surface Value, Census of 1910</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bond</td>
<td>$25</td>
<td>6</td>
<td>$45.43</td>
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<tr>
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<td>10–100</td>
<td>6</td>
<td>38.48</td>
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<td>Christian</td>
<td>10–50</td>
<td>6</td>
<td>88.18</td>
</tr>
<tr>
<td>Franklin</td>
<td>35–100</td>
<td>6</td>
<td>112.03</td>
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<td>Fulton</td>
<td>15–100</td>
<td>5</td>
<td>45.60</td>
</tr>
<tr>
<td>Gallatin</td>
<td>20–25</td>
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<td>Grundy</td>
<td>10–25</td>
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<td>70.74</td>
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<tr>
<td>Henry</td>
<td>135</td>
<td>6</td>
<td>129.92</td>
</tr>
<tr>
<td>Jackson</td>
<td>25–75</td>
<td>2, 6</td>
<td>142.92</td>
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<tr>
<td>La Salle</td>
<td>10–100</td>
<td>6</td>
<td>161.76</td>
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<td>Livingston</td>
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<td>6</td>
<td>156.49</td>
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<td>Logan</td>
<td>20–50</td>
<td>6</td>
<td>129.92</td>
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<tr>
<td>Macon</td>
<td>15–50</td>
<td>6</td>
<td>70.74</td>
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<tr>
<td>Madison</td>
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<td>6</td>
<td>38.45</td>
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<td>6</td>
<td>129.92</td>
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<td>Marshall</td>
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<td>5</td>
<td>171.85</td>
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<tr>
<td>McLean</td>
<td>25–30</td>
<td>6</td>
<td>122.04</td>
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<td>Menard</td>
<td>25–50</td>
<td>6</td>
<td>73.49</td>
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<tr>
<td>Montgomery</td>
<td>20–30</td>
<td>6</td>
<td>124.28</td>
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<tr>
<td>Morgan</td>
<td>20–50</td>
<td>5</td>
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<td>Peoria</td>
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<td>Randolph</td>
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<td>St. Clair</td>
<td>10–100</td>
<td>6</td>
<td>39.88</td>
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<tr>
<td>Saline</td>
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<td>6</td>
<td>138.80</td>
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<td>Sangamon</td>
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<td>Scott</td>
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<td>6, 5</td>
<td>88.32</td>
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<tr>
<td>Shelby</td>
<td>100–150</td>
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<tr>
<td>Vermilion</td>
<td>15</td>
<td>1, 2</td>
<td>129.80</td>
</tr>
<tr>
<td>Warren</td>
<td>15</td>
<td>2</td>
<td>164.88</td>
</tr>
<tr>
<td>Will</td>
<td>50–150</td>
<td>6</td>
<td>30.61</td>
</tr>
<tr>
<td>Williamson</td>
<td>15</td>
<td>2</td>
<td>154.27</td>
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</tbody>
</table>


\(^2\) These prices are not offered as an authoritative basis for valuation but indicate in a general manner the prices at which coal has been sold or at which it is held in some of the important counties.
CHAPTER II

EXTRACTION IN ILLINOIS

8. Plan for Division of State into Districts.—At the beginning of the work of the Cooperative Coal Mining Investigations, the State was divided into districts in order that those beds which are similar in general conditions might be studied and considered together. This subdivision into districts is shown by Fig. 2, and the districts are described in Table 5.

Table 5

| Districts into which the State has been Divided for the Purposes of Investigation |
|---|---|---|---|
| Investigative District | Coal Seam | Method of Mining | Counties |
| I | 2 | Long-wall | Bureau, Grundy, La Salle, Marshall, Putnam, Will, Woodford............. 1 to 11 |
| II | 2 | Room-and-pillar | Jackson.......................... 12 to 16 |
| III | 1 and 2 | Room-and-pillar | Brown, Calhoun, Cass, Fulton, Greene, Hancock, Henry, Jersey, Knox, McDonough, Mercer, Morgan, Rock Island, Schuyler, Scott, Warren............... 17 to 24 |
| IV | 5 | Room-and-pillar | Cass, DeWitt, Fulton, Knox, Logan, Macon, Mason, McLean, Menard, Peoria, Sangamon, Schuyler, Tazewell, Woodford............... 25 to 42 |
| V | 5 | Room-and-pillar | Gallatin, Saline............... 43 to 49 |
| VI | 6 (east of Duquoin anticline) | Room-and-pillar | Franklin, Jackson, Perry, Williamson............... 50 to 65 |
| VII | 6 (west of Duquoin anticline) | Room-and-pillar | Bond, Christian, Clinton, Macoupin, Madison, Marion, Montgomery, Moultrie, Perry, Randolph, Sangamon, Shelby, St. Clair, Washington............... 66 to 90 |
| VIII | 6 and 7 (Danville) | Room-and-pillar | Edgar, Vermilion............... 91 to 97 |

In the present publication the conditions prevailing and the methods followed in the various districts are described, and the extent to which these affect the percentage of recovery is discussed. Material and information has been gathered at various times, and
Fig. 2. Map of Districts of Cooperative Coal Mining Investigations
some of it, especially that relating to physical conditions and usual methods of operation, has been published in previous bulletins of this series. These facts are summarized in Bulletin 13.*

9. Conditions Affecting Extraction.—Since there is an immense quantity of coal underlying the state and only a comparatively small portion has been extracted, it is perhaps natural that little serious attention has been given to the subject of high recovery. Those controlling production have been concerned principally with other phases of the subject, not because they have been indifferent to the highest possible utilization of resources, but because they have believed that the methods in use were giving the lowest possible cost of production; and low cost of production has been regarded as a necessity for the development of the Illinois fields in competition with other coal fields.

Table 3, rearranged from Bulletin 13, gives the dimensions of the workings and the estimates of recovery for the mines examined by the Coöperative Coal Mining Investigations.

The values for the percentage of extraction given in the last column of Table 3 are, in most cases, founded upon estimates furnished by the operators. In many instances subsequent investigation has shown that these values are not correct. There are only a few mines in the state from which it has been possible to obtain accurate data on recovery because of the lack of information on which such data could be based. Generally, it has been found that persons estimating the percentage of recovery have been inclined to use values too high and have failed to take into account some of the sources of loss. Later figures on extraction, the most trustworthy it has been possible to obtain, will be found in the descriptions of the districts.

10. District I.—The No. 2 bed varies in thickness from two feet, eight inches to four feet, the average thickness being about three feet, two inches. On the east side of the LaSalle anticline the thickness of cover ranges from 40 to 200 feet; on the west side the bed lies at a depth of 350 to 550 feet. In the eastern, or Wilmington, section the roof is a smooth gray shale, though sandstone is found in some places. In the western or LaSalle field the roof is a gray

shale. In the Wilmington field the floor is a dark gray fire clay varying in thickness from a few inches to several feet. When this clay is wet, it heaves badly under pressure. In the LaSalle field the floor is fire clay, but a hard sandstone is sometimes found immediately beneath the coal. *

Nearly all the coal produced in this district is mined by the long-wall method, and this method, of course, gives the highest possible percentage of recovery. G. S. Rice says that at one mine in which a record was kept for six years the loss of coal from all causes was five per cent. †

11. District II.—The No. 2 seam is found under shallow cover ranging from 25 to 160 feet. In most places the floor is sandstone, but shale or clay is occasionally found. In places a wet and fluid sand is found about thirty feet below the surface, and it has a marked effect upon surface subsidence, causing the formation of rather deep pits instead of gentle sags. The bed is divided into two benches by a shale parting, varying in thickness from one-eighth inch to thirty-six feet. The bottom bench varies in thickness from $3\frac{1}{2}$ to 4 feet, and the top bench has an average thickness of two feet. Where the parting between the benches is less than four inches thick, the two benches of the seam are worked as one and the working faces in rooms and entries are from six to seven feet high. Where the parting is more than four inches thick, only the lower bench is mined and the parting becomes the mine roof. When both benches are worked and the bed is more than six feet thick, only the lower six feet of coal are mined, eight to twelve inches of top coal being left; but if the coal is not more than six feet thick the full thickness of the bed is mined, and the gray shale overlying the coal becomes the roof.

With one exception, the mines examined are operated by the unmodified room-and-pillar method. Operations are carried on without close adherence to the projected sizes of rooms and pillars. The result of this practice is a rather high percentage of extraction, as pillars are gouged to a considerable extent. ‡ At one mine in this

district which is operated on the panel system and in which a serious attempt is made to remove pillars as far as possible, the percentage of extraction is probably higher than at any other mine in southern Illinois. At this mine the shaft is 115 feet deep. There are triple main and cross entries, each ten feet wide, with 20-foot entry pillars. Barrier pillars on main and cross entries are twenty feet wide. Rooms are twenty feet wide with 10-foot pillars. All cross-cuts are eight feet wide. Although there are no exact figures on the percentage of recovery, it is evident from the dimensions of the workings that about two-thirds of the coal is extracted in the first working. Since by slabbing pillars, forty to fifty per cent of the pillar coal is also obtained, the final recovery probably amounts to about eighty per cent. The rooms are widened about thirty feet before the end is reached, little or no pillar coal is left beyond this point, and as much of the remainder of the pillars as possible is taken out by slabbing.

The possibility of extracting a large amount of pillar coal depends upon the character of the top which may be allowed to fall without serious consequences, because the shale and sand overlying the coal seal the opening so that the influx of water is not seriously increased by a break. When the top falls, the necks of the rooms are boarded up and the water is handled by a pump.

12. District III.—The No. 1 and No. 2 beds are worked. The cover overlying the coal is thin. The topography of the surface in many places is rolling, with hills about 150 feet high near Matherville. Bed No. 2 lies at depths of seven feet to one hundred feet with an average cover of fifty-five feet. Bed No. 1 averages four feet in thickness and is broken in places by small faults, slips, clay veins, and rolls. A poorly developed parting divides the bed into two benches, the upper of which is in most places about two feet thick.

The immediate roof in the northwestern part of the district is of hard black shale which is easy to support. In the southern part a bituminous calcareous shale, two to five inches thick, lies in places immediately over the coal. This shale, called clod, is hard when first exposed to the air but after exposure softens and falls. Throughout the district the cap rock is limestone. In limited areas where the shale is missing, this limestone forms the immediate roof. Above
the cap rock occurs a dense, fine-grained, non-crystalline limestone locally called "blue rock."

Below bed No. 1 there occurs in places an irregular band of hard bone, three to six inches thick. The floor proper is of light gray micaceous fire clay which contains plant stems and roots. This clay heaves badly when wet and sometimes swells enough to fill the entry. In parts of some mines a carbonaceous shale lies between the fire clay floor and the coal; sometimes this shale is supplanted by sandstone. These casual deposits are called "false bottoms."

Bed No. 2 varies in thickness from 1 foot, 10 inches to 4 feet, and averages 2 feet, 6 inches. The bed has a slight dip to the east. A band of mother coal and iron pyrites persists throughout the bed. This occurs about fourteen inches from the roof. The immediate roof is of smooth and regular calcareous shale, known locally as soapstone. The floor is of soft gray fire clay which contains nodular concretions of iron pyrites called sulphur balls. The coal in this district lies near the surface, but at no point is the overburden stripped.

Except at two mines, the mining system is the simplest form of double-entry room-and-pillar. Table 3 shows the dimensions of workings in the mines examined. The coal is gained during the first working with a waste of pillar coal amounting to about 45 per cent of the bed. At the two exceptions 75 per cent of the pillar coal is recovered on the retreat, a large percentage for Illinois room-and-pillar mines.

A main entry and a parallel air-course, each six feet high and eight feet wide, are driven from each side of the shaft toward the boundaries. At right angles to these main entries, pairs of cross entries are driven every 500 feet. On the cross entries, after leaving a barrier pillar of 50 feet, rooms are turned on 45-foot centers. Room necks are 7 feet long and 8 feet wide, and are widened to the left at angles of about 45 degrees; thus they reach the full room width of 26 feet at distance of 14 feet from the beginning of the widening. After the first room on each entry has been holed through, the room-pillar cross-cuts are closed by gob stoppings, and the line of No. 1 rooms is kept open; thus two additional air-courses are provided.

After the entry has been driven to the limit and the rooms on it have been worked out, the last pillar on the entry is drawn; then the other room pillars are drawn until the pillar between rooms
3 and 4 is reached. The room pillars between the main entry and room 4 are left to protect the main entry and air-course. The method of drawing pillars is illustrated in Fig. 3. When the room is driven up to its full length, a 12-foot cut is made across the end of the pillar (a), a 5-foot slab about 8 feet long is shot from the side of the pillar, a 4-foot slab is shot from the end (b), and the end of the pillar is squared up by shooting off another 4-foot slab (c). Beginning again at (d), the process is repeated.

The hard roof is easy to support and often stands while 25 to 200 feet of pillars are being drawn. When the weight of the roof becomes too heavy, the roof breaks at the pillar ends. The cracking of the props gives ample warning of the break, and work is discontinued until the roof falls. The interval between the first heavy cracking of props and the breaking of the roof is usually not more than twelve hours.

A break line of about twenty-five degrees with the face of the rooms is roughly maintained. When roof falls prevent access to the squared-up pillar ends, a 12-foot cut is again made completely through the pillar, as at the face of the room when drawing began, and with this new pillar end the procedure continues; consequently, very little pillar coal is lost. Carl Scholz, President of the Coal
Valley Mining Company, states that at mine No. 3 at Matherville the loss of pillar coal does not exceed four per cent.

At the No. 3 mine of the Coal Valley Mining Company, the cost of producing coal is much less on pillars than on advance work in rooms. Room coal costs on the average $1.25 per ton at the pit mouth, and pillar coal costs $1.015. This difference in cost exists because track, yardage, bottom digging, and driving through rolls and slips are properly charged against room coal, while there are no such charges against pillar coal. When pillars are drawn, therefore, the average cost per ton for the total production is materially reduced. At this mine rooms are worked with one man at the face, but two men are placed at each pillar and at the face of each entry. Only one man has been injured in connection with the pillar drawing.

With the extraction of such a large percentage of the bed surface subsidence is to be expected. The topography of the surface is rolling, and subsidence is usually indicated by cracks in the hillsides. The largest single area affected was reported to be one acre which subsided from 6 to 12 inches. *

13. District IV.—In District IV the No. 5 coal is mined. The average thickness of this coal is 4 feet, 8 inches according to data taken at 240 mines and given in the Thirty-first Annual Coal Report of Illinois. The No. 5 bed outcrops in Peoria, Fulton, and Knox Counties, but is found at greater depths toward the east. It lies from 300 to 600 feet below the surface in Macon County, 400 feet in McLean, and from 260 to 300 feet in Logan.

The roof is of black sheety shale varying in thickness from a few inches to 35 feet and containing occasionally "niggerheads" of pyrite. In many mines there is, in places, a layer of pyrite two or three inches thick between the coal and the shale. Where this layer is present, the shale is protected from the air and stays up; where it is not present, the shale falls badly and sometimes caves to a height of 35 feet. A limestone occurs above the shale in most mines, though in a few places a fine grained micaceous sandstone is found. In some cases the shale is absent, and the cap rock becomes the roof.

A great many clay veins extend through the coal and the roof shale; there are also small faults, slips, and rolls, and places where

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the coal has been eroded and the space has been filled with drift. It is difficult, therefore, to calculate the total tonnage and to project any plan of operation. In many places the coal adheres to the roof and separates from it with difficulty. In one mine about an inch of coal is left to protect the roof shale from the air. In most mines the floor consists of a dark gray clay which heaves badly when wet.

Operations are conducted on the unmodified room-and-pillar system or on the so-called panel system. Dimensions of workings are given in Table 3. There are also four mines in the district which are operated on the long-wall system. Mining methods have not been given very careful attention, and the variations in the coal bed tend to minimize the effect of such attention as has been given. The method of mining generally practiced in the district involves the running of parallel main entries from the shaft toward the boundaries, and the turning of cross entries from the main entries at intervals of 350 to 400 feet. Rooms are turned off these cross entries on 30-foot to 42-foot centers, and are driven 20 to 30 feet wide. Room pillars average 9 feet in width and rooms 26 feet, but pillars are gouged as the miner pleases. This haphazard method is productive of so many squeezes that in some mines a modification of the system has been employed in which stub or room entries are turned off the cross entries. This method approaches the panel system and is called, locally, "block-room-and-pillar." Sometimes a sufficiently large cross barrier pillar is left to confine a squeeze to the block in which it originates, but generally the barrier pillar is gouged and squeezes ride over it unchecked until they reach a horseback or some ungouged pillar which is large enough to stop them. In several mines squeezes originating in rooms have traveled to the main barrier pillar and to the solid coal at the entry face. In one mine an entry was saved from a threatened squeeze by very heavy timbering ahead of the squeeze.

Eleven of the sixteen mines examined are at present operated on this semi-panel system, but the relative dimensions of room and room pillar have not been changed from previous operations. These dimensions are not safe under the roof found in the district. Room width is not uniform, but rooms are narrowed to avoid horsebacks and widened again where the coal resumes its normal thickness. There is a temptation to get all the coal possible on the advance,
because the numerous rolls make uncertain the total tonnage which can be extracted from any area, and the rolls interfere seriously with any projected plan since cutting through them is expensive.

Pillars are drawn in only a few mines, and in these drawing is not done systematically but is confined to shooting slabs off the thickest parts of the pillars. Room pillars are tapered to cross-cuts in nearly all mines. In one case an attempt was made to draw pillars, and a track was laid along the rib, but objections were raised by the miners to this position of the track, and the attempt was abandoned. Principally because of the insufficient pillar-width, the floor of fire clay heaves badly even when dry.*

Nineteen mines were examined in this district, and the estimates of the percentage of recovery furnished at seventeen ranged from 55 to 75 per cent, averaging 67.26 per cent. It is probable that most of the estimates are too high for, although the gouging of pillars tends toward high percentage of extraction, careless methods always result in the loss of much larger quantities of coal than is supposed. One company, which has given careful attention to the forms and dimensions of its workings, is extracting about 70 per cent of the coal. It is doubtful however, if the extraction throughout the district as a whole amounts to 60 per cent.

14. District V.—Bed No. 5 in Saline and Gallatin Counties lies at a depth of 25 to 450 feet, being nearest the surface along the southern portion of the district. The bed varies in thickness from 4 to 8 feet, and averages 5½ feet in Saline County and 4 feet in Gallatin County.

The roof of the No. 5 coal in this district is of shale which is sometimes laminated and interbedded locally with bone and stringers of coal for a distance of 3 feet above the seam. The roof usually contains many concretions of iron pyrites called "niggerheads." It breaks quickly when wide spans are left supported, and it is drawn when it shows a plainly marked parting not more than 4 inches above the coal; but such a parting rarely occurs and the coal bed is so thin that the top coal cannot profitably be left in place. There are numerous falls which can be avoided only by making entries narrower than at present.

The floor is of fire clay which in places contains much sand and heaves badly when wet. The bed contains many hills and rolls causing grades as high as 15 per cent in the entries of some mines. The coal is not pinched out at these hills, but follows the contours with undiminished thickness. In some mines about 9 inches of bottom coal is left below a "blue band," but as this bottom coal is not of good quality, increased facility in shooting compensates for the loss of coal.

The room-and-pillar system of mining is used exclusively, a main haulage entry and a parallel air-course being noted in every mine examined except one,—in which triple main entries were driven, two for intake air and one for return air and haulage. In the smaller mines and in many of the larger ones, the dimensions of workings are not suited to the roof conditions. The main entries vary in width from 14 to 16 feet. A few shaft pillars have been gouged. The room stumps, which are left when rooms are turned off the cross entries, are generally small. The closing of entries by roof falls may often be attributed to local squeezes which ride over the room stumps. Table 3 gives dimensions of workings for each mine examined.

The custom of driving wide rooms and entries, of leaving narrow pillars throughout the mine, and of obtaining all the coal possible on the advance without attempting to draw pillars has resulted in a high percentage of extraction for Illinois mines. The percentages given in Table 3 were calculated from the most nearly exact data obtainable at the time of their publication but are unquestionably too high. This reported extraction, averaging 67.1 per cent for the seven mines examined, was accomplished only with greatly increased expense for cleaning up.* One of the large operators of this district reports an average recovery at ten mines of 60.5 per cent over a 5-year period with a maximum of 72 per cent and a minimum of 52 per cent where the cover varies from 60 to 414 feet. Pillar drawing is not practiced, and it would be impossible to gain the percentages of coal given in the table if the dimensions given were adhered to, but pillars are gouged to such an extent that there should be a higher percentage of extraction than is calculated from the dimensions of rooms and pillars in the table.

*Andros, S. O., "Coal Mining Practice in District V," Ill. Coal Min. Invest., Bul. 6, pp. 9 and 12, 1914.
15. District VI.—This district has experienced a rapid development, because the No. 6 coal commands a ready market; consequently mining on a large scale is possible. Bed No. 6 lies close to the surface along the Duquoin anticline* but dips sharply to the east, reaching a depth of 726 feet at Sesser. A general uplift has brought it to the surface along an east-west line extending through Carterville to Marion and along a southeast line from Marion to the boundary of the district. East of the area affected by the Duquoin anticline, the bed has a pronounced dip to the north. Along the outcrop line there are a few slopes and strippings, but the steep dip of the bed leaves only a small acreage with thin cover, and the remaining openings are shafts. The seam itself is thick, ranging from 7½ to 14 feet and averaging, as shown by 130 borings, 9 feet, 5 inches. A clean persistent parting of mother coal lies 14 to 24 inches below the top of the bed, and a second parting generally appears 5 to 8 inches lower down. Above the upper parting the coal occurs in layers 3 to 6 inches thick, with partings of mother coal between them.

The immediate roof consists of a gray shale 15 to 110 feet thick. This shale does not stand well when the coal is removed, and the top coal is generally left as a roof, at least until the rooms are finished. The bottom is generally of clay, four inches to eight feet thick, below which is limestone. There is only one persistent band of impurity in the bed. This, which is known as the blue band, generally consists of bone or shaly coal and is found uniformly at a height of 18 to 30 inches from the bottom. Its thickness varies from ½-inch to 2½ inches.f

The large number of squeezes which have occurred in mines of District VI would seem to indicate the presence of one or more thick beds of strong rock among the overlying strata. A study of the logs of numerous wells does not, however, show the presence of any continuous strong bed which would be a serious obstacle to the introduction of methods allowing a larger percentage of extraction. The State Geological Survey makes the following statement concerning the overlying limestone: “Over a large part of the area within 25 feet of the coal is a limestone cap rock which in places rests upon the coal, except for the draw slate that lies between. Where the lime-

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stone cap rock is not present within 25 feet of the coal it may be entirely absent, or lie at a considerably greater distance above the coal, amounting in some places possibly to as much as 100 feet." *

The limestone cap rock is of variable thickness up to about 11 feet, the average thickness being 4 to 5 feet.† In some places sandstones are found at various distances above the coal, but none of these seems to be close enough to the coal to affect the choice of a mining method. In other words, it seems that there is no layer of rock, sufficiently near the coal to require serious consideration, which cannot be broken by careful attention to the proper methods.

An examination of bore hole records of the Connellsville district of Pennsylvania, where the percentage of coal extracted is very high, indicates that there is more difficulty in breaking the overlying layers of rock in that district than would be experienced in most cases in District VI of Illinois. At a few mines an unusually wide room pillar is left in the middle of a panel for the purpose of limiting the area affected by a squeeze.

According to Table 3, all mines in the district, except strippings, are worked by the room-and-pillar method or by the panel method. Where the latter is employed, frequently no attention is paid to panel pillars so that the advantage of this method in the stopping of squeezes is largely lost. Practice is not uniform in regard to the number of rooms, which may be as low as 14 or as high as 30, turned from a room entry. The description of mining practice in this district‡ given in Bulletin 8 of the Coöperative Investigations says, "The immediate roof overlying the coal falls in slabs after short exposure to the air and top coal is usually left to protect it, but the cap rock is a tough coherent shale which does not break easily. The first mines opened in the district had widths of rooms and pillars unsuitable for this tough cap rock. New mines as they were opened adopted the dimensions of the older mines and a great waste has resulted through the loss of pillar coal. It will never be possible in this district to draw any considerable portion of the pillars where rooms 20 to 29 feet wide are driven with narrow room

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†Ibid, p. 32.
‡Andros, S. O., "Coal Mining Practice in District VI," Ill. Coal Min. Invest., Bul. 8, p. 12, 1914.
pillars. Fear of yardage charges has been an important factor in maintaining the present improper dimensions. . . . With present dimensions when rooms have been driven 200 to 300 feet there is a large area of unsupported cap rock. If an attempt is made to draw pillars under such conditions a squeeze is usually started which often rides over room and entry pillars and sometimes affects a large acreage. In one mine 85 acres were squeezed; in another, 80."

Early operations were carried on without regard to the possible production of squeezes. Pillars were gouged out or entirely removed whenever the demand for coal seemed to excuse this procedure; a natural consequence was the occurrence of squeezes. At one mine there have been five squeezes of which two involved about 80 acres each, one about 40, one about 20, and one possibly 10. The present plan for the future operation of this mine contemplates leaving barrier pillars 150 feet wide along the important entries, and removing this pillar coal later. It is believed that this plan will confine roof movement to the worked out areas and that the entry pillars and barriers can be extracted later. This plan is much the same as that shown by Fig. 32, page 102.

At another mine a large squeeze approached within 125 feet of the air shaft and caused a depression on the surface which necessitated the regrading of a considerable amount of track; including the track scales. Practice at this mine represents one extreme, since no attempt is made at room-pillar drawing beyond driving cross-cuts about 30 feet wide at the ends of rooms, and as much coal as possible is taken on the advance. An attempt will be made to take out barrier and entry pillars on the retreat. Rooms are driven 25 feet wide on 45-foot centers, and cross-cuts are 25 feet wide. The excavated area is about 50 per cent and the top coal, which is only 18 inches thick, is left up.

The figures for recovery of coal given in Table 3 are unquestionably too high although they were based on the best information available at the time. The average percentage of extraction in District VI is not more than 50 per cent, and it is probably nearer 45 per cent. The maps of mines may show an excavated area of 50 per cent or even more, but they do not take into account the unmined top coal. The thickness of coal taken out is generally about 7 feet and top coal ranging from a few inches to 4 or 5 feet in thickness is left. Even if the top coal is ignored, the extraction
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is not so high as the estimates generally indicate because of losses in squeezed areas and boundary barriers.

Special investigations on the subject of recovery made at several mines in Franklin County gave results which are summarized as follows:

At one mine, the recovery in worked out areas where pillars are not drawn is about 65 per cent; where the pillars are taken, it is about 75 per cent.

At another mine, close observations were made in connection with a study of subsidence. In a panel where the extraction was considered good and possibly above the average for the mine 40 per cent of the coal is left as pillars. Two feet or 20 per cent of the thickness of the bed is also left as top coal, and the loss from this cause would be 20 per cent of the remaining 60 per cent or 12 per cent of the total. The total loss is then at least 52 per cent. No attempt has been made to extract room pillars, but some entry pillars are taken, and top coal is taken over the area in which these pillars are drawn.

At one of the mines where the thickness of the coal is greater than the average, little pillar work has been done. The coal varies from 9½ to nearly 16 feet in thickness,* and about 9 feet of it is taken out. Generally about one foot of coal is left on the bottom to avoid the possibility of taking up a bed of “black jack” which is not easily distinguishable from coal. This black jack is probably a coal of very high ash content. The leaving of bottom coal results in the elevation of the working place in the bed so that the top coal left is only 3 feet or even less in thickness. In a few places in this mine some pillar coal has been taken out. Where this was done, break-throughs about 24 feet wide were driven at the ends of the rooms. Then work was commenced at the ends of the pillars, and coal was taken out by pick work. This work seems to have been successful, but it has not been followed systematically. The largest number of pillars which have been taken together was six, and no attempt was made to obtain a break in the roof.

The leaving of coal on the bottom is a practice followed at only a few other mines. In some cases where the blue band is thick the mining is done above it, and a portion of the upper part of the bed, ordinarily included in the top coal, is taken down. At two mines where this method is followed in part, the blue band and the coal below it are left in where the blue band is thick and the top coal is taken to within about ten inches of the roof, at which point there is a parting. Greater care is required to prevent the breaking of the top coal where this is done.

At one of the mines in the southern part of Franklin County a little pillar coal is drawn, though pillar coal is not depended upon for an important part of the output. Rooms are 25 feet wide with 20-foot pillars. Rooms are holed through into those of adjoining panels. When the rooms have reached their full lengths, cross-cuts 24 feet wide are driven across the ends of the pillars. In addition to these cross-cuts the pillars are probably slabbed to some extent. The coal is about 9 feet thick, and about 1½ feet of top coal is left up. No bottom coal is left. The barrier pillars are about 100 feet thick. Break-throughs are 21 feet wide. It seems hardly proper to speak of this kind of work as the extraction of pillar coal, but it represents a practice which is common in this district.

At one of the mines, pillars are drawn, beginning in the middle of a panel, in six rooms at a time; then another group of six pillars is attacked, one pillar being left untouched between the groups. This is simply another method of attempting to get as much coal as possible before being driven out by a fall of the top, and is not an attempt to break the cap rock.

Systematic work in the recovery of pillar coal as done at one of the mines is illustrated in Fig. 4. The mine is operated on the block system commonly called the panel system, though the panels are not kept sufficiently isolated to warrant the use of the term. Cross entries are driven at intervals of 1,370 feet, and panel entries are driven through from cross entry to cross entry. On each pair of panel entries twenty-eight rooms are turned to each side on 40-foot centers. A barrier pillar 125 feet wide is left along the cross entry. After the room entry is driven the rooms are necked, but only the first
fourteen rooms on each side of the room entry are worked, and these are finished before the rooms at the other end of the panel are driven. Break-throughs are normally 11 feet wide; those at the ends of the rooms are 24 feet wide. Pillar drawing is commenced when the rooms at one end of the panel are finished, and the coal is taken out through the first cross entry, that is, the one next to room No. 1. The coal from the remaining portion of the panel is taken out through the next cross entry, that is, the one next to room No. 28. The advantage of this method lies in the fact that the extraction of the coal from the second half of the panel is not interfered with, as far as haulage and ventilation are concerned, by movements caused by pillar drawing in the first half. The pillar coal is attacked first by the driving of 24-foot cross-cuts at the ends of the rooms; then other cuts are made in the pillar
with the breast machine in such manner as to leave stumps between the cuts and the break-throughs. These stumps are removed as far as possible by pick work, but the miners are not always able to finish as much work with the machines as is desired since this work is frequently interrupted by movements of the roof. As much of the coal as is possible is then taken out with picks. While the work at this mine is as systematic as that at any mine in southern Illinois, the company has no exact record of the amount of pillar coal extracted, but it is known that the pick-mined coal amounts to approximately 10 per cent of the output. When the pillars are not drawn, the recovery is estimated by the operators to be about 65 per cent; when they are taken, the estimates run about 75 per cent.

Through the courtesy of the Franklin County Coal Operators' Association (Illinois), data have been made available regarding the extraction of coal in that county as presented in the following paragraphs:

The coal mined is the No. 6 bed of the State Geological Survey classification. Measurement of 113 sections taken in twelve of the largest mines in the county gave an average thickness of 9.2 feet of coal, the average minimum thickness for the same twelve mines being 8 feet, and the average maximum thickness 10.64 feet. The blue band, which is characteristic of the No. 6 coal bed, varied from \(\frac{1}{4}\) to 2 inches in thickness, and its average distance from the floor was 21.5 inches. Owing to the difficulty of keeping up the shaly material above the coal bed, the top coal is almost universally left as roof protection, and, up to the present time, very little of this top coal has been recovered, although some operators are expecting to recover it at a later date in connection with pillar drawing. In one of the twelve mines from which the data were obtained, top coal was not left in the rooms. This, however, is exceptional practice, the average thickness of the top coal left in the twelve mines being \(1\frac{1}{2}\) feet. The average thickness of coal mined was 7.46 feet, and the average tonnage per acre to January 1, 1916 was 6,627 tons. This is equivalent to 40.7 per cent extraction, if it is assumed that all the 9.2-foot bed is available for ship-
ment, or to 41.6 per cent if it is assumed that the blue band and refuse discarded in the loading, or 0.2 foot, is deducted from the thickness of the bed. A very careful estimate for each of the twelve mines noted, made by dividing the total amount of coal in the area mined up to January 1, 1916 into the actual shipments since the mine began operating, gave percentages of extraction varying from 37.7 to 49.5, or an average of 41.4 per cent.*

For six of the twelve mines, data were available for the average percentage of extraction in the portion of the bed actually mined; that is, the total thickness less the top coal left up to protect the roof. This average is 48.65. These mines are all comparatively new mines, and in only a few cases has any portion of the workings reached the boundary so as to permit drawing the pillars in return workings. At many of the mines it is hoped to increase the percentages of extraction through subsequent pillar drawings, but the amount of such increase is, of course, problematical. In many instances squeezes have already occurred, but as a general thing only the room pillars have been affected.

The twelve mines under discussion are representative of the practice in Franklin County and to a great extent of that of southern Illinois. In a number of these mines experiments are now being conducted to determine in what respect present methods of working may be modified to yield a larger percentage of extraction. Although these mines are operating under practically the same physical conditions and all on the panel system, the variation in the detailed operations, such as the number of rooms per panel, or the width of barrier pillars, indicate the necessity for a critical comparative study of details to determine the best method for the given conditions.

Investigations in Williamson County supplied the following facts:

At one mine rooms are 21 feet wide on 40-foot centers. From 2 to 2½ feet of top coal is generally left up on the advance. In one part of the mine the coal is 11 feet thick and only 7½ feet of it is taken out. It is estimated that 40 to 50 per cent of the pillar coal is won. The top coal, which is the

* The Peabody Coal Company reports that the percentages of extraction at its four mines in this district are 67, 68, 55, and 55.
best part of the bed, is taken out when the pillars are drawn. There are no definite records on recovery, but it is probable that 55 or 60 per cent is gained. If $7\frac{1}{2}$ of the 11 feet are removed, and 40 per cent of the pillars and all the top coal over the area in which the pillars are drawn are removed, the extraction is about 60 per cent.

In another mine a rather high percentage of extraction is attained because of favorable conditions which permit the leaving of small pillars. The coal is 9 feet thick and the depth only 100 feet. Rooms are 24 feet wide on 35-foot centers. In some cases top coal, about 20 inches thick, is left if the machine runners think the top is insecure. Probably from 65 to 70 per cent of the coal is taken out. No pillar work could be done with rooms and pillars of these dimensions, but on one side of the mine 15-foot pillars are now being left with the intention of taking them out on the retreat.

At some mines in the western part of Williamson County considerable trouble has been experienced, because large quantities of water enter when the top is broken. The cover here is only about 100 feet thick and there are only 3 to 4 feet of solid rock. The rooms of one mine are 20 feet wide and are driven on 40-foot centers, although they are sometimes crowded. Some rooms were driven on 32-foot centers, but the pillars were not sufficient to prevent squeezes. Entries are 12 feet wide and entry pillars 20 and 25 feet wide. The coal is 5 to 11 feet thick with an average thickness of 8 feet. Top coal averages 20 inches in thickness. Above the bed is a shale; above this is a so-called soapstone, ranging from 2 to 8 feet in thickness and averaging about 4 feet; and above this is a black shale. In some places a draw slate from 1 to 2 feet thick occurs above the coal, and above this is limestone 1 to 3 feet thick. Where is no draw slate, there is no limestone. An unconsolidated sand is found in some places above the coal. The pillars are sometimes slabbed a little to compensate for the coal left in entry and barrier pillars. When this slabbing is done, the extraction amounts to about 50 per cent. In some cases extra cross-cuts are taken, and the extraction is thereby increased to about 75 per cent. On the whole, the extraction is estimated to be about 60 per
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cent,— an estimate which is probably reliable since the work
is more carefully done here than at many other mines of the
district. Where more than 60 per cent of the coal is taken
out in this mine, the roof breaks and water enters in large
quantities. Although the amount of water is influenced by
precipitation, the flow is continuous. In one case where the
rock had been broken and a large quantity of water had entered
the mine, it was thought that the strata was drained to some
extent and that it would be possible to allow the top to break
at a slightly higher elevation. It was found, however, that
the new break allowed a large amount of water to enter the
mine, and it has been impossible for the company to do any
pillar work. It is planned, as some of the workings reach the
boundaries, to draw pillar coal. In these cases pumps will
already have been installed, and it will be possible to conduct
the water to these. The water, moreover, will be entering in
abandoned places and not between the workers and the shafts.
Some of the workings are now not far from the boundaries,
and the plan can be put into operation in the near future.

At another mine the coal is 9 feet thick, the top is of white
shale, and the bottom of fire clay. The top coal is about 2 feet
thick. The mine is operated on the panel system. No pillars
are drawn until the rooms on an entry have been finished;
then a cross-cut three machine-cuts wide, or about 20 feet,
is driven at the ends of the pillars in about half the rooms on
the inside end of the stub. Following this, another cross-cut
is made farther back in the pillar leaving a stump about 10
feet wide. The distance between the first and second cuts varies
according to conditions, or according to the judgment or incli-
nation of the machine men. If it is made farther back, some
of the pillar coal is lost. This operation is repeated until
the first break-through in each pillar is reached, the remainder
of the pillar being left standing until all the rooms on the stub
are finished; then the room stump and the entry pillars are
drawn. No effort is made to obtain a break in the roof, and
the leaving of stumps of pillars is likely, by partially sustain-
ing the roof, to bring on a squeeze. At present the driving of
rooms without necks is being tried, the purpose being to avoid
payment for narrow work; and it is believed there will not
be sufficient difference between the support left under that system and that left under the present system to endanger the entries. These rooms without necks are turned six machine-cuts wide and are widened to seven cuts beyond the first cross-cut.

At another mine the average thickness of the coal is 9 feet, 4 inches. The top coal is about 2 feet thick and is left up until the pillars have been partly drawn back, being taken down just before the track is removed. There is generally a good parting between the main bed and the top coal, which is said to be poorer than the main bed. Above the bed is shale of unknown thickness, which has never broken high enough to expose any other rock above it. This shale slacks when exposed to the air. It does not form a very good top and most of the entries are timbered. The bottom is generally of clay, but in some places limestone appears next to the coal. Rooms are 20 feet wide on 30- to 35-foot centers and are 185 to 190 feet long. Stub entries are turned on 400-foot centers, and 16 to 18 rooms are turned from a stub. The room pillars are gouged to a considerable extent. It is planned that all the rooms in a panel shall be driven to their full length before pillar drawing is commenced, but this plan is not always followed, and squeezing sometimes commences before all the pillars can be attacked. This, of course, is promoted by the gouging of room pillars. When the rooms are finished, cross-cuts 20 feet wide are driven at the face with breast machines. The rest of the pillar work is generally done with picks though machines are used when possible. Movement of the roof, however, generally interferes with machine work after the first cross-cut. The pick work generally consists of slabbing along the sides of pillars, but machines are sometimes used. Squeezes have always been confined to the panels, and no entries have been lost until the entry pillars have been drawn. A careful computation, based upon a comparison between the actual area worked and the number of tons hoisted, shows that the extraction at this mine has been 48.89 per cent. This is one of the most thoroughly worked mines in the No. 6 bed, and the estimation of percentage of extraction is undoubtedly as close as any that has been made. The results found furnish one of the reasons for the
statement that extraction in most mines of the district is less than the operators of the mines believe it to be.

At a Perry County mine the general system is the same as in Williamson County. Room entries are driven through from cross entry to cross entry. A somewhat closer adherence to the panel system is to be noted, however, in that 25-foot pillars are left at the ends of rooms. Rooms are 24 feet wide on 60-foot centers, and they are driven 250 feet long. Break-throughs are staggered. When the room is completed, an 18-foot cross-cut is driven through the pillar at the end. Top coal, about 3 feet thick (the best of the bed in quality* as it is at the mine last mentioned), is left up until pillar drawing commences. Pillar drawing is commenced in the middle of the panel. After the completion of the cross-cut at the end of the first pillar attacked, the top coal is loosened by a light shot near each rib. Work on the pillars is then prosecuted by making a cut through the pillar, if the condition of the top will permit, wide enough to leave an 8-foot stump at the end of the pillar and another of the same dimension next to the nearest break-through. These two 8-foot stumps and whatever is left by the machines are taken out by hand work. Two men are used on solid work and two on the machine. This method has been found successful and a considerable amount of pillar coal has been recovered, but pillar drawing is not a necessary part of the system and is not always carried out. Where the pillar coal and the top coal are taken, the recovery is said to be from 75 to 80 per cent of the coal in the area actually worked.

Several plans are now being tried or considered for the more nearly complete extraction of the coal in this district. One of these, which has so far been given only an incomplete test, is a panel long-wall method. Double entries, which would have been the room entries of a panel under the ordinary methods of operation, were driven 340 feet long. At the end, two rooms were driven on each side separated by 25-foot pillars. The rooms at the extreme end of the block on each side were 9 feet wide and the ones further back were 18 feet wide; each was 200 feet long. They were connected at the ends so that ventilation was obtained, the course of the air current being as shown...

in Fig. 5. Then the outby ribs of the 18-foot rooms were worked as long-wall faces by continuous-cutting chain machines making a 6-foot cut. The top behind the working face was propped. It was the intention to support the immediate roof until the face had advanced some distance and then to make an attempt to break the overlying rock by the withdrawal of the props. This plan was found to be impossible, however, as the top fell when the face had advanced only about 40 feet. Other conditions made it necessary to discontinue the experiment temporarily. In operating by this method, sprags were placed in the cutting behind the machine to prevent the premature fall of the coal. No trouble was experienced in getting the coal down; it was produced very rapidly and was easily handled. At present it is not known whether the top can be broken along the desired line, but it will be seen that this line is only 400 feet long and that it is interrupted in the

FIG. 5. PANEL LONG-WALL
center by the entry pillar. Even if it is not possible to break the top and to work the coal back continuously on two longwall faces, it seems that the attack can be repeated farther back in the block and that coal can be produced as cheaply as by the ordinary method; also that a much higher percentage of extraction can be attained. If it should be necessary to follow the method by repeated attacks on the block, there would be some resemblance to the "single room" method successfully worked in West Virginia.

Various other plans for higher extraction have been suggested and some have been partly applied, but the great demand for coal, which has been stimulated by the European War, has caused coal producers to concentrate all their attention upon the immediate production of a large tonnage. Anything in the nature of experimental work will be postponed until the return of more nearly normal conditions, but there is reason to believe that successful efforts will be made to increase the percentage of extraction and that the present large loss will be greatly decreased.

16. District VII.—The coal worked in District VII is the No. 6 bed on the west side of the Duquoin anticline. The thickness varies from 2½ feet to 14 feet and averages about 7 feet. There is a well defined parting plane in the coal about 18 inches from the roof. Where the roof is of black shale and where the coal is 7 feet or more in thickness, the upper bench or "top coal" is left. The roof is a non-calcareous black shale, a calcareous gray shale called locally "white top" or "soapstone," an unconsolidated dark gray or black shale called "clod" and made up of fragments of varying size and hardness extremely difficult to support, or a hard gray limestone called "rock top." A poorly defined cleat or cleavage in the coal may be seen in some places. The floor throughout the district is of fire clay which generally heaves when wet.

The thickness of the coal is almost ideal for easy working and for large production; some of the mines have obtained daily capacities which rank among the highest in the world. The older mines have been worked without much regard to system, but the newer ones are more carefully planned. The planning, however, is directed toward large daily production rather than toward a high percentage of extraction.

Varying roof conditions often make different entry and room
widths necessary in different sections of a mine. In many mines the entries and rooms under rock top are too wide and the pillars too narrow,—a condition responsible for squeezes which sometimes have endangered even the shaft. Squeezes have occurred in thirteen of the twenty-five mines examined in this district; they have generally begun in sections in which the roof was of limestone. In mines in which the rooms are not frequently surveyed there is no definite knowledge of room-pillar width except at cross-cuts. Table 3 gives dimensions of workings at each of the mines examined.

In ten of the mines examined where the immediate roof was of thick black shale, top coal was left to prevent variations of temperature and humidity from affecting the shale of the roof proper, which spalls badly when exposed to the air. Where no top coal is left, this black shale usually falls with the coal or is drawn. Where there is less than four inches of shale between the coal and the limestone, the shale is drawn. In some mines where the latter is more than four inches thick it is propped; in others it is drawn, unless it is more than two feet in thickness.* The Peabody Coal Company reports extractions at its mines in this district of 65, 62, 60 and 50 per cent. At the twenty-five mines examined, the average estimated percentage of recovery furnished by the operators was 55.5 per cent. So far as is known, no efforts have been made to extract a higher percentage of coal. The reason for this attitude is to be found partly in the condition of the surface, which in many places is so nearly level that any noticeable subsidence disturbs the drainage and affects the value of the surface for agricultural purposes.

At present the abandonment of a large percentage of the coal is a result of the difficulties experienced in attempting to secure satisfactory agreements with the owners of the surface. In some cases the owners of coal rights are not the owners of the surface and are not free from responsibility for surface damage. Since the operators have found that the estimates of damage caused by subsidence are likely to be very high, it has become the custom to operate the mines under methods which will avoid subsidence. Unfortunately it has not been possible to estimate the exact amount of coal which must be left in the ground, and squeezes and subsidences have sometimes occurred when it was thought that sufficient coal had been left.

Even where low value of the land or good drainage reduces the cost of possible injury to the surface by subsidence, no effort is made to secure a higher extraction. The occurrence of squeezes is feared, and experience shows that the only way to prevent them without radically changing the system of mining is to leave large amounts of coal in the form of pillars. One company which was formerly getting 50 to 60 per cent of the coal with frequent squeezes and subsidence has changed the dimensions of rooms and pillars so that now only 40 to 50 per cent is obtained. Thus far, with the new dimensions, squeezes have not occurred. No effort has been made to extract pillars systematically with the purpose of breaking the cap rock and thus preventing a squeeze by relieving the stress on the pillars, but there is nothing to indicate that this plan could not be carried out.

The plan of a portion of one of the mines is shown as Fig. 6. This
may be taken as a fairly typical projection of large mines in this district. In many of the mines, including parts of the one illustrated, the workings are on a panel system, but probably not enough attention is paid to the matter of leaving pillars sufficiently wide to prevent the spread of squeezes beyond the boundaries of the panels. This illustration is presented, because the mine was surveyed with unusual care in connection with an investigation of subsidence which is being carried on by the Co-operative Coal Mining Investigations. The rooms and pillars are about 30 feet wide; this dimension was adopted with the belief that the top would be held up by pillars of this width left between 30-foot rooms. It had been found that the roof would fall if 25-foot pillars were left between 25-foot rooms. In the restricted area measured, the extraction amounts to 59.2 per cent of the area worked; that is, 40.8 per cent of the area has been left as pillars.

17. District VIII.—In District VIII, seams 6 and 7 are mined. In both seams there are numerous rolls of roof and floor called "faults," or "horsebacks." In many cases the roll completely displaces the coal.

Seam 6 averages 6 feet in thickness. Near Danville the immediate roof is of grayish black shale about 6 feet thick. This shale, lying between the coal and a cap rock of dark gray nodular limestone, makes a roof which is easy to support. In the vicinity of Westville and Georgetown, the immediate roof is generally of gray shale which shows no distinct bedding, has little cohesion, falls in conchoidal masses, and is extremely difficult to support. Stringers of coal, furthermore, extend from the seam proper into the roof material and render the task of supporting the roof more difficult. Occasionally there are 3 to 4 inches of black shale between the coal and the gray shale which forms the cap rock. Wherever this black shale is broken, air and moisture disintegrate the gray shale cap rock, and the roof becomes unsupportable. In all parts of the Danville district the floor is of soft fire clay.

Seam 7 varies in thickness from 2½ to 5½ feet, the average being 5 feet. The coal has two benches separated by a clay band one inch thick, which persists throughout the bed from 6 to 8 inches above the floor. This bed also has numerous rolls.

While the stripping operations, which are important in this district, are conducted in the No. 7 bed, the largest underground oper-
ations are in the No. 6 bed. The mines are operated on the room-and-pillar method, or a modification of it, but the numerous rolls in the roof prevent close adherence to the system. The frequent occurrence of rolls has a marked effect upon the manner of driving rooms. In a roll area it is difficult to support the roof, and the expense of driving through the hard rock of the roll is great; consequently, when a roll is encountered in driving rooms it is customary to change the direction
of the room and to drive it parallel with the roll until the coal resumes its normal condition, as shown in Fig. 7, which is a map of a mine typical of the district. Often it is necessary to abandon a room before it has been driven to its proper length. Since the rolls are of frequent occurrence, the amount of coal that may be gained in any section of the mine is problematical; consequently, the operator, on reaching that portion of the coal where the seam regains its normal thickness, will attempt to get as much of the coal as possible during the first working. Little attempt is made to preserve a constant room-pillar width, and the practice of gouging pillars is common in the smaller mines.* No systematic pillar drawing is attempted, because with present practice there is little pillar coal left to draw when the rooms are driven to their full length. The roof is so treacherous, especially in the vicinity of the rolls, that it is not safe to leave wide spans of roof unsupported by pillars.

The width of room pillars at the mines examined varied from 4 to 16 feet, and room widths varied from 21 to 43 feet. Table 3 gives dimensions of workings at each mine examined. Very narrow room pillars were found in mine No. 91, where the following dimensions were recorded; room centers, 47 feet; room widths, 43 feet; room pillar width, 4 feet.

Although pillar gouging in the district has resulted in a high percentage of extraction from the bed in the first working, it has caused a subsequent loss of coal through squeezes due to narrow pillars. The average extraction for the six mines examined, as reported by the operators, is 70 per cent. Table 3 gives also the percentage of the bed extracted at each mine. These percentages were calculated from measurements made in the mines and were checked by records of production per acre obtained from the books of each operating company and by planimeter measurements of mine maps. The Peabody Coal Company reports an extraction of 66 per cent at its mine in this district.

At one of the mines, almost all the pillar coal was extracted after all the advance work had been done, and the roof was supported largely by the rolls which occurred at intervals of 60 to 100 feet. At another mine pillars are being extracted, and it is estimated, that the total recovery will amount to about 85 per cent.

18. **Conclusion.**—It will be seen that nearly all the work in Illinois described as pillar drawing is unsystematic. It is merely incidental to the mining of room coal, and preparation for it is rarely made in laying out the mines. There are no apparent reasons, so far as physical conditions are concerned, except in a few instances, why plans could not be made for leaving pillars large enough to support the top during the advance work and for recovering the pillars on the retreat. Squeezes could thus be avoided, and the percentage of extraction could be increased materially. The commercial conditions which seem to make such a course difficult could probably be overcome, except in those cases in which subsidence of the surface subjects the operators to claims for damages in excess of amounts which would seem to be reasonable compensation for the injury done. The law covering payments for damages due to subsidence ought to be made so clear that there could be no doubt concerning the amount to be paid, and this amount should be limited to a fair compensation for the injury actually done.

At present there is promise of a considerable improvement with regard to the percentage of coal extracted from Illinois mines. The subject is receiving more and more attention on the part of coal producers and careful planning of the work with a view to high extraction as well as to low cost will follow as the natural result of greater interest on the part of the operators.
CHAPTER III

METHODS AND RECOVERY IN THE UNITED STATES

19. Early Methods in the United States.—This chapter presents a discussion of early methods of mining coal in the United States, information regarding the percentage of coal recovered in different districts, and descriptions of the most advanced methods employed for obtaining high extraction, especially those which are applicable to conditions in Illinois. In collecting this material all available sources of information have been utilized. The descriptions of methods have been taken largely from the technical literature of coal mining, but in instances in which the correctness of the description seemed in doubt, or in which statements concerning the percentage of extraction seemed to need verification, the subjects have been reviewed by persons familiar with the local conditions.

In response to the large number of inquiries sent out, many persons have furnished the desired information in as nearly complete form as possible, but in many cases there has been available no authentic information on the subject of recovery. The estimates are necessarily more or less approximate because the conditions are such that it is practically impossible to obtain correct values, or the subject has not been considered of sufficient importance by the operators to warrant the expenditure of the time and money necessary for obtaining the values. It is believed that the values for percentage of extraction given in the following pages represent the most reliable information obtainable on the subject, but they are not presented as being absolutely correct.

At the time mining was begun here, this country was a colonial possession of Great Britain; the methods of mining to which immigrants were accustomed were those of Great Britain, and the application of these methods to mining problems in America was a matter of course. The development of the early English methods is discussed in the appendix. The coal miners of this country, furthermore, have been for the most part men who received their training in the work in England, Scotland, or Wales, or children of such men, and not until
a comparatively recent date did these miners lose their dominance in the American coal fields. The conditions under which coal was found in this country were also not very different from those in Great Britain. It was natural, therefore, that bituminous coal mining practice in this country should correspond to that of Great Britain at the time the industry began here.

Mining in this country was begun in the Richmond (Virginia) basin about the middle of the eighteenth century. There seems to be no clear record of the methods followed, but it is known that a pillar system was employed, and that, as the coal was reached in some places at a depth of several hundred feet, a considerable amount of the coal was left in the ground. It is said that the pillars were to be extracted on the retreat, but no definite record is found to indicate that this was done.

Western Pennsylvania was the next district to take up coal mining on an important scale. Maryland and West Virginia followed, basing their early methods for the most part on what had been done in Pennsylvania.

20. Pennsylvania.—The early history of coal mining in the western Pennsylvania district is typical of that in other sections of the country, having a similar hilly topography. When coal mining was commenced, an abundant supply of coal was found outcropping on the hills in the neighborhood of Pittsburgh, and these seams were attacked by numerous small mines on the outcrop. As the workings were extended under cover, the single entry system was followed, and as it was impossible to obtain good ventilation with this system, the rooms were driven to only a short distance, and the entry itself was not long. Later the double entry method was employed, in which two parallel entries were used, respectively, for intake and return air. Since the distance to which rooms could be driven was limited, it was impossible to work any large territory by this method; hence, as the size of the mines increased, the cross entry system was introduced. The underground developments were the same whether the coal was reached by drifts, by slopes, or by shafts.

Among the many experiments tried in the Pittsburgh bed was that involving the use of double rooms with double necks, or of double rooms with single necks, but the amount of timber required for posts made these methods too expensive and by 1906 they were in use in a
very few mines. The long-wall system also was tried and abandoned.*

No record has been found of the time at which the drawing of pillars was commenced, and it is probable that this method was followed more or less from the beginning in such mines as were systematically developed.

Toward the end of the last century, the double entry system had been further developed by the turning of room or butt entries from the cross or face entries. In some mines a few of the entries were driven to the boundary, and then all the rooms were opened at once, but some of the center rooms would sometimes reach their limits before those whose pillars should have been drawn first. In other cases only the inby half of the rooms on each entry was turned first, while in still others one entry was completely exhausted before any side work was done on its parallel entry. In most cases, a room-and-pillar method was used with double entries, each about 9 feet wide. Main entries were separated by a pillar 51 feet wide with cut-throughs for ventilation. The main entries were driven on the butt of the coal, and face entries were turned from them about 1,000 feet apart. From these face entries, secondary butt entries or room entries were driven

about 400 feet apart. Rooms about 20 feet wide and 200 feet long were turned on the face of the coal. The room necks were 21 feet long and 9 feet wide. Room pillars were 15 or 20 feet wide, according to the cover above the coal. The rooms were turned from the butt entries as fast as these were driven, room pillars being drawn as mining pro-

![Diagram of improved method of room-and-pillar mining.]

gessed.* The objectionable features of this method are:—poor ventilation, dangerous gob, entries filled with fallen dirt requiring expense for cleaning up, maximum extent of track for the minimum quantity of coal, thus greatly increasing the cost of animal haulage, loss of thousands of tons of coal, compulsory driving of narrow work in room turning, and squeezes, which damage the coal and greatly increase the hazard of mining.

The difficulty of ventilation becomes most serious when the rooms from one entry are holed through into those approaching from a neighboring entry (see Fig. 8). Often this will occur two-thirds of the distance up each of these entries; thus all the pillars below the short circuit are deprived of proper ventilation at a point where it is constantly needed. After the pillars are drawn and the roof falls, there is no appreciable movement of air through the gob, and it often fills with explosive gas.

A method described by Dixon, in the article previously referred to, was soon adopted with various modifications, although it is possible that it was already in use in one or more places at that time. According to this method the territory was laid off into blocks (see Fig. 9) 1,570 feet long, allowing for a barrier pillar 200 feet wide along the main entries and for another 200 feet along the next pair of face entries. A pair of room entries separated by a 54-foot pillar was driven through the center of this block, and thirty rooms were turned from each entry. Rooms were 240 feet long, about 26 feet wide, and were driven on 39-foot centers, thus leaving 13-foot pillars. Room turning was begun at the inby ends of the room entries, a reversal of the common practice of the time. The drawing of pillars was commenced as soon as the rooms were finished, and the line of break was kept at the proper angle by carefully timing the extraction of pillars. In this method the ventilation was considerably better than in the earlier method; but the air current, after passing through the district of pillar work on one room entry, went through the advancing rooms turned from the other. This difficulty was avoided in later methods by exhausting one room entry before room work was done on the other. The roof in the entries was easily maintained because the entries, with the exception of those on which rooms were being worked, were in solid coal. At the finishing of a block the minimum of track was in use for the minimum of coal passing over it. Track was not left in place awaiting the withdrawal of entry pillars; therefore it was not exposed to the corrosive action of mine water. Since the room pillars were attacked immediately, there was little danger of deterioration of coal or of trouble from falls. Most of the props could be recovered as they had not been subjected to any great pressure. Under the old system 50 per cent of the wood rails in rooms were lost while awaiting the attack on the ribs, and about 75 per cent of the posts were lost.

Referring to the conditions and the methods employed in mining, F. W. Cunningham* said in 1910:— "The operator in the Pittsburgh coal field, with the price of coal where it is to-day, must get the largest percentage of lump with the least amount of fine coal, and this by machine mining, in order that he may compete with coal operators in other fields." The rooms, therefore, are made as wide as possible to obtain the greatest percentage of lump coal, and the pillars are left

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as narrow as possible, because the greatest percentage of crushed coal comes from them. This fact explains why the use of narrow rooms and wide pillars, common in the Connellsville district, does not appeal to operators in the Pittsburgh district. It also explains the loss of much pillar coal, because a period of dull market results in the stopping of pillar work and only large coal from the rooms is marketed. A large number of rooms, accordingly, may be driven up to their limits without the extraction of room pillars, and the recovery of these pillars is unprofitable after the rooms have stood for a number of years.

Fig. 10 illustrates the series of operations incident to one method of extraction of stump and chain pillars. In this method, rooms are turned and worked out progressively along one of a pair of room entries, probably the last, the pillars being drawn back as soon as the rooms are finished. There is thus a diagonal line of rooms advancing and another diagonal line, practically at right angles to this, retreating. On the other room entry of the pair, the driving of rooms is commenced at the inby end and proceeds outward. In some instances the entry pillars have been drawn on the retreat as illustrated in Fig. 10, and in others they have been left until all the rooms and room
pillars have been finished. In the latter case it has sometimes been possible to obtain the coal from these entry pillars, but frequently all or part of it has been lost. The method illustrated in Fig. 10 was in use in the Pittsburgh district proper, that is in the high coal along the Monongahela River. Cunningham says that the extraction by this method would average about 80 per cent. Some companies, however, claim an extraction of 90 per cent. Some differences in percentages of extraction may be accounted for by the different methods followed in estimating: the whole bed from the limestone to the top of the seam may be taken into consideration, or the thickness of the slate partings may be subtracted.

One of the principal reasons for taking the rooms turned from one of a pair of butt entries on the advance and those turned from the parallel butt on the retreat was that this procedure made it possible to have the air current always blowing from the room work to the pillar work. This constantly moving current of air prevented gases set free by the pillar work from being carried to men working in advancing places. The miners in the pillar workings used locked safety lamps, while those in the room workings used open lamps.

Until about 1910, mining machines were used in the Pittsburgh district only in room and entry work, while pillar coal was undercut with picks. A method designed to permit the mining of pillars by machines is illustrated by Fig. 11. Cunningham gave the following facts concerning this method:—24-foot rooms are turned on 39-foot centers. After the room is worked out with a machine, a cut about 25 feet wide is made across the end of the pillar; then another cut of the same width is made far enough back on the pillar to leave a stump 5 to 8 feet wide, and the stump is removed by pick work after the machine work is finished. The stumps serve to protect the machine runners and the machine by supporting the top. It was said that at one mine where this system was used 70 per cent of the pillar coal was extracted with machines, and 30 per cent was pick mined. Good falls were obtained, and no ribs were lost. The recovery of timber was not so good as in the Connellsville region or in mines where there is no refuse gobbed along the roadways.*

An old and common method of working is illustrated by Fig.

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12. Track is laid in the middle of the room, and the room pillars are made as narrow as possible after the room has advanced 100 feet, or to the first cut-through. Commonly no attempt is made to recover the pillar coal beyond this point, though it is often recovered nearer the entries by working the pillar along the side of the fall. One of the chief operators in the Pittsburgh district claimed a recovery of 90 per cent of marketable coal by this method, but it seems that such a recovery could be made only over an area of a few acres and that the recovery over the entire area of the mine would be much lower. Schellenberg expressed the opinion that the recovery would not be more than 60 per cent if an area of 10 acres were considered.
In the discussion of Cunningham's article, G. S. Baton said that entry pillars were not often recovered in the Pittsburgh district except under remarkably favorable conditions. In his opinion not more than 40 per cent of the entry pillars were recovered where there was much overburden. It is probable that a larger percentage than this is being recovered now in the more carefully operated mines. Another practice in pillar drawing which had been used in the Pittsburgh district and in other districts is illustrated by Fig. 13. A curtain of coal is left to keep out the gob when drawing room pillars, and the loss of coal amounts to about as much as it does where the pillars are narrowed and not drawn.*

It has been seen that in most of the methods employed in the Pittsburgh district, the pillar coal is taken out by pick work, and it has been within only a very recent period that even the room coal has been undercut by machines. Machine mining of pillars is cheaper than pick work and operators have recently introduced this more advanced method wherever it seemed possible. The immediate reason for this action has been the increased cost of production, largely due to high wages and expenses caused by changes in the laws affecting mining, without a corresponding advance in selling price. Since the demand

is still greater for the lump coal than for the smaller sizes, it has been necessary to increase the size of the pillars to prevent the objectionable crushing of the pillar coal. Another reason for increasing the width of the pillars is to be found in the practical difficulty of using machines on very narrow pillars. The thickness of room pillars varies, but the most common distances between the centers are 33, 36, 39, and 42 feet. With 33-foot room-centers, the room pillars are lost entirely; with 36-foot room-centers, about 55 per cent of the pillars are recovered; and with 39- to 42-foot centers, from 60 to 70 per cent of the pillars are recovered.* Many miners at the present time have not the skill to do the best pillar work, even if the cost were not too high, and for this reason, if a higher percentage of pillar coal is to be won, cutting with machines, which can be operated successfully only on wider pillars, must be employed.

A method adopted for future working at the Marianna and the Hazel mines of the Pittsburgh-Buffalo Company in Pennsylvania and

the Annabelle mine of the Four States Coal Company in West Virginia is illustrated by Fig. 14.* The plan as outlined is intended for coal under a cover of 300 to 500 feet. There are two sets of triple main entries separated by an unbroken pillar 50 feet thick. The operation really includes two distinct mines except that the coal goes over the same tipple. The loaded and empty haulage roads on each side are driven 10 feet wide, and the airway is driven 16 feet wide. These widths are necessary in order to avoid the expense of a fourth 10-foot entry.

The panel system planned is known as the "half advancing and half retreating" system. The panels are divided into blocks 500 feet wide by entries driven "end on" in pairs, and from these butt entries

*Ibid.
the rooms are turned on the face of the coal. The butt entries on the side toward which the development of the panel is progressing, that is on the inby side, are termed "advance headings"; the exterior or outby entries are "retreat headings." A chain breast machine is used in rooms and entries and a short-wall machine on pillars. Both machines continue in use until the last room on the retreat entry is completed; then the short-wall machine is left to finish the pillars, and the breast machine is transferred to another pair of butt entries under development. By the time room 14 is turned, room 2 has been finished, and work can be begun on the pillar between rooms 1 and 2. Rooms on the advance entry are 255 feet long and those on the retreat entry 246 feet long from the entry centers; this difference in length is made, because the chain pillar and entry stumps are brought back with the
room pillars on the retreat entries. The method has been worked out for two general conditions; first, where a draw slate is encountered, and secondly, where there is no draw slate.

The method to be used where draw slate is encountered is illustrated by Fig. 15. In this illustration room 1 is shown as finished. In rooms 2 to 9, inclusive, the pillars are being drawn. Room 10 has reached its limit, and the cross-cut at the face is being driven through the pillar to room 9. Rooms 11 to 18, inclusive, are being driven. Fig. 16 shows in detail the method of recovering the pillars by the short-wall machine where draw slate is encountered. From the point A, the track is laid in 14-foot sections, and steel ties are used; consequently, the track is easily assembled or detached. Curved rails are used in the same way so as to give easy access to the cross-cuts. After the cross-cut B is finished, the curves and two 14-foot sections of the track are detached, and an 18-foot cut is made in the pillar at C by working on the butt of the coal and leaving a stump D, 10 by 39 feet. The draw slate from the first cut is gobbed in the room proper. The remainder of the draw slate from this cross-cut is gobbed in the outby part of the cross-cut, and the track is laid in the inby part. A cut is next made through the stump D, into the gob above, and small blocks or stumps E and F are left on each side of the cut to be taken out with the pick. After the block E has been removed, all the tracks in the cross-cut, except the two curve rails, are removed; when the block F has been removed, the curve rails and the two 14-foot sections of straight track are taken up, and the operation of driving through the pillar is repeated as the illustration shows. In this way the room pillar is extracted back to the point A.

The method of operation in the second case, where the draw slate is not encountered, is the same as in the first case, except for the manner of attacking the pillars which is illustrated in detail by Fig. 17. After the room has been completed and the cross-cut B driven, the two curve rails and seven sections of track are detached; thus the track is left in position to be assembled quickly for easy access to the cross-cut H, which is next driven. The 39- by 94-foot pillar is then split from H to B, and a 9- by 94-foot pillar is left on each side; then an 18-foot cross-cut D is driven through the 9- by 94-foot pillar on the rib nearest the gob, and a stump is left to be removed by the pick. The other 9- by 94-foot block is removed in the same way, and the operation is continued until the whole pillar has been removed. The entry
stumps and chain pillars of the butt headings are won in the same manner as the room pillars.

Both of these methods are in use at several mines and are meeting with success. In both methods 90 per cent of the coal won is cut by machines. This percentage can be increased considerably, since it has been demonstrated that under favorable conditions part of the pick blocks can be recovered by the machine. One-third of the coal is mined from the rooms and two-thirds from room pillars. When draw slate is encountered, the 39- by 10-foot stump pillar will always afford ample

FIG. 17. DETAIL OF PILLAR WORK IN ABSENCE OF DRAW SLATE

protection to the miners; and where no draw slate is found, the two 9- by 94-foot stump pillars together with the timbering will give adequate protection.

Among the plans tried in the Pittsburgh district with the object of reducing the cost of mining by substituting more machine work for pick work is one (Fig. 18) which promised to be successful, but failed, because the miners demanded room-turning prices for the short rooms.* This added cost would have defeated any other advantage of the system. The method, however, seems to be based upon principles which may find application under other circumstances. The method was adopted, because a provision of the mining scale of the Pittsburgh district prohibited the drawing of ribs by machines unless short-wall machines were used. The plan was to continue the employment of the breast machines already in use and thus to increase the percentage

of room coal. It seemed profitable to increase the percentage of room coal since the cost for machine-cut run-of-mine coal was 45.28 cents per ton, including a differential of 2/3 of a cent on account of rolls, while the price for pick mining was 64.64 cents per ton; the average price for cutting, loading, and pick work was 51.92 cents. This average was based on the assumption that the working was regular with rooms 25 feet wide on 40-foot centers. Machine work was done with the common breast machines. The mining system was the ordinary method of machine mining with 25-foot rooms on 40-foot centers with crosscuts three runs wide and room necks 21 feet long. Rooms were 250 feet long, but as the neck was 21 feet long, the length of the actual room was 229 feet. All estimations of the percentage of extraction were based on a block 229 feet long and 120 feet wide. In this old system of mining, 65.7 per cent of the coal was produced as machine coal and 34.3 per cent as pillar coal drawn with the pick. The mine was operated on a run-of-mine basis. The new system was started with 36-foot rooms on 117-foot centers; but it was expected that if the system should prove successful, these dimensions would be changed.

Fig. 18. Method of Reducing Pillar Work in Pittsburgh, Pa., District
to 40-foot rooms on 120-foot centers. The illustration shows the form
and dimension of rooms. Two 25-foot rooms were driven from the cross-
cut with 10-foot pillars on each side. These pillars were somewhat
weak, but the rooms were not long, and the pillars were drawn quickly.
It was admitted that the system would reduce tonnage for a time if
the mines developed were not sufficiently advanced, but it was claimed
that when the main rooms had been driven to within 50 feet of their
intended length, the production from them would be much greater
than from the ribs of three rooms of the older system. As soon as the
pillars were drawn, the recovery of the so-called "rooster" coal would
rapidly increase the output. In the Pittsburgh bed, the rooster coal
lies above the draw slate and a laminated coal 12 inches to 2 feet
thick. Although in most mines this coal is not taken out, in the Pan-
handle district it seems to be better fuel than the bottom coal and is
being mined in several places. The cover in the section in which this
method was employed was from 75 to 125 feet thick. The small pillars
were extracted by pick work, and the rooster coal also was obtained
at pick prices.

21. Connellsville District.—The methods of production in the
Connellsville field have become more intensive than those in the other
districts of western Pennsylvania. The excellent quality of the Con-
nellsville coke and the fact that the coal from which it is produced is
found in only a limited area have made the coal so valuable that it
has been found advisable to pay particular attention to high percent-
age of extraction. In this district, there has been, moreover, no
objection to the crushed coal from pillars as the product goes to the
coke ovens where fine coal is desirable. The same fact influenced the
relative sizes of rooms and pillars. While in the gas coal district it
was thought desirable to take as great a quantity as possible from
rooms, in the Connellsville district the practice of getting a large part
of the coal from the pillars has developed in order that the percentage
of extraction may be as high as possible. It is of interest to trace the
more recent developments in mining practice here, because the extrac-
tion in the better planned mines of this district is unusually high.

Conditions and methods in this district are discussed by F. C.
Keighley* as follows:

"The coking coal known variously as the No. 8, Pittsburgh, or Connellsville seam has in places an extremely bad roof. This difficulty is strongly marked in the Connellsville basin, but can be found in other troughs. . . . The thickness of the coal and its softness might lead one to anticipate that it could be mined cheaply, but the friable roof creates a difficulty which its other qualities cannot overbalance. . . .

"I have projected workings at depths ranging from 200 to 700 feet, using a dozen or more different schemes, and have never found any marked difficulty in protecting the main headings and air-courses of any mine. But I have experienced some trouble occasionally in protecting the branch, or butt, headings, and I have always had more or less trouble with the rib coal in the rooms.

"It is true that in many cases the roof will fall in headings and air-courses in spite of all that can be done, but such falls are gradual and are removed as part of the regular mine operations. On the other hand, when falls occur in the rooms they often come suddenly and cover a large area, and the break extends so far above the coal that they often reduce and may entirely cut off the production from a certain section of the mine, not only for a day, but perhaps for weeks at a time.

"It is clear, then, that any improved method of mining must provide for the protection of the rooms rather than for the care of the headings.

"Panels have been projected 1,000 feet wide and 2,000 to 4,000 feet long. . . . Such a panel is subdivided into a number of smaller panels that are themselves served by two parallel entries driven at right angles or at some other angle to the flat or face heading depending on the pitch of the coal. These are known as butt headings. These sub-panels are generally 1,000 feet long and 300 to 600 feet wide.

"Various widths have been chosen for rooms with 8 to 30 feet as limits, but the general belief is that rooms and headings should be driven 10 feet wide in the Connellsville region. There seems to be no opportunity to improve on this width. The best work has been obtained with large room ribs—50, 70 and 90 feet thick; but the success has not been as great as might be expected, though, with room ribs of the two larger dimensions, and with any ordinary care in mining, a general creep or squeeze cannot occur."
“This is not true when room ribs are made of smaller dimensions, such as 30, 40 or even 50 feet. In the initial stage of rib drawing with such light ribs great success is secured, but when trouble occurs it is usually in the form of a general squeeze or creep that almost paralyzes the output. It has often seemed for a time that the small ribs in the rooms resulted in cheaper mining; but when a squeeze or creep took place the small rib did not permit of the driving of a new road with safety and profit, and consequently the coal remaining in the rib could not be taken out.

“With 70-, 80-, or 90-foot ribs there is always sufficient coal left to permit driving a new road with safety through the pillar no matter how badly the roof may have fallen or the coal be shattered on the edges of the pillars.

“Nearly all experienced miners concede that with narrow ribs only 50 per cent of the coal is recovered. The best results claimed is 65 per cent, while 90 and 95 per cent has often been recovered with the larger-rib system. The problem is whether the heavy cost of timber and the still greater cost of labor will counterbalance the loss of from 35 to 50 per cent of coal. I am disposed to believe that the larger rib, making a larger yield possible, will assure a handsome margin.”

Fig. 19 illustrates a modern method of pillar drawing.* In this method a cut is made across the pillar, and an 8-foot stump is left; then this stump is taken in a retreating direction in from two to four sections, according to the width of the pillar. In the example given the rooms are 12 feet wide and are on 84-foot centers. After

the removal of the coal in each section, the props are drawn and
the roof is allowed to fall, the break being controlled by a row
of props across the end of the cut. After the last section of the
stump has been taken out, the last of the track drawn, and the
roof dropped across the room on the line of the end of the
remaining pillar, another cut is made across the pillar and the
process continues. While the falls represented in the sketches appear
to be large, a better break is obtained with these than with short
falls. This method has proved to be safer for the miners and to give
a greater recovery of posts and coal than the methods which pre-
ceded it.

A highly developed and systematized room-and-pillar method is
the so-called concentration method used in some of the mines of
the H. C. Frick Coke Company,* and developed largely by Patrick
Mullen, one of the company's inspectors. This method was designed
to satisfy certain requirements, among which were safety of operation,
completeness of extraction, reduction of cost through the greater use
of machines, and an increase of daily output per man. A patent cov-
ering this method has been applied for.

It is well understood that liability to accidents is decreased by
close supervision. Under the older system in the Connellsville region,
it was possible for the face boss to visit each working place only
once in two or three days. In order to increase the amount of super-
vision without increasing the number of officials, the plan of getting
the working faces closer together was tried; this plan, however, neces-
sitated a decrease in the number of working places and in the number
of workmen, and it was realized that only by increasing the production
of each miner could the output of the mine be kept up.

The only possible way of increasing the output per man was by
replacing pick work with machine work. This substitution was made
in room work; but it was found that, on account of narrow headings
and narrow rooms with large room centers, machines in the narrow
work alone would not accomplish the desired results, since the bulk
of the coal comes from the pillars. The problem of the use of ma-
chines for pillar extraction, which was an entirely new one in the Con-
nellsville district, has been worked out very successfully (see Fig. 20).

* Mullen, Patrick, "New Mining Methods as Practiced by the H. C. Frick Coke Com-
Coal Age, Vol. 9, p. 125, 1916.
The mine is blocked by driving at A double butt entries, 10 feet wide on 50-foot centers and 1,200 feet long, across the panel with break-throughs every 100 feet; the pairs of butt entries being driven 350 feet apart, the panel is divided into blocks about 350 by 1,200 feet. These blocks are then subdivided into blocks about 90 by 100 feet, by 12-foot face rooms at B 350 feet long on 112-foot centers, driven at right angles to the butt entries and connected by 10-foot break-throughs on 100-foot centers. A pillar of this size is considered ample to support any thickness of cover under any conditions of floor or cover to be found in the Connellsville region. In this manner a whole panel can be prepared for the intensive part of the work in which butt rooms are driven from the face rooms 10 feet wide on 25-foot centers.

As the main face room advances, the necks of the butt rooms to be driven are excavated to a depth of three machine cuts. After a main face room has been advanced 50 feet, there are available
for the machine to cut two places which allow a production of forty tons; and when the room has advanced to a point where the first cross-cut is turned off, there are three places to cut in each main face room yielding sixty tons. This main room may continue to the end of the section or to the end of the coal field, butts or producing entries being turned off at projected distances. It is necessary that the operation be carefully planned and that the proper order of the work be closely adhered to. Fig. 21 shows the general schedule of operations with the position of the line of roof fracture at different dates. It is claimed that the general plan can be easily modified to suit all conditions such as depth of cover, presence or absence of draw slate, and nature of coal, bottom, and roof.

The projection takes three forms known as (a) maximum, (b) medium, and (c) minimum, according to the rate at which coal is produced (see Fig. 22.) The maximum plan is applicable where the thickness of cover does not exceed 125 feet, where the coal is hard, and where the general physical conditions of roof and bottom are good. The medium plan is applicable where the cover does not exceed 250 feet with the same physical conditions of the coal, bottom, and roof as for the maximum plan. The minimum plan may be applied to coal underlyng any thickness of cover; the coal may be hard or soft, and the physical conditions of roof and bottom may be good or bad, provided, of course, that mining machines in any form can be used.

With the minimum plan, the butt rooms are driven in succession so that each room is 50 feet beyond the one succeeding. Two butt rooms advancing furnish 40 tons and one butt rib retreating furnishes 40 tons, or a total of 80 tons on the retreat; the main face room advancing yields 60 tons, or a total of 140 tons from one main face room. These quantities apply, of course, to coal of the thickness of that mined in the Connellsville basin — about 7 feet.

The medium plan will yield the same tonnage from the advancing main rooms, but the retreating work is so arranged that the face of each butt room is 30 feet behind that of the preceding room. This arrangement allows three butt rooms to be advanced at a time with a production of 60 tons, while two butt ribs are being extracted with a production of 80 tons; thus 140 tons are taken from the butt rooms and ribs and 60 tons from the advancing main rooms, a total of 200 tons for each main room.
In the maximum plan the working of the butt rooms is so timed that the face of one room is 15 feet behind the face of the preceding one; four butt rooms are advanced and four butt ribs are simultaneously withdrawn. The four advancing butt rooms will produce 80 tons and the four retreating butt ribs will produce 160 tons. With the 60 tons produced from the advanced main room, there is thus produced 300 tons for each main room.

The work is thoroughly systematized and proceeds with great regularity. After the miner has cleaned up his place and the day's run
is completed, the machine crew enters and cuts the place to a depth of approximately 7 feet. Following the machine crew, the timber men reset any posts which the machine men have removed, post up any cross bars which have been notched in the coal over the machine cut, and put the place in good condition according to a prescribed system of timbering. The timber men are followed by the driller who bores the holes with an electrically driven drill. The driller is followed by the shot firer who charges and tamps the hole, and after an examination of the conditions, fires the charge. After the coal has been shot down, empty cars are placed by the gathering locomotives so that when the loader arrives at his working place in the morning he finds it in safe condition, the coal ready to load, and the empties in place. Miners loading under these conditions regularly obtain 18 to 20 tons per shift. The average of the loaders for short-wall mining machines in all mines of the company for the month of August, 1916, was approximately nineteen tons per shift. At mines where there is a full equipment of mining machines, the machine coal runs from 80 to 90 per cent of the total output. The recovery under the concentration system is from 90 to 92 per cent, while under the ordinary methods it is 80 to 85 per cent.* In the values given, the top or bottom coal left in place is not considered. The average thickness of top coal left is about 6 inches and the values for extraction, based on the entire thickness of the seam would be somewhat lower than the values given. Coal is left for two reasons. In the entries, from 6 to 8 inches of top coal is left as a protection. In the room work, such top or bottom coal is left in place as is necessary to keep the sulphur content of the coke made from the coal down to the required amount. It is found that the highest sulphur content of the bed occurs at the top or at the bottom and, by frequent analyses, it is determined how much of this top and bottom coal may be left.

22. Central Pennsylvania.—A method known locally as the "Big Pillar System" has been developed to meet conditions incident to the soft bottom in the Lower Kittanning, "B," or Miller, bed in the southern and eastern parts of Cambria County, and in the adjoining territory.†

The physical conditions for which this system was developed include a hard roof, very difficult to break, and a soft fire clay bot-

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* Dawson, T. W., Personal Communication.
tom. A sand rock from 10 to 40 feet thick occurs above the coal; but between this sand rock and the coal there is usually from 1 to 6 feet of slate or sandy shale, which is more or less affected by the air and which breaks away from the sand rock, especially in the roadways. The falling of this top tends to relieve the pressure, but not enough to prevent squeezing. The worst squeezes are encountered where the sandstone is only 10 feet thick.

**Fig. 23. "Big Pillar" Method Used in Cambria County, Pa.**

Under these conditions, the ordinary system of turning rooms with 40-, 50-, or 60-foot centers does not work satisfactorily. When the room pillars are drawn back to the stump, under the ordinary system the pressure is so great that a stump, even 30 or 40 feet square, will not protect the entry. Instead of breaks occurring in the roof along the line of the stumps the bottom breaks and heaves, and squeezes occur. Since the coal is soft and has a columnar fracture, the stump is badly crushed, and no amount of timbering is sufficient to prevent the closing of the entry. Thousands of feet of entry and much coal have been lost as the result of squeezes in a bed of this kind. The bed is only about 3½ feet thick so that it is necessary to take up the bottom, and the provision of space for storing bottom is one of the considerations involved in planning this system. The average dip is about eight per cent.

In the "Big Pillar" method (Fig. 23), haulage entries are driven on the strike and rooms are turned up the pitch. Entries are 10 or 12 feet wide. Rooms are turned on 100-foot centers from the entries, and, at a distance of from 100 to 125 feet from the entry, rooms called "crooked" rooms are turned at right angles, that is,
parallel with the entry. There is thus left along the side of the entry a series of blocks 75 by 75 feet or 75 by 100 feet, according to the length of the rooms driven from the entry. As soon as a crooked room has intersected the straight room toward which it is being driven, an intermediate room is turned up the pitch from the crooked room; thus the rooms above the crooked rooms have 50-foot centers. The straight rooms are driven to such distances that the roof will break at the edge of the big pillar or by settling will relieve the strain. Sometimes they are only 250 feet long, and sometimes, under heavy cover, as much as 400 feet.

When the straight rooms are started, they are widened on the outby side so that the cross, or crooked, room can be turned off the straight rib, a matter of importance because of the necessity of storing bottom which is taken up in the roadway. Beyond the crooked rooms, the straight rooms are widened on the inby side; thus the men who drive a room are able to start the drawing of the pillar as soon as the room is finished. The room pillars are drawn back to the crooked rooms, and the irregular little blocks caused by the necks of these rooms are removed as completely as possible. The big block is then left standing to serve as a barrier to protect the entry, and if the space mined out is sufficiently broad, the roof will usually break. Even if the roof does not break, the strain seems to be relieved before reaching the entry. The upper edge of the big pillar may be badly crushed, and the roadway of the room may be heaved almost down to the entry, but the entry itself will be practically unaffected.

When the entry is finished and the stumps are being drawn, the system presents a special advantage in that a better output can be obtained than with the smaller stumps. Where stumps are small, the output is limited to the work of two gangs, but with the big pillars eight or ten places may be worked at all times on the retreat. The big pillars are split by a room driven up from the entry at the same time that a skip is taken along the rib of the old room. These two working places are cut through to the old falls about the same time, and the intervening portions of the pillars are brought back. This method leads to large recovery of coal, although there are no statements available concerning the exact percentage. There is some loss in the extraction of the pillars, and the coal at the edge of the big pillars is badly crushed. The method is not used in other beds in the same district, because the conditions are better.
In the Somerset County district, there has been developed a panel system which permits a high degree of concentration of work and a large percentage of extraction. The coal is low, and the miner is obliged to push his cars to the face of the room and to drop them down to the entry. The seam often dips from two to five per cent, and butt entries are driven off the main haulage slope on a grade of one per cent in favor of the load. From these, entries are driven to the rise at convenient distances, from which rooms are turned on the strike of the bed. Not only does the method result in a high percentage of extraction and facilitate the handling of the cars by hand in the rooms, but it also concentrates the work of mining. Two men working together will produce from ten to twelve tons of pick-mined coal per day, but when the men work singly it has been found that a good miner can load from seven to eight tons per day.* Under this system, the total extraction is reported to be about 93 per cent. About 50 per cent of the coal comes from rooms and entries, and the remainder from pillars.† This method is similar to that illustrated in Fig. 32, page 102, which shows a plan of operation of the Carbon Coal Company in West Virginia.

Because of the recognized objections to the room-and-pillar system, much attention has been given to the possibility of employing the long-wall system in the Pittsburgh bed and in other beds of western Pennsylvania. So far as can be learned, there is only one mine at which a long-wall system is being used in these districts, although there is an approach to it in some so-called "panel long-wall" or "block long-wall" methods. In these methods, dependence, however, is not placed on the weight to break down the coal; in fact, weight at the face is prevented so far as possible by causing the roof to break near the face.

It is worth while to review some of the experiments in the introduction of long-wall methods, because it is only by these methods that complete extraction is attained, although there is a close approach to it in the best applications of some forms of pillar working.

One of the attempts‡ was started about 1899 in the Lower Kittanning, "B," or Miller, bed where the coal was from 3 feet, 6 inches

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†Oxe, Edward H., Personal Communication.
to 3 feet, 10 inches in thickness, and had an average dip of eight per cent. The roof was of blue slate and the floor of hard fire clay. Most of the coal lay under a fairly level surface about 174 feet thick, near the top of which was a moderately hard sandstone. The plan adopted involved blocking out the mine with entries and taking out the coal in each entry on the retreat. The faces were 250 to 300 feet long. One machine-cut produced from 125 to 150 tons of coal. Break-rows were made of stout, round, hardwood posts, 6 to 8 inches in diameter. These were capped with a 2-inch lid of soft wood set on a little slack to facilitate drawing. It was found that the track along the face took up too much space, and a conveyor, which was put in made it possible to set the props closer to the face. At first there were two faces, one slightly in advance of the other, each served by a conveyor which delivered coal to cars let down the block entry. Later, as shown by Fig. 24, a conveyor, by which the coal was lowered to the cars on the level, was installed in the block. Because of the unfavorable trade conditions in 1907, operations could not be carried on
with the regularity essential to the success of the system as then used. The attempt, accordingly, was temporarily abandoned, but a revival of the plan is being seriously considered.

Another attempt at long-wall mining was made with very similar mechanical arrangements in the Cement seam near Johnstown. In this instance two faces were cut, but a shortage of power compelled the abandonment of the experiment before the second face had been completed. Until that time the mining had been economical and the recovery was almost perfect.*

At present the Maryland Coal Company of Pennsylvania is using eight long-wall conveyors at St. Michael. The coal is about forty-two inches thick. No description of the operation is available, but it is evidently considered successful, as the number of conveyors is being increased. Two other companies in Pennsylvania and one in Maryland have recently decided to employ the same method.†

23. Summary of Facts Relating to the Percentage of Recovery in Pennsylvania.—The recovery in the Pittsburgh bed, not including the coke district, is estimated to be about 80 per cent. This estimate is made on the following basis: The actual tonnage mined is compared with the computed tonnage of the district worked out; everything between the fire clay and the drawslate is included, and no deduction is made for impurities in the bed or for the average thickness of four inches left on the bottom. This computation is obtained from one of the largest operating companies of the district and is based upon actual measurements. It is the opinion of this company, assuming that this method of calculation is used, that 85 per cent is probably the best possible recovery in this district. Some other companies claim an extraction of 90 to 95 per cent, but this is calculated after deducting the coal left in the bottom, the bearing-in bands, and any other impurities in the bed which are taken out and not weighed. Such high recoveries, of course, imply careful planning for the extraction of pillars and for the execution of this work without delay.‡

Another company the workings of which lie along the Monongahela River south of Pittsburgh, estimates the recovery as 86.7 to 90.6 per cent.

* Moore, M. G., Personal Communication.
† Link-Belt Company, Personal Communication.
‡ Schluderberg, G. W., Personal Communication.
In the Connellsville district the best practice gives from 80 to 85 per cent with the methods ordinarily used there. With the new "concentration" method of the H. C. Frick Coke Company a recovery of from 90 to 92 per cent is obtained.*

In the Johnstown district it seems impossible to obtain estimates of the percentage of extraction, because all the seams in that district vary in thickness within short distances, and are somewhat cut up by rolls. In some seams, for example, the Miller seam in the vicinity of South Fork, the recovery is almost perfect. The conditions are favorable, the roof being well adapted to extraction of pillar stumps in retreating.†

One of the companies operating in Jefferson County claims an extraction of 90 per cent. The operations are in the Lower Freeport bed, and conditions are somewhat peculiar because of bad roof, lack of uniformity of the seam, and faults. Each district requires individual development before an estimate can be made of the proportion of faults to the whole area, and it is impossible to make an accurate estimate of recovery until a district has been completely worked out. The value given represents the proportion of coal extracted from the area mined in which coal existed, and does not apply to the area of faults.‡

One operator in Clearfield County estimates an extraction of 95 per cent, based upon the amount of coal mined up to December, 1916.§

One of the companies operating in Somerset County estimates that, where mines are operated in an area of less than 300 acres and under a cover not exceeding 200 feet, the recovery should be, and in a number of instances is, in excess of 90 per cent. In the case of a property of 1,000 or more acres, where the coal extends underneath a hill giving cover of 300 to 700 feet, the recovery is from 85 to 90 per cent. Low coal, faults, and adverse grades still further reduce this percentage.§

The attainment of the higher percentages in Pennsylvania has been reached only within very recent years, and is not yet by any means universal. There are still in operation a large number of old mines,

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* Dawson, T. W., Personal Communication.
† Moore, H. G., Personal Communication.
‡ Van Horn, H. M., Personal Communication.
§ Personal Communication.
§ Delaney, E. A., Personal Communication.
mostly small, in which high percentages of extraction are not obtained. The more recent operations are planned for, and give, probably as high a yield of coal as can be expected from the area worked.

24. Maryland.—In the Georges Creek region of Maryland, the Big-vein coal has been mined for about one hundred years, and the methods used there furnish an illustration of progress in coal mining engineering which is especially interesting in view of the increasing attention given to the percentage of recovery.

In a paper on maximum recovery of coal, H. V. Hesse discussed the wasteful early methods of mining in the Georges Creek region and suggested economic methods, as follows:

"A region of uniform and unusually severe conditions in the bituminous fields has been selected to illustrate the results obtained over a long period. The Georges Creek region of Maryland, with remarkable deposit of semi-bituminous 'Big-vein' coal, has operated in this seam and shipped to the market for nigh unto a hundred years. . . . More than one miner still lives who 'dug coal' before the war with the South, and . . . he tells of the detail method of extracting the coal, on account of which thousands of tons lie buried to-day, much beyond recovery. . . .

"The 'Big-vein' seam occupies the geologic horizon of the Pittsburgh bed, but differs considerably in structure and quality from the coal of Pittsburgh, Connellsville, and Fairmont. . . . The top coal averaging 2 feet thick is left up for a roof. Where this comes down the strata immediately above promptly follows. Very little of this top coal is therefore recovered. Both roof and breast of the seam contain slips known among the miners as 'horsebacks,' which frequently fall out without any warning. The coal is soft and the 'butts' and 'faces' entirely absent.

"The methods of extraction in vogue at different periods in the history of this field have established the fact that it is impossible to maintain wide working places for any length of time. Headings are driven 8 feet wide and rooms from 12 to 15 feet. In the earlier days there was practically no definite system of extraction, headings and rooms being driven at random and no pillars recovered. Fig. 25 shows such a method in use about 1850. This is reproduced from an actual survey made under the most trying circumstances. . . . It is estimated that fully 55 per cent of the original coal, not counting the top coal, remains and it is expected to recover at least one-half of this, or 27 per cent of the original, by careful operation and the use of about double the amount of timber necessary under a good system of mining. The maximum cover over

this district is 300 feet and the few comparatively large pillars, which were inadvertently left standing at irregular intervals, saved the balance from being crushed. In other sections of the same mine where a similar method was followed, but these large pillars not left in, the workings are entirely closed and the remaining pillars, containing over 50 per cent of the original coal, probably lost forever. Fortunately mining operations during this period were not conducted on a large scale and, consequently, the territory thus affected is limited to a very small portion of the company’s holdings.

Fig. 26 "illustrates two methods followed during the years between 1870 and 1880. These workings are inaccessible to surveys at the present time owing to the creeps and squeezes induced by the irregular method of robbing the small pillars. . . . In the first method . . . the rooms were 14 feet wide and pillars 26 feet. These pillars were found to be totally inadequate and extracting them impossible. Cross-cutting the pillars at frequent intervals was then attempted after completion of the rooms, but this was generally accompanied by creeps closing a whole district at a time. The maximum height of the superincumbent strata in this territory is 200 feet.

"The second method shown on Fig. 26 was adopted later. . . . By this method headings were driven from the main entry on the rise of the seam at intervals of 1,000 feet to the level above, and two pairs of cross-headings turned to the right. The rooms were driven from these cross-headings at 50-foot intervals and 14 feet wide, leaving a pillar of 36 feet. The length of the rooms varied from 300 feet to 550 feet. These pillars were also of insufficient size, robbing was conducted spasmodically and although more coal was recovered than in the adjoining districts a great deal was lost. In addition to the small pillars, the method of robbing them was calculated to promote squeezes. It appears to have been the method to hold the strata with props until sufficient coal had been removed to enable the weight to break the props. As a general rule, however, before this was attained the weight had induced a creep which is well known to have no limits within a territory of small pillars.

Fig. 27 "represents a method in use in 1890. . . . Rooms were turned as shown from all headings on 100-foot centers and pillars split by half rooms. The length of rooms varied from 300 feet to 600 feet and they were 14 feet wide, leaving pillars 42½ feet wide. These pillars were not strong enough to support the overlying strata of 500 feet and the usual creep resulted when pillar drawing commenced. . . .

Fig. 28 "shows a method adopted in 1900. The maximum dip is 15 per cent and the greatest thickness of superincumbent strata 425 feet. The slope, together with parallel air-course and manway, are sunk on the heaviest dip of the coal and double entries turned off to right and left at intervals of 1,000 feet on grades of 1¼ per cent to 2¼ per cent in favor of the loads. From these haulways, cross-headings are deflected at intervals of 240 feet at an angle of about 25 degrees and driven on a grade of 4 per cent to 7 per cent. Rooms varying in length from 100 to 800 feet are turned on the rise of the coal from
FIG. 26. METHOD OF WORKING THE GEORGES CREEK BIGHORN, 1770-1880.
these cross-headings. The rooms are driven 15 feet wide on 65-foot centers, leaving pillars 50 feet wide. Twenty-five rooms are driven in each of these diagonal panels. Unusually large protecting pillars are left along the main haulage roads. This system has been found to be especially adapted to rapid gathering of cars thus ensuring a large tonnage. It has been found, however, that a very large recovery from the pillars is impossible, owing to the many sharp angles, which, in a thick seam of soft coal, are always difficult and oftentimes impossible to extract. This sharp-angle method was even resorted to formerly in cross-cutting the pillars preparatory to drawing them, but this has been changed to a rectangular method, thereby increasing the actual percentage of pillar coal recovered from 80 per cent to 83 per cent. The distance of rooms apart has also been increased in the last few years to 100-foot centers giving pillars 85 feet thick. It is expected that the extraction of these will show a further increase in the percentage of yield from pillars. The present yield from headings, rooms, and pillars under this system is about 90 per cent, considering the recovery from headings and rooms as 100 per cent.

Fig. 29 illustrates a method instituted in the latter part of 1904. The main haulway is an extension of the slope from the opposite side of the basin. Double entries are turned off from this entry, on 1½ per cent grade, 400 feet apart, from which rooms are driven directly on the rise of the coal. Rooms are from 13 feet to 15 feet wide and they are driven at 100-foot intervals, leaving a pillar 85 feet wide. The length of a panel is about 2,500 feet, containing 22 rooms. There are five such panels in this district and when completed it is proposed to draw the pillars in a retreating fashion with the line of pillar work on an angle of 45 degrees across the whole district. A similar method in another district . . . is yielding 88½ per cent from the pillars with a total recovery of 94 per cent from headings, rooms, and pillars . . . the greatest height of the overlying strata is 250 feet.

George S. Brackett states* that in 1898 he made some careful estimates of the percentage of recovery over a period of a year in the Georges Creek region of Maryland. The data for the computations were obtained from two mines which were worked under the following general conditions:

The thickness of coal was 7 feet, 3 inches; the inclination was 5 to 18 degrees; the system of mining was the room-and-pillar retreating method. All the entries were driven to the boundary before any rooms were opened, and a good line was maintained on the drawing of pillars. No. 1 mine had moderate grades, and a better roof than No. 2. No. 2 had grades

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* Personal Communication.
as steep as 18 per cent, and the roof was decidedly heavy on pillar workings.

The following results were obtained:

<table>
<thead>
<tr>
<th>Mine</th>
<th>Total Per Cent of Extraction</th>
<th>Per Cent of Pillars Obtained, Including Chain and Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1 Mine</td>
<td>97.6</td>
<td>97.0</td>
</tr>
<tr>
<td>No. 2 Mine</td>
<td>82.1</td>
<td>71.3</td>
</tr>
</tbody>
</table>

The average total recovery of the two mines was nearly 90 per cent.

25. West Virginia.—The modern methods used in the large mines of West Virginia are among the most advanced found in this country. In many parts of the state, coal mining is carried on by large corporations which are financially able to conduct operations with a view to ultimate economy. In most cases this ability has resulted in the development of methods of operation which lead to very high percentages of extraction.

In the Fairmont district in the northern part of the state, the more recently opened mines are planned for large production and a high percentage of extraction. According to the West Virginia Geological Survey, the Pittsburgh bed, which is the one mined in this district, contains more than 7 feet of clean coal* and the average total thickness of the bed is about 8 feet. The newer mines are projected on the panel system; the last rooms on each room entry are turned first, and the pillars are drawn immediately, a line of break being maintained at an angle of about 45 degrees with the entries. A plan of operation used in this district is illustrated by Fig. 30. The method of attacking pillars is shown in Fig. 31. One of the principal operators in the Fairmont district estimates the recovery, where mines are laid out systematically on the panel system, to be from 85 to 90 per cent of the entire seam.†

A company operating to the south of Fairmont estimates that 85 per cent is a good recovery. In the workings of this company, the rooms represent 27 per cent of the total area; the pillars down to the heading stump, 39 per cent; and the chain and barrier pillars, 34 per cent. The recovery in these three classes of working would be respectively, 100, 90, and 70 per cent. This would give a total yield

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† Smyth, J. G., Personal Communication.
PERCENTAGE OF EXTRACTION OF BITUMINOUS COAL

of 86 per cent. This company has no very accurate figures on recovery.*

In the mines in the Freeport coal bed in the Piedmont, or Elk Garden, district, there is ordinarily a good shale roof, although there are places in which the shale is replaced by sandstone. In the mines in the Kittanning bed there are from 3 to 14 feet of shale above the coal, and above this are 40 feet of sandstone, although there are places where the sandstone forms the roof for short dis-

*Brackett, George S., Personal Communication.
stances. The percentage of extraction in this region is about 90 per cent; in most of the new mines, however, an extraction of 97 or 98 per cent is being reached. This rate of recovery is higher than it formerly was, because changes have been made in the order of driving rooms and drawing pillars. The earlier custom was to drive long entries, from which rooms were turned on the advance. The room pillars could not be drawn until the entry was finished because of the danger of squeezes, and as this process sometimes occupied four or five years, falls occurred which made it impossible to recover a high percentage of the pillars. Under the present system, room entries are driven long enough for 20 rooms, and the inside room is turned first. Work on room pillars is commenced as soon as rooms 19 and 20 are finished, and room and entry pillars are taken out rapidly. Nearly all the pillar work is done with picks, and there is little machine work carried on in the district. The pillars are attacked by cross-cuts, and a stump about four feet wide
is left next to the end. This stump is removed as soon as the cut through the pillar is finished.*

In the Central West Virginia district the operations are in the Lower Kittanning bed which averages 6\(\frac{1}{2}\) feet in thickness.† The conditions are almost ideal for a high rate of recovery. The bottom consists of hard shale. The immediate roof is of bone coal 3 to 10 inches thick, above which are shales of varying hardness, 10 feet to 15 feet thick. Above this layer occurs sandstone of an average thickness of 10 feet, and above this, shale and overlying earth. Nowhere is the overburden greater than 90 feet in thickness. The extremely favorable nature of the roof is shown by the fact that a complete break is easily obtained with as few as 3 or 4 rooms. In more recent workings 20-foot rooms are turned on 50-foot centers. The rooms are driven 300 feet long, and a 50-foot pillar is left between the heads of the rooms and the adjoining air-course. This pillar is never pierced except in case of extreme necessity. The 30-foot room pillars are taken out by driving cross-cuts through them every 30 feet retreating. The entry pillars are taken out with the room pillars. If the entry stumps and the barrier pillars at the ends of the rooms are considered, it is estimated that 75 per cent of the coal obtained is taken out as pillar coal and 25 per cent as room coal. The cost of room and of pillar coal is about the same. Bischoff estimated that the recovery is at least 90 per cent, and possibly 95 per cent, although no accurate records have been kept. In view of the unusually favorable conditions, it seems probable that this estimate is correct as there is no apparent reason for loss, except that represented by the small amount of coal which the loaders fail to shovel up. This statement, of course, refers to only the area of actual mining operations.

The Pittsburgh bed is being worked also in Braxton and Gilmer Counties about 75 miles south of the workings just mentioned. While the same method of working is followed, the physical conditions are different, and the extraction is not more than 75 per cent. The coal is 6 to 8 feet thick. The bottom is of fire clay 8 to 15 feet thick, and the immediate roof is of fire clay 2 to 6 feet thick. Above this occurs a sand rock thicker than that found in the neighborhood of Elkins, with a heavier overburden. In this southern district the

* Personal Communication.
† Bischoff, J. W., Personal Communication.
coast of pillar coal is about three cents greater per ton than the cost of room coal.*

The Kanawha region is unlike the fields farther south in that there is a larger number of operating companies with a corresponding lesser concentration of ownership. Because of the number of individual operations it is impossible to give any general or standard method, but the room-and-pillar method is universally used. At least one operator is leaving a large barrier pillar, Fig. 32, and a large room stump for entry protection. The first break-through is driven about 80 feet from the entry, and break-throughs are kept

* Bischoff, J. W., Personal Communication.
perfectly lined up. Rooms are driven in order, and room pillars are
drawn back to the first break-through as soon as the adjoining rooms are
completed. The recovery under this method is said to be about 90 per
cent and where the roof is extremely good as much as 95 to 97 per cent.*

In a paper on the removal of coal from the No. 2 Gas Seam in the
Kanawha district, J. J. Marshall reported a very high percentage of
recovery and gave the following facts concerning the seam:† The
coal bed is made up of two benches separated by a solid parting
the thickness of which varies from 10 inches to 40 feet. It has been
found that it is not economical to remove this slate when its thick-
ness is more than 24 inches. The aggregate thickness of the two
benches averages about 9 feet, the upper bench ranging from 4
feet, 6 inches to 5 feet, 6 inches of clean coal and the lower bench
from 3 feet, 6 inches to 4 feet of clean coal. Where it is impossible
to mine both benches together, only the upper bench has been taken.
The thickness of cover varies from a few feet to 100 feet. After
the ordinary method of driving rooms and of drawing pillars on the
advance, the mine described has been developed until it is now in
position for the butt entries to be worked on the retreating system.
On June 30, 1911, the percentage of recovery was said to be as shown
by Table 6, nearly all the coal being mined by pick work:

| Table 6 |
|---|---|---|
| **Percentage of Extraction in Kanawha District** | **Total Acres** | **Percentage of Recovery** |
| High Coal, Both Benches | 84.61 | 91.8 |
| Upper Coal, Upper Bench Only | 67.87 | 98.7 |
| | 152.48 | 94.9 |

Computations of areas are made from the mine map, and the
method of computation does not insure the accuracy of the percent-
ages given. It seems that the values are too high. If there is a loss
of 4 feet or more in thickness across the working face, it is recorded,
but if the loss is less than this, it is too small to show on the map
which is drawn to the scale of 100 feet to the inch, and the recovery

* Cabell, C. A., Personal Communication.
† Marshall, J. J., "The Removal of Coal from the No. 2 Gas Seam in the Kanawha
is regarded as practically complete. It was said to be seldom necessary to record a loss, especially in the upper coal.

In the Cabin Creek portion of the Kanawha district little attention has been paid to the extraction of pillars until recently, and the extraction has amounted to only about 50 per cent. For the past 3 or 4 years, however, the extraction has been about 85 per cent. Since the proper sizes of pillars are now known and the men have a better understanding of pillar work, it is expected that the percentage of extraction will show some further increase.*

Two mines in the New River field, one in the Fire Creek bed and the other in the Sewell bed, have a recovery which is considered practically complete.† At those two particular mines the roof conditions are very favorable; in other sections of the field where they are not so good and where less attention is paid to recovery, it is thought that a fair average extraction is about 90 per cent.‡

The Pocahontas district, in the southern part of West Virginia, is one of the most important coal producing regions in the country, largely because of the high quality of the coal. Pocahontas coal is low in volatile matter and therefore is nearly smokeless; it contains little ash and little sulphur, and it makes an excellent coke. Because of these characteristics there is large demand for it. It is extensively used in coke production, in power plants, in the navy, and in domestic heaters. For coking purposes, however, Pocahontas coal is not used so extensively at present as it was a few years ago. Several beds are being operated, but the principal mines are in the Pocahontas No. 3 bed. The seam varies in thickness from about 4 feet on the west to about 10 feet on the east, but the change is gradual and the thickness is quite uniform within the area of a single mine. This seam has a fire-clay or slate bottom, and a draw-slate roof.¶ It always has one streak of bone about 2 inches thick to which the coal adheres on both sides; consequently when a piece of bone is thrown out, about twice as much coal is lost.

The No. 4 bed, which has two streaks of similar bone, is found 75 to 80 feet above the No. 3. Above this bed occurs a seam of interstratified coal and slate locally termed a "black rash." This rash contains on the average about 25 per cent of ash, and it is considered

* Keely, Josiah, Personal Communication.
† Personal Communication.
‡ Cunningham, J. S., Personal Communication.
¶ Eavenson, H. N., Personal Communication.
worthless, but sometimes over rather large areas there occurs in it a streak of clean coal from 6 to 8 inches in thickness. Miners are supposed to leave all this rash in their working places, and most of it is left, but sometimes some of this clean coal is loaded out. This fact will explain the higher yield from the No. 4 bed. In other words, the coal actually mined and loaded sometimes has a thickness greater than that considered in calculating the contents of the bed. The fact that a considerable amount of good coal is lost with the bone explains the smaller yield in mines in the No. 3 bed. It is believed that if it were not for this loss the extraction would average about 95 per cent.

As a rule, throughout southern West Virginia, the coal lands are held by land-holding companies, which lease to operating companies. The royalty is generally 10 cents per ton of coal and 15 cents per ton of coke, with a yearly minimum.

The beds are nearly flat and quite regular, of an almost ideal mining height, generally with good roof and bottom, and with little gas and water in the drift mines. It is possible, therefore, to lay out a definite plan of mining in advance, and to follow such a plan more closely than in sections where natural conditions are less favorable. In many cases the landholders specify that the coal shall be mined in accordance with certain plans, and prescribe a minimum of extraction. Certain departures from the standard methods, however, are permitted where it seems advisable.

Fig. 33 illustrates the plan of development formulated by the Pocahontas Coal and Coke Company,* which may be carried out by one of three possible procedures as follows:

**Panel No. 1.**—Drive rooms on 3rd cross entry as soon as come to, begin robbing as soon as second room is completed and rob advancing on 2nd and 3rd cross entries to within 100 feet of 2nd cross entry, on 1st cross entry drive last room first and rob retreating as shown, taking out the barrier pillar left on 2nd cross entry.

**Panel No. 2.**—Drive entries to the limit before turning rooms except as shown, turn last room on 3rd cross entry first, begin robbing at inside corner of panel, develop rooms only fast enough to keep in advance of robbing and bring robbing back with uniform breakline until completed to barrier pillars.

Panel No. 3.—Continuous panel, drive entries to the limit before turning rooms except as shown, turn last room on 1st cross entry first, begin robbing as soon as second room is completed, develop rooms only fast enough to keep in advance of robbing, and bring robbing back with uniform breakline until limit of mining is reached.

According to W. H. Grady, chief mine inspector of the Pocahontas Coal and Coke Company,* the essential advantages of this plan of mining include: provision for tonnage during the development period, provision for meeting the market demand, large barrier pillars insuring against squeezes and rendering impossible the de-

struction of coal over an extended area, 4-entry system for all extensive main entries with two as intakes and two as returns with break-throughs intervening only at the points where the cross entries turn off, rendering unnecessary the building of expensive masonry brattices every 80 feet, and insuring the maximum quantity of air for ventilation at a minimum cost for brattices and ventilating power, and cross entries with narrow chain pillars which permit the rapid advance of the entry.

The success of this method, with regard to high output, is shown by the values given in Table 7, taken from Grady's article. The percentage of recovery is based on the thickness of the total seam, including the portion rejected. The lower percentages of extraction shown in Table 7 were reached where pillars were being robbed after standing for many years. Operations had not proceeded far enough at the date of the paper quoted to permit a definite statement as to how great the final recovery would be. A later statement* has been received to the effect that the mines of the lessees of the Pocahontas Coal and Coke Company will probably show an average recovery of 90 per cent. Since some of these operations have extended over many years and since they were not so well managed formerly as at present, it is probable that the recovery now is more than 90 per cent.

In the Pocahontas district, much attention has been given to the subject of recovery, and the values which have been supplied by operating companies are as accurate as such values can be made. II.

### Table 7

**Recovery of Coal in Mines of Pocahontas Coal and Coke Company**

<table>
<thead>
<tr>
<th>Plant</th>
<th>Thickness of Seam in Feet</th>
<th>Acres of Entry Room</th>
<th>Acres of Pillar Room</th>
<th>Total Acres</th>
<th>Total Tonnage</th>
<th>Tons Mined per Acre</th>
<th>Theoretical Tons per Acre</th>
<th>Percentage of Recovery</th>
<th>Proportion of Seam Rejected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.15</td>
<td>3.06</td>
<td>4.57</td>
<td>11.03</td>
<td>18.66</td>
<td>165,254</td>
<td>8,856</td>
<td>9,922</td>
<td>89.3</td>
</tr>
<tr>
<td>2</td>
<td>5.65</td>
<td>4.40</td>
<td>4.80</td>
<td>14.80</td>
<td>24.00</td>
<td>188,391</td>
<td>8,185</td>
<td>9,115</td>
<td>89.79</td>
</tr>
<tr>
<td>3</td>
<td>5.16</td>
<td>2.68</td>
<td>5.82</td>
<td>13.80</td>
<td>25.00</td>
<td>180,326</td>
<td>7,218</td>
<td>5,325</td>
<td>89.6</td>
</tr>
<tr>
<td>4</td>
<td>4.42</td>
<td>5.88</td>
<td>6.65</td>
<td>15.09</td>
<td>27.62</td>
<td>162,457</td>
<td>6,960</td>
<td>7,131</td>
<td>97.6</td>
</tr>
<tr>
<td>5</td>
<td>5.94</td>
<td>2.00</td>
<td>10.09</td>
<td>19.20</td>
<td>30.29</td>
<td>334,005</td>
<td>9,203</td>
<td>9,582</td>
<td>96.0</td>
</tr>
<tr>
<td>6</td>
<td>4.32</td>
<td>2.11</td>
<td>3.64</td>
<td>5.20</td>
<td>15.04</td>
<td>94,427</td>
<td>6,278</td>
<td>6,569</td>
<td>90.0</td>
</tr>
<tr>
<td>7</td>
<td>5.34</td>
<td>5.31</td>
<td>6.34</td>
<td>0.00</td>
<td>9.65</td>
<td>83,000</td>
<td>8,601</td>
<td>8,141</td>
<td>99.8</td>
</tr>
<tr>
<td>8</td>
<td>5.42</td>
<td>3.72</td>
<td>6.06</td>
<td>0.72</td>
<td>10.50</td>
<td>144,769</td>
<td>8,181</td>
<td>8,777</td>
<td>93.2</td>
</tr>
<tr>
<td>9</td>
<td>4.65</td>
<td>8.10</td>
<td>16.80</td>
<td>2.34</td>
<td>27.24</td>
<td>201,044</td>
<td>7,380</td>
<td>7,534</td>
<td>98.0</td>
</tr>
<tr>
<td>10</td>
<td>8.03</td>
<td>5.20</td>
<td>8.47</td>
<td>10.09</td>
<td>23.76</td>
<td>262,975</td>
<td>11,088</td>
<td>12,923</td>
<td>85.6</td>
</tr>
</tbody>
</table>

* Eavenson, Howard N., Personal Communication.
N. Eavenson, whose communication has already been referred to with regard to the character of the beds mined, says that the measurements of areas worked out are as close as it is possible to get them on a large scale. The thicknesses given are those of the clean coal, and do not include any bone or black rash. In many instances a record has been kept of coal left in small areas, and the values shown by these tests agree very closely with those given in Table 8. It will be seen from the table that the amount of extraction for mines 9, 10, and 11 is given as more than 100 per cent. This record is explained by the statement previously made concerning the loading out of coal supposed to be left in the mines. At No. 9, the rash is much cleaner than at the other mines of the company, and while the seam is thicker, it carries only a very small amount of dirt; thus a higher percentage of clean coal is given.

TABLE 8
STATEMENT OF THICKNESSES AND RECOVERIES, ALL MINES, UNITED STATES COAL AND COKE COMPANY 1902 TO 1916, INCLUSIVE

<table>
<thead>
<tr>
<th>Mine No.</th>
<th>Area Worked Out per Cent</th>
<th>Average Thickness Clean Coal</th>
<th>Net Tons Recovered Per Acre</th>
<th>Percentage of Recovery</th>
<th>No. of Seam Worked</th>
<th>Date of First Shipments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rooms and Entries Pillars</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>45.5</td>
<td>54.5</td>
<td>5.52</td>
<td>1746</td>
<td>97.0</td>
<td>3 &amp; 4 1903</td>
</tr>
<tr>
<td>2</td>
<td>39.7</td>
<td>40.3</td>
<td>5.67</td>
<td>1790</td>
<td>99.4</td>
<td>4 1902</td>
</tr>
<tr>
<td>3</td>
<td>61.2</td>
<td>38.8</td>
<td>4.56</td>
<td>1429</td>
<td>79.4</td>
<td>4 1903</td>
</tr>
<tr>
<td>4</td>
<td>57.3</td>
<td>42.6</td>
<td>6.19</td>
<td>1381</td>
<td>87.8</td>
<td>4 &amp; 4 1903</td>
</tr>
<tr>
<td>5</td>
<td>63.5</td>
<td>36.5</td>
<td>6.88</td>
<td>1606</td>
<td>88.2</td>
<td>3 1904</td>
</tr>
<tr>
<td>6</td>
<td>63.6</td>
<td>36.4</td>
<td>6.09</td>
<td>1769</td>
<td>98.3</td>
<td>3 1903</td>
</tr>
<tr>
<td>7</td>
<td>66.9</td>
<td>33.1</td>
<td>6.27</td>
<td>1770</td>
<td>98.3</td>
<td>4 1905</td>
</tr>
<tr>
<td>8</td>
<td>70.8</td>
<td>29.2</td>
<td>5.98</td>
<td>1728</td>
<td>90.0</td>
<td>4 1904</td>
</tr>
<tr>
<td>9</td>
<td>74.2</td>
<td>25.8</td>
<td>7.24</td>
<td>1908</td>
<td>100.0</td>
<td>4 1905</td>
</tr>
<tr>
<td>10</td>
<td>85.1</td>
<td>14.9</td>
<td>5.31</td>
<td>1806</td>
<td>100.3</td>
<td>3 &amp; 4 1907</td>
</tr>
<tr>
<td>11</td>
<td>73.3</td>
<td>26.7</td>
<td>5.26</td>
<td>1807</td>
<td>100.4</td>
<td>3 &amp; 4 1907</td>
</tr>
<tr>
<td>12</td>
<td>69.8</td>
<td>30.2</td>
<td>8.22</td>
<td>1622</td>
<td>90.0</td>
<td>3 1908</td>
</tr>
<tr>
<td></td>
<td>65.9</td>
<td>34.1</td>
<td>5.95</td>
<td>1738</td>
<td>98.5</td>
<td></td>
</tr>
</tbody>
</table>

At the No. 3 mine, which shows the lowest percentage of extraction, the roof is exceedingly bad. Above the coal there occurs a layer of shale and slate, from 5 to 10 feet thick, which it is impossible to support even by close timbering. The mining practice is fully as good at this mine as at the others, but the yield is much less because of the more difficult conditions. The table shows the areas worked out at different mines and the percentages recovered. It is Eavenson's opinion that the average recovery in the larger mines through-
out the Pocahontas field is fully 90 per cent, and that in many mines even a higher figure is reached.

One of the landholding associations of the Pocahontas district furnishes information* concerning some of the operations of its lessees, and submits a table (Table 9) showing the percentage of recovery. It takes account of operations up to January 1, 1917.

### Table 9

**Percentage of Recovery on Live Work and Robbing**

Pocahontas District

January 1, 1917

<table>
<thead>
<tr>
<th>No. of Mine</th>
<th>Area Mined</th>
<th>Percentage of Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Live Work, Per cent</td>
<td>Robbing, Per cent</td>
</tr>
<tr>
<td>1</td>
<td>10.1</td>
<td>83.9</td>
</tr>
<tr>
<td>2</td>
<td>9.3</td>
<td>99.7</td>
</tr>
<tr>
<td>3</td>
<td>9.4</td>
<td>90.6</td>
</tr>
<tr>
<td>4</td>
<td>24.2</td>
<td>75.8</td>
</tr>
<tr>
<td>5</td>
<td>38.3</td>
<td>61.7</td>
</tr>
<tr>
<td>6</td>
<td>12.1</td>
<td>87.0</td>
</tr>
<tr>
<td>7</td>
<td>15.9</td>
<td>84.5</td>
</tr>
<tr>
<td>8</td>
<td>15.4</td>
<td>84.6</td>
</tr>
<tr>
<td>9</td>
<td>51.8</td>
<td>48.2</td>
</tr>
<tr>
<td>10</td>
<td>63.7</td>
<td>46.3</td>
</tr>
<tr>
<td>11</td>
<td>63.5</td>
<td>36.5</td>
</tr>
<tr>
<td>12</td>
<td>61.7</td>
<td>48.3</td>
</tr>
</tbody>
</table>

†Values obtained by assuming that 37.5 per cent of the pillar work is done under the same conditions as live work, i.e., with recovery of 97 per cent; thus 0.625X + 0.375 × 97 = 84.6, X = 77.2.

It will be noted that the extraction at mine No. 2, the first of the leases to exhaust the No. 3 Pocahontas seam, is not more than 73 or 74 per cent. In addition to the losses which will be mentioned, there was a considerable loss here of top coal. A thickness of 18 to 24 inches was left up in the first mining with the expectation that it would be recovered on the retreat, but most of this coal was ultimately lost on account of the bad roof. It is also possible that the loss in the coke yard at this plant, where the maximum number of ovens was run in proportion to the output, amounted to almost double the average tabulated amount.

An inspection of the table shows that, in most cases, the highest percentage of recovery has been reached at those mines where the

pillar work has been least in proportion to the live work, that is, at those still in the earlier stages of working. Future operations in these mines may be expected to lower these values, but it would seem that 80 per cent would be a very conservative estimate of the average amount of coal that should be won in the various mines of the property up to the exhaustion of all properties under lease.

J. J. Lincoln has discussed losses in the Pocahontas field, and the facts brought out are of general interest in connection with the subject of coal recovery. It is said that losses may be considered under three headings; (a) mixing of coal with refuse, (b) loss in drawing pillars, and (c) loss in coke making.

There is loss in removing the bone and pyrite from the coal, as some coal adheres to the refuse. Under the present mining methods, this loss is from 2 to 4 per cent, and occurs in both new work and robbing.

The following losses are to be expected in pillar drawing in addition to loss of coal attached to refuse: (1) In drawing each stumps are occasionally crushed by the pressure of the top before broken rock from the adjacent gob from covering the coal. This loss will run from 3 to 10 per cent, according to conditions. (2) When the pillars are drawn by splitting, a similar loss, frequently greater, occurs. (3) As the drawing progresses small sections of stumps are occasionally crushed by the pressure of the top before they can be removed. (4) Stumps, sections of pillars, or entire pillars may be crushed by the weight before they can be removed, or may be surrounded and cut off by the broken top. In the mines where actual losses from this source are closely recorded they do not reach 1 per cent, and there is no mine in which they will reach 2 per cent. The third loss is not directly chargeable to mining, but occurs in the making of coke. Where the tonnage of coke produced is used as a measure of the amount of coal taken out, this loss becomes significant in calculating the percentage of coal won. The ratio used by the company in all calculations of tonnage has always been 1.6 tons of coal to one ton of coke. This ratio assumes an actual average yield of 62\(\frac{1}{2}\) per cent of coke, but in practice this yield is not obtained, the average yield under existing conditions being nearer 55 per cent. This loss has always been charged, with the other losses, directly against the mining. This ratio cannot be used directly in determining the actual amount of coal mined, because only a part
of the coal is coked. The loss varies in amount from 1 to 5 per cent, according to the conditions in the different operations, and the actual percentage of extraction is slightly higher than that given in the table because of this error.

Losses in mining and coke making may then be tabulated as follows:

"(a) Removing Refuse—Coal thrown into gob with bone and sulphur bands . . 2 per cent to 4 per cent
(b) Robbing:—
   1. Stumping, or
      Splitting pillars . . 2 per cent to 10 per cent
   2. Sections or Stumps . . 0 per cent to 2 per cent
   3. Pillars lost . . . . 0 per cent to 2 per cent
(c) Additional coal consumed in coke making over and above the amount covered by the constant of calculation,
   1.6 tons equals 1 ton coke . . 1 per cent to 5 per cent
   Total . . 5 per cent to 23 per cent"

A peculiar system followed by the Gay Coal and Coke Company of Logan, West Virginia, and called a single-room system* has resulted from an attempt to apply the long-wall method to a seam the average thickness of which is 5 feet, 7 inches. This seam dips to the southwest about 1\(\frac{1}{2}\) per cent, is practically free from partings, and is of the nature of splint coal, the bottom bench being rather strong, and the top bench somewhat friable. The average thickness of cover does not exceed 500 feet while the maximum is less than 1,000.

A block of coal was cut by two entries 600 feet long, Nos. 4 and 5 (Fig. 34). These were connected at their extremities, which were 300 feet apart. The purpose was to take out the block of coal thus formed in a retreating direction by commencing at the inner end and by working outward with a face about 300 feet long. One hundred beech or hickory posts were used to support the roof near the face. The top of each was covered with 1-inch poplar, and the

bottom with 1/16-inch sheet steel. Each post was mounted on a hydraulic head weighing about 700 pounds and tested to a pressure of 3,000 pounds per square inch. These were set along the face 6 feet apart in parallel rows 3 feet apart. The cost of the equipment was approximately $5,000.

When the walls became more than 30 feet apart, rows of props on 15-foot centers were set 8 to 10 feet apart. When the distance between the walls had reached 60 feet, the portable posts were put into use, a row of 50 posts on 6-foot centers being set 10 feet from the face. The heads were covered with wooden cap pieces, and the plungers were raised by a pressure of 50 pounds per square inch. When the face had advanced 6 feet farther, the other 50 posts were put in; as the work progressed, the first row was moved 6 feet ahead of the second, the posts being moved one at a time. An occasional row of posts similar to the first was also set as a precautionary measure.

When the walls were 100 feet apart, it was thought advisable to blast down the roof. The portable posts were set in a single row 6 feet from the face. Examination after the rock had fallen showed that the immediate roof consisted of a seam of strong sand slate at least 30 feet thick without any sign of a parting and that difficulty
would be encountered in attempting to apply the long-wall method in this mine.

The advantages to be derived by working on a long face were so great that the company devised another plan which involved working out the remainder of the block by a system of rooms 80 feet wide, parallel with the long-wall face and separated by 30-foot pillars. Each room was to be opened by driving a sub-entry across from entry No. 4 to entry No. 5 (Fig. 34), and thereafter the manner of working was to be identical in every respect with that of the long-wall system.

From the experience gained it was thought that, with the roof in normal condition, rooms could be worked 90 feet wide with 30-foot pillars. Entries Nos. 4 and 5 were therefore continued eastward, and sub-entries were spaced for the rooms as shown on the map (Fig. 35). The last of the sub-entries was widened to 40 feet, and a single row of ordinary props, 8 to 10 inches in diameter, was set close to the face on 15-foot centers. When the face had moved 10 feet farther, a second row was set. When the room had reached a width of sixty feet, a row of portable posts was set on 10-foot centers, and at 70 feet another row was set. The ordinary props were used for detecting the action of the roof.
One of the advantages of this system of mining is that a large amount of coal per employee may be obtained. In fact the production per man is considerably greater than with the room-and-pillar method, and greater even than would be possible with the long-wall method. The highest rating in this seam for car distribution, exclusive of this mine, is 13 tons per loader; this mine is rated at 20 tons per loader. It is the opinion of Mr. Gay that it would be possible to produce about 11 tons per inside employee per 9-hour day for five days a week. The method also results in the recovery of a very high percentage of coal. A calculation based upon the number of tons shipped and the area excavated, according to planimeter measurement, indicates that the extraction was 85.9 per cent.

Since this description was published, the system has been modified to reduce the narrow work, but the general plan has been followed. Instead of driving a single room to form the working face, parallel rooms separated by an 18-foot pillar are driven; thus the use of brattices is unnecessary, and ventilation is improved. The hydraulic posts were soon abandoned, as posts without the hydraulic heads are cheaper, and they are easily recovered. One of the most important facts concerning the operation is that there has not been a single fatal accident in the mine since work was begun.

Another system in which an effort was made to obtain the advantages of long-wall working was tried a few years ago in West Virginia.* In developing this system (Fig. 36) triple entries are driven from the outcrop, near which double entries are turned off at right angles. From these, entries are driven parallel with the main entry; thus blocks of coal about 900 feet wide are cut off. Block entries are turned from the main entry and from these side entries, parallel with the cross entry, spaced about 500 feet apart, and driven for about 800 feet; thus the coal is blocked into areas approximately 500 by 800 feet. In working these blocks, a room is turned first at the end of the block entries to form a working face for the long-wall machine. The blocks are then worked back toward the main entry for 500 feet; thus a barrier of 300 feet protects each main entry. Track is laid along the face as near the coal as possible, and is moved as the face progresses. The roof is allowed to fall, but the line of break is kept at the correct distance from the face by three or more rows.

of props, the last row being moved forward after a cut is made. The trolley wires are hung on hangers as usual, but to keep them tight they are carried on portable drums. Current for the motor and machines along the face is taken from the trolley wire on the entry by means of a cable which is also coiled on a portable drum. Ventilation is controlled by placing a regulator in the return air course of each block. Each block or face is provided with a separate supply of fresh air by having overcasts placed at the air courses to admit the return air into the main air course entry. No doors are required at any points in the mine.
It was claimed for this method that a block will produce 440 tons per day with the use of only 500 feet of track in addition to that on the entries, that practically all the coal is obtained, and that the work of the rolling stock and cutting machines is concentrated. The trial of this method was temporarily abandoned because of an inadequate car supply, but the work was considered successful. It was not carried far enough to provide reliable data for an estimation of total extraction.

26. Ohio.—The literature of coal mining contains little information regarding conditions in Ohio. Some of the operations in the Hocking Valley district have been described in articles which state that large quantities of coal are left in the roof because of the poor quality of the product. An article on Hisylvania Mine No. 23 states* that the bed mined in the Hocking Valley district is the Middle Kittanning, Hocking Valley, or No. 6. The bottom consists of a few inches of fire clay overlying hard rock. The roof is of shale, 6 to 8 feet thick. The coal bed consists of three benches. The thickness of good coal is about 6 feet, and above this is about 5½ feet of a poorer coal separated from the lower portion of the bed by a distinct parting. This upper bed, with the upper bench of the lower bed, is known as top coal. In this district all coal in excess of 6 feet, and in many places in excess of 4½ feet, is to be credited to this upper bench which has a maximum thickness of 10 feet.

James Pritchard† estimates the percentages of extraction in the districts as follows:

In the Pittsburgh vein district, the Cambridge field, and the Hocking field, districts which produce approximately three-fourths of the coal of the state, the rate of extraction will range from 60 to 70 per cent. In the Massillon and Jackson fields, the rate of extraction may reach 85 per cent. In the Deerfield and Mahoning districts, the rate of extraction may reach 85 per cent. Throughout the remainder of the state, the maximum percentage of extraction will run from 60 to 70 per cent. The average rate of recovery is approximately 60 per cent, with a minimum of 55 per cent and a maximum of 75 per cent.

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† Pritchard, James, Chief Deputy and Safety Commissioner of Mines, Personal Communication.
The average value represents the most common percentage of extraction. The conditions in the Pittsburgh vein district of eastern Ohio are described by Roby* as follows:

The extraction is limited by various physical and commercial conditions. The roof consists of a bed of weak coal of poor quality, variable in thickness, and separated from the main bed by a layer of drawslate which disintegrates on exposure. Overlying the roof coal is an unstratified "soapstone" 4 to 8 feet thick, and above this is a thick layer of hard limestone. The country is hilly, and the total cover varies from 30 to 600 feet in thickness. The character of the roof makes it necessary to leave larger pillars than would be required under a good roof. The roof coal is left up, and as it is poor in quality and not marketable, it is not considered in making estimates of extraction. The room-and-pillar method is used. There has been much discussion concerning the possibility of applying the long-wall method, but the fragility of the roof and the tendency of all rock below the limestone to shear off at the solid face have seemed to make the method impracticable.

It is desirable that rooms be worked out as quickly as possible because of the tendency of the roof and pillars to fail. Because of these conditions, the numerous interruptions which have been caused by strikes and business depressions have tended to make the rate of recovery lower than would have been the case with uninterrupted operation.†

J. C. Haring states that the recovery in the Massillon district has not exceeded 75 per cent. The highest recovery in the district is probably at the Pocock No. 4 mine where it is estimated that fully 90 per cent of the coal has been obtained.

At Steubenville, the mine of the LaBelle Iron Works has been operated on the long-wall system since 1913; prior to that time the room-and-pillar method was employed.‡ The bed is the Lower Freeport which is a little over 3 feet in thickness and has a good shale roof.

At present a considerable amount of stripping is being done in the No. 8 coal in the vicinity of Steubenville. The coal outcrops on

† Haring, J. C., Personal Communication.
the slopes of hills, and the rapid increase in the thickness of the overburden restricts the operations to a narrow belt, although they may extend for a considerable distance along the outcrop.

27. Kentucky.—The development of coal mining in Kentucky has been comparatively recent, and some of the Kentucky fields are still so young that it is impossible to obtain estimates of recovery. The state may be divided broadly into two districts, the western district being closely allied with the fields of Indiana and Illinois, and the eastern district with those of West Virginia and Virginia.

The statements presented in the following paragraphs concerning the western district are made on the authority of N. G. Alford,* who says that the fields contain about 38.3 per cent of the coal-bearing areas of this state and that in 1912 47.7 per cent of the total production came from this district. The smallness of many operations is shown by the statement that 21 per cent of the mines produced less than 10,000 tons per annum each; 51 per cent produced less than 60,000 tons each; 23 per cent produced more than 100,000 tons each; and two companies, operating 18 mines, produced 2,750,000 tons each.

Generally, the rate of recovery in the mines of western Kentucky is about 66 2/3 per cent, although in some instances it is as low as 44 per cent. Without an exception the mines of this district are developed on the room-and-pillar system with double or triple entries. With the exception of two or three isolated operations, all the coal is produced from three seams.

Most of the coal comes from the No. 9 and No. 11 beds, the former producing about three-fourths of the total output of the field. This bed is present in eight counties and approaches 5 feet in thickness. In most places it is reached by shafts of 300 feet or less in depth, although there are some local surface depressions which permit access by slopes or drifts. It has a black shale roof and a soft fire-clay bottom.

The No. 11 seam lies from 40 to 100 feet above the No. 9, and follows the latter in commercial importance. Its average thickness is 6 feet. Above the coal is a stratum of limestone of thickness varying from a few inches to 40 feet. This limestone is usually separated

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from the coal by a thin stratum of heavy laminated clay 6 to 24 inches thick. This top adheres uncertainly to the limestone above it, and presents a constant danger. Near the outcrop the top becomes very treacherous. The bottom of this seam consists of soft fire clay which frequently heaves in haulage entries that have been opened for some time. About half the mines in this seam are shaft mines, and the remainder are drift mines.

The third seam in commercial importance is No. 12, which is found best developed in Clay and Webster Counties. Its approximate depth below the surface is 225 feet. Its average thickness is 7 feet. The bottom is of fire clay which is high in calcium and which disintegrates rapidly when drainage water is directed through it in ditches. The roof consists of light gray disintegrated shale 10 to 15 feet thick. If all the coal is removed, this top will fall to a height of 6 or 8 feet, and heavy timber sets, thoroughly and solidly lagged, are required to support it. Because of this condition it has been found necessary to leave 16 inches of top coal as a roof. Sixty per cent of this top coal is recovered from rooms, but no attempt is made to recover it from entries. When the development of the No. 12 seam was begun, rooms were driven 21 feet wide on 33-foot centers; but this width of pillar was found to be too narrow, and it has been increased to 20 feet, with rooms 21 feet wide. Under these conditions a recovery of 44 per cent is the best which has been reached up to this time. This low percentage of recovery is in part due to physical conditions, and in part to over-development and keen competition.

Several factors contribute to limiting the recovery in the No. 9 and No. 11 beds. The most important of these is probably inadequate planning of future workings. Frequently pillars are left too small; consequently the bottom heaves, and the pillars are crushed. Partial recovery of pillar coal by taking slabs off the ribs is not general, and the total recovery of pillars has not been attempted. The operators in this district hold the opinion that pillar robbing in the No. 11 seam is particularly hazardous and impractical, because heavy limestone overlies the seam; in the Connellsville district of Pennsylvania, however, pillars are successfully drawn under a heavy limestone. Alford expresses the opinion that if the workings in the No. 11 seam were properly laid out and started, little difficulty would be found in increasing the percentage of recovery.
In this district there is an over-production with a limited market; consequently competition is keen. When business conditions are normal, the margin of profit is so small as to preclude any costly improvements, and little money has been expended in experiments. Another source of loss lies in the waste at the tipples in the summer, because the demands of consumers are more exacting in times of dull markets. Good coal attached to lumps of pyrite is often discarded in large quantities, and so far this waste has been accepted as unavoidable. This district furnishes one of the best illustrations of the effects of over-development and lack of harmony of interests. There are, however, some operations which are carried out on a considerable scale and with careful attention to the proper planning of the work.

The estimates covering production mentioned previously are confirmed by a personal communication from another operator, S. S. Lanier, who has been a close observer in the district for thirty years and who estimates that the extraction is about 65 per cent.

The eastern Kentucky district is of such recent development that estimates of production are not very reliable. H. D. Easton, operating in the southeastern part of the state, thinks it safe to say that a recovery of 90 per cent is being reached in the Straight Creek seam in Bell County, but much trouble has been experienced from squeezes due to lack of systematic working.

Mines are operated on the room-and-pillar system with rooms turned from both sides of the room entries. Rooms are generally 40 feet wide with 20-foot pillars. Cross entries are driven about 1,200 feet apart, and these usually extend to the property line or to the outcrop. It has been the practice to extract the pillar coal on the retreat, and so far as possible to keep the face lined up over a sufficient distance to get a fall of roof. Room tracks are swung across the face of the pillar and are moved as the pillar is drawn back. If the pillars are narrow, the room tracks are not moved even though the coal has to be shoveled 15 or 20 feet.

There has been no very systematic work in pillar recovery in the southeastern part of the state, and pillars or stumps have been left scattered promiscuously, with the result that many costly squeezes have occurred. One company has lost an entire mine as a result of this practice. It has been the general opinion that it would be impossible to get a clean break in the overlying strata because
of the solid sandstone above the coal, but such breaks have been obtained very successfully, even in rather limited areas.

The Harland district, the Hazard district, and the Elkhorn district are all too newly developed to provide a reliable basis for estimating recovery, but it is possible that the percentage of recovery will be very high.

In eastern Kentucky the surface is of no great value, and it is almost invariably owned by the coal companies so that the necessity for sustaining it is not a factor affecting the percentage of extraction.

There are some operations in the central southern part of the state, but the mines are not yet sufficiently developed to yield adequate data for reliable estimates of extraction.* The mines are opened by drifts, and as the coal is irregular, the hills have been entered at many points. A heavy sandstone occurs between the two seams worked, and pillars have not been drawn in the lower seam, because it has been feared that the upper seam would be damaged. In the upper seam, pillar drawing has not been practiced to any great extent, because when tried, it has resulted in breaks extending to the surface through which considerable water has entered. It is the intention of the operators to extract the pillars when the mines have been worked out, and the final percentage of extraction will probably be high.

28. Tennessee.—Little information is available on the percentage of recovery in Tennessee, and the statements obtained are not altogether in agreement. One operator,† formerly connected with the industry in Tennessee, states that a few years ago the mining practices were not good. On the first mining, about 50 per cent of the coal was taken, and the ultimate recovery was probably about 80 per cent. Because of the low value of coal lands, less effort is made to get a maximum recovery than in some other districts where coal lands are more valuable.

R. A. Shiflett,‡ Chief Mine Inspector, says that it would be difficult to give any general percentage for extraction since the coal measures vary in dip from horizontal to 40 degrees, and in some

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* Butler, J. E., Personal Communication.
† Coxe, E. H., Personal Communication.
‡ Personal Communication.
cases from horizontal to vertical. In a large number of mines it is impossible to map out any definite method of mining, and conditions have to be met as they are encountered.

Nearly all the drift mines are developed on the double-entry room-and-pillar system. Rooms are driven from 250 to 300 feet, and room pillars are drawn as soon as the rooms are finished. If conditions are favorable, the entry pillars and room stumps are recovered on the retreat; and where the coal is practically level, 40 to 50 inches thick and with good roof and bottom, about 90 per cent is extracted under careful management. This percentage is not reached in many mines because of lack of attention to high extraction. It is thought that the extraction in general does not exceed 65 per cent, but that this percentage could be greatly increased by proper methods and careful management.

One company,* whose method was to turn rooms on the advance and immediately to draw room pillars back to within 65 or 70 feet of the entry on completion of the room, obtained a recovery of nearly 90 per cent up to about the beginning of 1916. At that time four cross entries were lost from heaving of the soft bottom. The cover is 500 to 800 feet in thickness, the coal is 56 inches in thickness, and the bottom is of soft fire clay from 4 to 7 feet in thickness. This company is planning the introduction of the long-wall method. A face of about 300 feet will be formed by connecting the ends of two entries. It is thought that the single stick timbering, with perhaps an occasional crib, will be sufficient. It is expected that the bottom will heave and reach the roof as the latter bends down. The scarcity of labor and the irregularity of the ear supply make the success of long-wall operations somewhat doubtful; and if it is necessary temporarily to abandon this method, another which is illustrated in Fig. 37 will be adopted. In this method apparently a little more than 50 per cent of the coal would be taken out from rooms, and the ultimate percentage of extraction should be almost complete. The method will permit concentrated working, and much of the trouble due to the conditions of the floor and roof will probably be avoided.

29. Alabama.—Although Alabama† is an important producer

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* Hutcheson, W. C., Personal Communication.
of coal, the working conditions are not so good as those of Pennsylvania, Kentucky, and some other states. One of the distinctive features of the Alabama coal field is that although there are five seams of coal, rarely more than one of them is workable at any one place; in one portion of Jefferson County, for instance, the Pratt seam, which is considered the topmost workable seam of the Alabama coal measures, may have a working thickness of 4 feet, while at a distance of two or three miles the same seam may not be more than 2 feet thick. The coal beds, including the Pratt bed, vary rather abruptly within a few miles with regard to thickness, impurities, and character of roof.

The Pratt seam has been worked longer and more extensively than any other seam in this district. It is probable that the recovery from this seam, under the best methods of working with the room-and-pillar system, is about 87 per cent. This percentage applies only where the thickness is three feet or more; coal thinner than this cannot profitably be removed.

The Mary Lee seam, which is supposed to contain the thickest workable coal, lies about 300 feet below the Pratt seam, and is the one that the operators of the Birmingham district expect to work during the next twenty years. So far as it is known, the thickness of the bed ranges from 6 to 10 feet. It is difficult to get reliable estimates of the recovery of coal in this seam, but one operator reports,
on the basis of an experience of twenty years, that the recovery has been about 90 per cent.

There are mines on lower seams in other localities, but little attention has been paid to the extraction of a high percentage of the coal. The operation of these mines depends largely upon market conditions, and they are probably not operated, on the average, more than half the time. Under these conditions the loss of pillar coal caused by falls of roof is necessarily large.

The Alabama mines, with the single exception of the Montavallo mine, where a change is being made to the long-wall system, are worked on the room-and-pillar system. The larger operations are in the neighborhood of Birmingham, and in this district the carboniferous measures are tilted and broken to a great extent. This condition affects the roof of the coal under cover for a considerable distance. Both top and bottom are of variable character.

In the larger operations at least, the triple entry system is used. Commencing at a distance of 800 feet from the surface, cross entries are usually driven about 350 feet apart. Until the entries have been driven a few hundred feet, it is not possible to determine whether they should be narrow or wide enough to provide storage for the impurities of the bed and the brushing of the roof. Rooms are generally opened narrow also, (30 feet wide) with 25-foot room pillars, until it is determined whether the character of the overlying strata and of the floor will permit the working of wider rooms.

Probably 75 per cent of the large operators in the district have adopted the plan of immediate pillar drawing in preference to that of driving the narrow work to the limit and pulling the pillars upon the retreat. In a number of instances, rooms are driven 40 feet wide with 30-foot pillars and are worked for a distance of 300 feet, or to the entry above; then a cut is taken across the end of the pillar, and the pillar is drawn back to the entry stump. When the room pillars are drawn on the advance, there is no difficulty in getting room stumps and air-course pillars after the entry work is complete.

Strong estimates the recovery in mines operated by the larger corporations to be from 87 to 90 per cent. Priestly Toulmin, another operator, * confirms these values by stating that the average extraction in Alabama is not less than 75 per cent and not more than 80 per cent, so that possibly 77\(\frac{1}{2}\) per cent would be a fair value. In

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* Personal Communication.
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some mines the extraction is less than 60 per cent, and in others it is more than 95 per cent.

C. F. DeBardeleben* furnishes the following estimates:

At one operation where 768.6 acres had been worked over, assuming the average thickness of coal to be 4 feet and that 25 cubic feet of coal in place make a ton, the coal available was 5,356,834 tons

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\begin{align*}
\text{Tons mined} & : 3,028,960 \\
\text{Extraction} & : 56.5 \text{ per cent}
\end{align*}
\]

Assuming that 12.5 per cent more will be obtained from pillars, the extraction will amount to about 63 per cent. At another operation where the average thickness is 5 feet and 316.6 acres have been worked over, the coal available was \(2,758,219\) tons

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\begin{align*}
\text{Tons produced} & : 1,847,582 \\
\text{Extraction} & : 67 \text{ per cent}
\end{align*}
\]

Assuming a probable extraction of pillars, the final recovery will amount to about 70 per cent. At a third mine, where conditions were favorable because of level coal and the absence of gas, 25-foot rooms were driven on 75-foot centers; the pillar was drawn back halfway to the entry as soon as a room was finished, the entry pillars and room stumps being extracted when the entry was abandoned. Under these conditions the recovery was about 85 per cent.

C. H. Nesbitt, Chief Mine Inspector of Alabama, estimates the average recovery to be 80 per cent, the highest percentages being reached in the Pratt and Montavallo beds.† There has been great improvement in the percentage of extraction in the past twenty years, and even in the past ten years. This improvement has been due largely to more nearly complete and accurate mapping, and to more improved and effective methods of controlling the water in slope and shaft mines.

30. Indiana.—Almost no information has been available concerning the percentage of coal extracted in Indiana mines. W. M. Zeller † reports that the extraction in the Brazil district is probably about 60 per cent. This estimate agrees fairly well with the estimates of operators in southern Illinois, and since such estimates have been found to be too high in almost all instances, it is probable that the

* Personal Communication.
† Personal Communication.
average extraction in Indiana, as in southern Illinois, will not exceed 50 per cent.

31. Michigan.—The coal beds in Michigan are irregular in extent and decrease in thickness with depth. Sometimes they are entirely cut out by erosion or replaced by sandstone and other materials. Usually the beds above the coal consist of black shale, and they are often weak. Owing to erosion, coal is sometimes found directly below clay, sand, or gravel, or below other unconsolidated rocks, where it is practically unworkable. At several mines the roof is of black bituminous limestone. In most instances the floor is of fire clay or shale, although sandstone is sometimes found. The thickness of coal varies from 2 feet, 6 inches to 3 feet, 10 inches, a fair average at Saginaw being 3 feet. In the Saginaw Valley the surface is level.*

R. M. Randall states † that the first company in the district operated within the city limits of Saginaw, and that because of the necessity of leaving pillars to protect the surface the recovery was only about 68 to 70 per cent. At present this company is operating in farming districts where it is not necessary to maintain the surface; and the recovery, within the last five years, has been about 90 per cent. The room-and-pillar system is used with rooms projected 40-feet wide on 50-foot centers and driven 150 feet, but the actual dimensions vary according to the conditions of the roof. Short-wall machines are used for undercutting. It is estimated that 75 per cent of the room pillars and 95 per cent of the entry pillars are recovered, and that the extraction on the advance is 70 per cent. The conditions at the old and at the new mines have been so different that it is impossible to give an average value for the extraction, but it is believed that the extraction in the new mines in the area actually worked will be from 85 to 90 per cent.

32. Iowa.—The physical conditions in the Iowa coal field are not uniform. The cover ranges in thickness from a few inches to 300 feet, and consists of the coal measure beds and glacial drift, the latter commonly constituting the larger part of the thickness. The workable coal beds generally have a top of draw shale varying

† Personal Communication.
from a few inches to two feet in thickness. Above this is a black shale, or sometimes a bituminous or argillaceous limestone. In the latter case this rock is often strong enough to permit a reduction in the amount of timber used and thereby to facilitate mining. This condition makes it possible in Appanoose County to work a bed in which the thickness of clean coal is only about 25 to 27 inches. The bottom everywhere consists of plastic fire clay, and in the Appanoose field the undercutting is done in this clay. Its occurrence is frequently the cause of creep in room-and-pillar mines. The most unfavorable conditions are found through the northern end of the Iowa coal fields.

Even in single districts the percentage of extraction varies between wide limits. The maximum extraction, estimated at 90 per cent or more, is reached in the Appanoose field, where the long-wall system is employed. An operator* familiar with conditions in these long-wall mines says that the extraction is complete, but that it is less than the previously calculated amount of coal in the ground because of the presence of faults.

In the room-and-pillar districts the extraction rarely if ever exceeds 75 per cent, and under especially bad conditions of bottom and top with an abundance of water, it may not exceed 50 per cent. Probably a fair average of recovery for the state is 70 per cent. The percentages given refer only to the bed mined and to the area of actual mining operations. When larger areas are considered, the percentage of recovery is less because of the loss of considerable quantities of coal through lack of cooperation between owners, a loss estimated to be at least 10 per cent.†

The engineer‡ of one of the operating companies says that in the room-and-pillar mines with which he is familiar the recovery will average about 75 per cent, and that a recovery of 80 per cent is expected in the newer mines.

33. Missouri.—The coal fields of Missouri may be roughly divided into three districts, the first district lying near the middle of the state in Macon and Randolph Counties where operations are conducted on the room-and-pillar method, the second district farther

* Taylor, H. N., Personal Communication.
† Beyer, Professor S. W., Personal Communication.
‡ Jorgensen, F. F., Personal Communication.
west along the Missouri River in the vicinity of Lexington where operations are conducted on the long-wall system, and the third district in the southwestern part of the state, where the conditions are similar to those of southeastern Kansas and northeastern Oklahoma and where the room-and-pillar system has generally been followed. Recently a considerable quantity of coal has been obtained in the southwest district by stripping.

In Randolph and Macon Counties, in the neighborhood of Bevier, the coal is considerably broken by faults and horsebacks, and recovery does not exceed 50 per cent.* In the long-wall district the extraction in the area worked out is practically complete, but most of the operations are conducted on a small scale and no estimates covering the probable extraction over the whole area are available.

In the southwestern part of the state the continuity of the coal is considerably broken by horsebacks, as in the neighboring parts of Kansas and Oklahoma. Mining methods have not been highly developed, and no great attention has been paid to completeness of extraction. It is not probable that the extraction in this district, within the areas worked, will be more than 50 per cent.

34. Arkansas.—Steel says† that the ordinary waste of coal in Arkansas is unusually great even for this country, a fact to be accounted for partly by unfavorable geological conditions. In addition to the wastes common to all coal producing states there are others due to local geological and physical conditions, which Steel considers unusually unfavorable in Arkansas.

There is considerable loss because of irregularities of entries, due to the varying dip of the bed. Entries which are turned from the slope at standard distances measured along the coal seam will have variable and perhaps severe grades if they are driven straight or will be very crooked if they are driven on grade. If the dip increases and the entries are driven on grade, the distance between entries decreases and sometimes the rooms between entries become so short that the entry from which they are turned is discontinued; then rooms from the entry below are driven long enough to take out all the coal, or part of it, which would have been taken out through the intermediate entry. Sometimes the length of rooms necessary to

* Taylor, H. N., Personal Communication.
extract all the coal would be so great that part of it is left. Sometimes this is won through the upper entry, and sometimes it is lost.

There are also losses due to irregularities in the coal, and entries are frequently not extended through areas of low coal to get the good coal lying beyond. Areas of thin coal are commonly abandoned. The losses due to thin or poor coal are greater perhaps in Arkansas than in other states, because the dip of the beds makes the driving of entries around these poor areas considerably more expensive, and it is not profitable to take out good coal lying beyond poor coal unless the area of the good coal is large. There is often considerable loss from the abandonment of parts of beds. In many places the different benches of thick beds are separated by thick partings; if a single bench is thick enough to mine, it is worked separately, and sometimes the bench above it or below it is lost. The loss of coal in this form, though not so great as formerly, is probably greater in Arkansas than in any other state, with the possible exception of Colorado. Loss due to the need of protecting the surface is not serious, because the value of the surface is low, and the rough topography insures good drainage.

H. Denman,* an operator familiar with the district, expresses the opinion that the recovery in both Arkansas and Oklahoma does not exceed 50 per cent. In certain portions of a mine the recovery may be as high as 70 per cent, but he believes if the whole area of the mine is considered, the percentage of extraction will not, in any case, exceed 55 per cent. These statements are applicable to both Arkansas and the neighboring Oklahoma district, as the same system of mining is used in both.

The system of mining in the Arkansas-Oklahoma field is practically the same that was used when the field was first opened about forty years ago. There is no systematic attempt at laying out mines with the view of drawing pillars, but the general plan is to get as much coal as possible in the first working and to abandon the remainder. There is one mine in which an attempt is being made to plan the work so as to obtain the pillar coal, but this attempt is so recent that it is impossible to foretell the degree of its success. The widths of rooms and pillars are influenced by the charges for narrow work and for yardage, which are so high that neither narrow rooms nor long break-throughs can be driven. At present the average room

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* Personal Communication.
neck is about 10 feet long, and if longer necks could be driven without increased cost, it might be possible to prevent squeezing of the entry and to obtain a considerable amount of coal from the entry pillars, but the yardage cost is so high that this procedure seems unprofitable.

35. Kansas.—The coal produced in Kansas comes from three districts, the one in the southeastern corner of the state being by far the most important. The others are the Leavenworth and the Osage districts. The Leavenworth district lies in the northeastern part of the state and may be considered as connected with the district of northwest Missouri, although the strata dip toward the west and the coal is found at greater depths in Kansas than in Missouri. All operations in the Leavenworth district are on the long-wall system, and the extraction, in the areas mined out, is practically complete. Coal in this district ranges from about 19 to about 24 inches in thickness. The depth is about 700 feet. A 3-foot bed lying at a depth of 1,000 feet was found at Atchison about ten years ago and was worked by the long-wall method, but the work was not commercially successful and was abandoned. The Osage district lies to the south of Topeka and is not important commercially. The coal is about 20 inches thick, and is mined entirely by the long-wall method. The extraction is practically complete within the area mined out. This is the thinnest bed of bituminous coal worked in the United States.

In the southeastern district of the state the coal beds lie on the west slope of the Ozark uplift and dip toward the west and northwest. The beds contain numerous horsebacks which interfere with systematic mining. The room-and-pillar method is followed, and little attempt is made to extract pillar coal. Practically all coal in Kansas, except that produced by the long-wall method and by stripping, is shot from the solid, a method which unquestionably leads to the production of small coal, especially where the holes are greatly overcharged as they usually are. The recovery is in the neighborhood of 50 per cent, although it may sometimes be greater in limited areas, because the horsebacks may be made to serve as pillars. H. N. Taylor, in a personal communication, confirms this estimate of extraction. He says that in places a considerable loss is experienced, because the rate for mining low coal is so high as to be considered prohibitive, and even if the rate is paid it is difficult to
get men to work the low coal. A. C. Terrill reports* that the closest estimates of those most familiar with conditions place the recovery at about 50 per cent.

The approaching exhaustion of the shallower mines has necessitated the working of the northern part of the district where the

cover is about 250 feet thick. At least one of the operators desired to work these deeper mines by the panel method, but it has not as yet been found possible to reach satisfactory arrangements with the mine workers. Since a makeshift adopted to prevent the spread of squeezes leaves two rooms out of seven unworked, the recovery has been reduced about 1,000 tons per acre. The operators still hope that they may be able to introduce the panel system and thus materially increase the recovery.†

In recent years a large amount of coal has been taken from this district and from the neighboring region in Missouri by extensive

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* Personal Communication.
† Taylor, H. N., Personal Communication.
stripping operations. In the area worked over, the extraction by this method is practically complete.

36. Oklahoma.—In Oklahoma the coal is produced largely by individual operators, the land being owned by the Indian nations and leased to operators in small tracts. * Elaborate plans for mining are not to be expected under these conditions. Elliot estimated that the recovery of the entire bed worked was not more than 55 per cent. He said that the low percentage of recovery was due to the extravagant system of room-and-pillar mining adopted, and that this system could not be changed because of unfavorable labor conditions.

The Rock Island Coal Mining Company obtains an extraction of 48.18 per cent in the McAlester district. In the Hartshorne district this company has five mines, their percentages of extraction being 56.6, 52.6, 55.0, 51.5, and 47.8, respectively. The average percentage of extraction at these five mines is 52.7 and the average of all the mines of the company in Oklahoma is 51.8. †

This company is now trying a panel long-wall plan (Fig. 38) with the hope of increasing the extraction from about 57 to about 70 per cent. The coal is about 3 feet, 4 inches thick, and dips from 5 to 8 degrees. The working face is parallel with the dip. The roof along the face was at first supported by cribs built of 8-inch by 8-inch timbers about 4 feet long and these cribs were withdrawn and moved forward as the face advanced, the roof being allowed to fall. A row of props was also used to support the top above a conveyor used for carrying the coal along the face. At present the use of cribs has been discontinued, except along the ribs of the entries, and 10-inch by 10-inch props are used to support the roof. These are drawn and reset as the face advances. The necessity of using props on both sides of the conveyor constitutes one of the difficulties of the operation. The roof breaks as the face advances. There seems to be no great difficulty in the use of undercutting machines, but sometimes the coal falls too soon for convenience in loading, and large lumps clog the conveyor. While this operation must still be considered in the experimental stage, the working face has been advanced about 130 feet without serious difficulty. It is planned that the pillars flank-

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† Schola, Carl, Personal Communication.
PERCENTAGE OF EXTRACTION OF BITUMINOUS COAL

ing the long-wall panel, left during the advance, shall be taken out on the retreat.

37. Texas.—There are three bituminous coal fields and one lignite field in Texas. In one bituminous field in the north central portion of the state, practically all the mines are operated on the long-wall plan, and the recovery is nearly complete. The two other bituminous fields are located in the southwestern part of the state along the Rio Grande. In this district the mines are operated on the room-and-pillar plan, and the recovery is said to be about 75 per cent. The lignite field extends entirely across the state from the northeast corner in a southwesterly direction to the Rio Grande. All lignite mines are worked on the room-and-pillar method, and the recovery varies greatly in different parts of the state, but 75 per cent is probably the average.*

38. North Dakota.—J. W. Bliss, State Engineer, estimates that the recovery in the coal mines of North Dakota is between 70 and 75 per cent. The manager of one mine claims a recovery of about 85 per cent. †

39. Colorado.—The principal producing districts of Colorado are the bituminous district in the southeastern part of the state, near Trinidad, and the lignite district just east of the mountains in the northern part of the state. The bituminous district is the more important. In the Trinidad district‡ the average thickness of the coal is about 6 feet. The top is strong, and the bottom is weak. Entries are driven to a fixed boundary, and the rooms which are needed to supply enough coal to keep the driver busy are turned. When the boundary is reached, rooms are turned at the inby end of the entry, and pillar drawing is commenced as soon as the rooms reach their limits. Nearly all the coal is taken out on the retreat. Rooms have a maximum width of 18 feet, and room pillars are 32 feet wide. All work is done with picks. The coal is soft and occasionally the pillars crush, but most of the difficulty encountered is due to heaving of the bottom. The cover averages more than 600

† Personal Communication.
‡ Weitzel, E. H., Personal Communication.
feet in thickness. The output from mines in this district is used largely in connection with steel making, and operations are very regular, most of the mines being worked every day in the year. The recovery at a typical mine in this district, calculated for operations over a period of several years, is 87.2 per cent.

In the domestic coal district in the neighborhood of Walsenburg, the average thickness of coal is 5 feet. It is stronger than the coal in the Trinidad district, and a squeeze is very unusual. The cover averages about 400 feet in thickness. As a rule the bottom in this district is stronger than the top, and little difficulty is experienced from heaving. The work is less regular than in the Trinidad district, although it is fairly regular except in March and April when the mines are usually worked about half time. Rooms are driven 25 feet wide on 50-foot centers. There is little difficulty in drawing pillars. The tendency in these districts has been to drive narrow rooms and to leave wide pillars, and this has assisted in increasing the percentage of recovery. The extraction in a typical mine in this district, calculated for operations over a period of several years, is 91.7 per cent. The chief engineer* of another company operating in this same district believes the extraction in certain portions of the mines of his company will reach 80 per cent. In the Canyon district the long-wall system is used, and the recovery is nearly complete.

40. New Mexico.—No information is available concerning the percentages of extraction in New Mexico.

41. Utah.—The principal coal fields of Utah are located in Carbon County.† The main coal horizon has from two to four workable beds, from 5 to 28 feet in thickness. The main workable bed, known as the Castle Gate, varies in thickness from 5 to 20 feet, and rests on a massive close-grained sandstone. The problem presented by these deposits is one of mining thick seams, comparatively level or slightly inclined. Formerly some seams 4½ to 8 feet in thickness were worked, but at present most of the mining is done in seams varying from 8 to 28 feet in thickness. The physical features to be taken into consideration in this district are: the number of workable seams, the thickness of seams and their relation to one another,

* Personal Communication.
the character of the coal, the dip of seams, the character of roof and floor, cover, faults, dikes, wants, the flow of water, sometimes gas, and the burned-out coal beds in place with their residual heat.

Throughout most of the fields there are at least two workable seams, and these are generally found in one coal horizon. In several sections, however, there are three and sometimes four workable seams 5 feet or more in thickness. The distances between these seams vary considerably, so that in some sections there are no unusual problems involved while in others two or more workable seams are found with so little intervening strata that the problem of successful extraction has not yet been solved. There may be, for example, an 8- to 14-foot seam underlying a 6- to 10-foot seam with about 200 feet of intervening strata; in another instance a 5- to 8-foot bed lies 60 feet below one 5 to 11 feet thick, and this lies from 12 to 20 feet below a 22-foot seam, which in turn lies 30 feet below a 6-foot seam. In still another instance an 11-foot bed is found from 3 to 40 feet below a 6-foot bed. There is considerable variation in the physical characteristics of the beds, some being hard and brittle and others tough. In some instances the cleavage is good, while in others it is not pronounced. Almost without exception the coals are hard to cut, and some are hard to shoot. The average dip does not exceed 10 per cent, and in some places the beds are practically flat. As a rule the floor consists of hard smooth sandstone from which the coal parts rather readily. In many cases the roof is of shale varying in thickness from a few inches to several feet. Where a sandstone roof is found, it is generally too hard to break for easy mining. In some places the cover is more than 2,000 feet thick, and there are only a few localities in which it is less than 1,000 feet in thickness. This heavy cover makes the mining of these flat thick seams a serious problem in itself, but the additional complication of great irregularity in depth and the unyielding qualities of the thick beds of overlying sandstone make the problem still more serious. A condition which modifies, at least locally, the laying out and working of a mine is the fact that near the outcrop there are sometimes found large areas of burned coal. These sometimes extend 2,500 feet in from the outcrop. Mining in burned areas is often dangerous, if the burning has been at the top, because of the disintegration of the roof.

With one exception all the mines of the district are opened from the outcrop by means of slopes of drifts. Where conditions of topog-
raphy and property permit, main slopes are driven directly on the pitch of the seams. All mining is by the room-and-pillar method. An attempt to use the long-wall method in one case failed because of the unyielding nature of the roof. The double-entry system is almost universal, although in one case a triple entry is used, and in some cases the double-entry system has been so modified by the connection of the first rooms on the cross entries that it has become practically a 4-entry system. In the earlier workings rooms were turned from the cross entries as these were driven, but the system resulted in the occurrence of bounces, which seem to take the place of the squeezes that occur with more yielding materials. In later operations the panel system has been used, and the pillars are drawn on the retreat.

Methods of drawing pillars are of particular interest, since they show how almost complete extraction can be attained under conditions which seem unfavorable. These are described by Watts substantially as follows:

In one method (Fig. 39), the block at the end of the pillar on the inby side of the cross-cut is divided by another cross-cut driven through its center, and from the center of this new cross-cut a narrow
room which splits the stump into two parts is driven to the gob. The upper inside stump is taken out first by slices beginning at the inby end; then the remaining stump is removed. The lower half of the original block or pillar meanwhile is split by a narrow road, and the process is thus continued down the pillar, each block being divided into four parts.

Pillar drawing in a flat seam 12 to 14 feet thick under a cover 800 feet thick and under a roof which broke fairly well when posts were removed has been successfully accomplished by the following method: 20-foot rooms were driven with 50-foot pillars (Fig. 40), and a cross-cut was driven through the pillar; thus a 30-foot stump was left. This 30- by 50-foot stump was then split by a 12-foot room which left a 24- by 30-foot stump next to the room and a 14- by 30-foot stump on the other side. The latter stump was then taken out in slices which begin at the gob, and the roof was supported by props set every 4 feet. The coal was undercut by hand and shot with black powder. When this block had been removed, the track was taken up, and all props were drawn except a row adjacent to the rib of block No. 3. These blocks were numbered in the order of their extraction, 1, 2, 3, and 4. Block No. 3 was then taken out from the
cross-cut to the gob, track was laid in the space, and block No. 4 was taken out in the reverse direction, that is, beginning at the gob. In this mine 3 to 6 feet of top coal are left up to protect the roof on the advance, but this coal is taken down on the retreat. When cross-cuts are made in pillars preparatory to drawing them the whole height of the seam is taken.

Pillar drawing in 16-foot coal with a cover of 400 to 1,000 feet, with no top seam and with the roof breaking well when props are drawn, is accomplished as follows: Rooms about 400 feet long are driven straight up the pitch which averages about 10 per cent. Pillars are drawn on the retreat, and the line of break is kept at an angle of 45 degrees with the entry; thus work is done on six or seven pillars at a time. Rooms are about 20 feet wide, and pillars are 50 feet wide. A cross-cut is driven through the pillar 30 to 35 feet from the end (Fig. 41); thus a block about 25 to 30 feet by 50 feet is cut off. This block is then split by a room about 12 feet wide. Blocks 1 and 2 are drawn by slicing which begins at the end next to the gob. The top is supported by means of props at 4-foot intervals, and after the two blocks have been removed and the track has been taken out, these props are pulled, and the area is allowed to cave. The track is then laid in the main room, and blocks 3 and 4 are taken out by

![Fig. 41. Pillar Drawing in Utah](image)
end slicing from the room; then the track is taken out, and the props are pulled. Another cross-cut meanwhile has been made through the pillar nearer the entry, and a room has been driven through the stump so that by the time the first stumps have been extracted, work is being begun on the lower stumps.

In this mine the size and the systematic placing of props have an important bearing on the successful recovery of the pillars. Until heavy pine props were used, trouble was likely to occur at any time. Now props as large as 10 inches in diameter at the small end with correspondingly heavy caps and, in some places, cross bars are used. Props are set at regular distances. Many of these props are recovered and re-used three or four times. By the adoption of this method, the safety factor is largely increased, the percentage of recovery is greater, and the product is of better quality. In some cases it is customary to mark pillars at regular distances so that the mine foreman or pillar boss may easily determine the progress of the pillar work daily and may keep the ends of the stumps in proper alignment.

Another method of pillar drawing sometimes used is similar to that last mentioned, although the stump left is a little shorter. This stump is then split into quarters, and the work of extraction proceeds from the cross-cut toward the gob, a thin section of coal being

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**FIG. 42. PILLAR DRAWING IN UTAH**
left to the last around the edges of the block to prevent the mixture of fallen roof with clean coal.

A plan which has proved satisfactory, partly because it does not split the pillar into many small stumps, is illustrated by Fig. 42. The original block of pillar coal 100 feet wide by 120 feet long is divided into equal parts by a cross-cut, and the upper half is taken out by slicing beginning at the inner side, a curtain of coal being left to prevent the loading of gob, and one or two rows of props being put along the side of the coal. Before the track and props are pulled, most of this section of coal is loaded out. In this case the rooms are 18 feet wide and the pillars 100 feet wide.

Little information is available regarding the percentage of extraction in Utah. There is probably only one mine in the state which has been worked out, and no reliable information can be obtained concerning this mine. It is believed, however, that the extraction was probably about 75 per cent. In coal 12 to 16 feet thick and under cover varying from 200 to 2,000 feet an extraction as high as 90 per cent has been made, if marketable coal alone is considered. If all the coal in the bed is considered, the recovery is about 80 per cent. In beds ranging from 15 to 30 feet in thickness, retreating work has hardly been started so that no information on total recovery is available. It is possible that it will be rather low. It could be made higher if the filling method could be used, but the price of coal does not warrant the use of this method.

A condition largely influencing the percentage of extraction is the presence of more than one workable seam with little intervening material. Under present conditions the percentage of extraction from an area containing seams with 3 to 12 feet of intervening rock is at best only 65 per cent of all the coal. In one mine an attempt was made to take out the coal from two beds, the lower being 11 feet thick and the upper 5 to 6 feet thick with intervening rock 2 1/2 to 12 feet thick. The workings were in the lower bed, and frequently the roof caved as soon as the pillars were drawn and practically all the upper seam was lost.

A. B. Apperson* gives the percentage of extraction in two mines as nearly 95 per cent of the total seam, while the extraction at another mine is about 85 per cent. At the mines yielding the lower percentage of extraction, the cover is about 800 feet. At one of the mines

* Personal Communication.
yielding the higher percentage of extraction, pillar drawing was commenced at the middle of the mine under a cover of approximately 1,700 feet. A good break is obtained about 50 feet behind the pillar extending the full length of line. Only small areas have been worked out in these mines.

42. Washington.—No reliable information is available concerning the percentage of extraction in Washington. Conditions are somewhat unusual in that most of the coal has been badly folded and faulted and consequently crushed, and the deposits have been steeply tilted.* It is impossible to separate the refuse in the mines, and a large percentage of it has to be washed.

*Daniel, Professor Jos., Personal Communication.
APPENDIX

DEVELOPMENT OF MINING METHODS IN ENGLAND AND ON THE CONTINENT

43. Brief History of Coal Mining Practice in England.—It is interesting to review briefly the history of the coal mining methods of England, because the mining methods employed in this country are largely applications of methods developed in England and brought over by miners.

The many methods of obtaining coal may be grouped on the basis of recovery under two main headings: one in which the whole of the coal seam is taken out in the first working, and another in which only a part of the seam is removed in the first working. These may be called the no-pillar, or long-wall, system and the pillar system.

The earliest mining was naturally done on the outcrop of the seams, and as this practice became difficult or impossible, the use of "bell-pits" (Fig. 43) was developed. These were holes or shafts, from 3 to 4 feet in diameter, which were sunk through the shallow overburden near the outcrop and widened out at the bottom in order to allow the excavation of as much coal as possible without permitting the roof to fall in. It was of course impossible to extract much coal from a pit of this kind, and in order to obtain the coal even from a small area it was necessary to dig a large number of pits. This method was gradually abandoned, and the coal was worked by means of galleries driven out from the bottom of the shaft, usually in an unsystematic manner; thus began the use of pillars to sustain the roof. The driving of galleries permitted the working of much
greater areas than could be reached from the bell-pits; however, no areas of more than a few acres were worked from one shaft, nor were systematic ventilation and regularity in laying out the workings introduced until the exhaustion of the shallow coal made necessary a study of methods to be employed in deeper workings. Until the introduction of the Newcomen engine, when pumping by steam power became possible, shafts were rarely as deep as 200 feet; they were 7 or 8 feet in diameter, and the area worked from one shaft was seldom more than 600 feet in radius.*

The structure of many coal seams is such that there are two directions, determined by the cleat of the coal, in which the seams can be most easily worked. The direction at right angles to the face cleats is known as "bordway," while the other direction approximately at right angles to the first is known as "headway." The excavations made in a direction at right angles to the principal or face cleats

were called bords, and, as the coal was most easily taken out in this direction, these excavations were made wider than the connecting passages or headways. The coal left in place to sustain the roof was called pillars; thus originated the term, "bord-and-pillar" method, which in its various developments is commonly known in this country as the room-and-pillar method. This method was developed in different forms in England and was variously called "bord-and-pillar," "bord-and-wall," "post-and-stall," and "stoop-and-room."

In early times the "pillars" were probably made very small and square measuring from 3 to 6 feet each way. In the eighteenth century the bords were usually made 9 feet wide and the pillars 12 feet wide, though they were of course irregular. The bords were commonly widened out between the headways (Fig. 44), and the pillars were thus gouged to as great an extent as was considered safe, it being desirable, in view of the comparatively small area which could be reached from a single shaft and in view also of the inadequate ventilation, to extract as much coal as possible within the area worked. This method of working was essentially wasteful as not much more than 50 per cent of the coal was obtained, and since the pillars left were unable to bear the weight of the cover, they were soon crushed and further working was made impossible.* Possibly a larger percentage of coal was taken out in some places as Redmayne † says it was rare that more than 65 per cent of the available area could be

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extracted; but he refers to John Buddle as saying, at a somewhat later period when the pillars were 18 by 66 feet, that not more than 45½ per cent of the contents of a fiery seam could be obtained under any method of working then known. It was not until much later that the exhaustion of the most easily worked deposits directed attention to the desirability of higher extraction.

A system with square pillars and working places of almost uniform width (Fig. 45) has continued in common use at Whitehaven and in Scotland down to the present time. In the north of England the pillars were usually oblong, probably because the highly developed face cleat of the coal made the extraction in one direction much easier than in others. The lengthening of the pillars reached its greatest extent in South Wales where cross holing was so little employed as scarcely to form a part of the system of working.

The date at which the extraction of pillar coal was begun is not known, but it seems certain that pillars were removed in the north of England before 1740. The following statement† is made concerning the removal of pillars:—"The documentary evidence cited goes to show that, previous to 1708, the general practice was to leave small pillars of coal standing for the support of the roof; 30 years later pillars were being partially, sometimes entirely, removed; and during the remainder of that century, in mines free from gas, a second working of the pillars was frequently carried out. In the deeper and fiery collieries, which began to be developed about the middle of the eighteenth century, the risk of creep as well as of gas explosions prevented the removal of the pillars. The invention of the safety lamp, improvements in ventilation, and the formation of much larger pillars in the first working . . . were introduced during the first 30 to 40 years of the present (nineteenth) century . . . which enabled the pillars to be removed in a second working."

Concerning the size of pillars, Jars, a French engineer who published "Voyages Métallurgiques" in 1774, says in "A Journey Through the North of England," that underground pillars of coal were made from 39 to 54 feet square, and that working places were from 5 to 16 feet wide. At this time the pillars were left until all the coal was exhausted. Another traveler who made a tour of Scotland in

1772 said that pillars 45 feet square were left and that not more than one-third of the coal was worked.*

The extraction of a portion of the pillars in gassy mines by a second working was just beginning to be a regular part of the bord-and-pillar system at this period. It could, however, be effected only in a very incomplete manner so long as the miners had to depend upon candles and steel mills for light. At this time also the extensive adoption of the long-wall system began.†

In the early part of the nineteenth century little change seems to have been made in the size of pillars used in the Newcastle district, according to a statement of an author who speaks of them as being 60 by 27 feet or, in some instances, 27 feet square. About this time the drawing of pillars seems to have become common in Northumberland, as Mackenzie, who wrote a "View of Northumberland" in 1825, speaks of the mode of working coal as being much improved in the last few years. He says (second edition, page 90), "from seven-eights to nine-tenths of the coal is at present raised, whilst formerly but one-half, and frequently less, was all that could be obtained." No doubt this statement refers to the general practice of removing pillars, which had been made practicable in gassy mines by the invention of the Davy lamp.

Conflicts of interests between coal producers and owners of the surface are of early record. It was, of course, the desire of the colliers to remove as much of the coal as possible, even where the surface was supposed to be maintained, and the result of making pillars too small was subsidence. There is probably no definite record of the first occurrence of subsidence, but one of the earliest mining leases written in the English language, dated 1447, indicates that it was the custom to leave pillars to sustain the surface and that subsidence had already taken place.‡

In the latter part of the eighteenth century the working of pillars in a fiery mine, such as Wallsend Colliery, was not considered practicable, and only about 39 per cent of the coal was obtained while 61 per cent was permanently lost. This coal was at a depth of 600 feet, and the workings represent the best practice of the bord-and-pillar system at that period.§

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† Ibid, p. 362.
‡ Ibid, p. 69.
§ Ibid, p. 298.
Until about the end of the eighteenth century an extraction of 45.5 per cent was considered the maximum which could be obtained in the deep collieries of the Tyne.* The first person to offer a partial remedy for this very unsatisfactory condition was Thomas Barnes, viewer of Walker Colliery, who projected a scheme in 1795 for recovering a portion of the pillars without causing loss of the mine. This system provided for dividing the workings into small sections of 10 to 20 acres and isolating these with artificial barriers formed by filling the excavated spaces with stones and refuse for a breadth of 120 to 150 feet. By this method one-half of alternate pillars, or one-quarter of the remaining coal, was removed, and the percentage of extraction was increased from about 39 to about 54 per cent. Wherever pillars were thus removed, a squeeze was brought on, but the barriers kept it from spreading. This method proved to be successful, and it was adopted at other collieries.

Probably about this time the pillars at Wallsend Colliery were left larger as a preparatory step toward a second working. Buddle said that after about one-third of the colliery had been worked by means of 36-foot winnings (12 feet to the bord, 24 feet to the wall or pillar) in which no more coal was left in pillars than was considered sufficient to support the roof, the size of the winnings was increased to 45 feet (15 feet to the bord and 30 feet to the pillar). "This change of size," he said, "was not made for the purpose of obtaining a greater produce in the first working of the seam. But the notion of the future working of the pillars then began to be entertained, and the increased size of the winnings was considered a more favorable apportionment of the excavation and pillar for the attainment of this object." This is the first record found of a second working in the deep Tyne Collieries.† Pillars seem to have been worked in the northern part of England about the middle of the eighteenth century.

44. Ventilation.—The distance to which workings could be driven and the extent to which pillars could be drawn, especially in gassy mines, were found to depend largely upon ventilation. In the latter half of the eighteenth century improvements in ventilation, which had been used earlier in the Cumberland field, were introduced into

the north of England, where the frequency of explosions made better ventilation necessary. Until this time it had been considered sufficient to conduct the air current along the working face, an arrangement known as "face-airing;" consequently, the worked-out places, which were behind the miners in advancing work, were left without ventilation. As long as the extent of workings was very limited, this method was not attended with great danger; but, as the mines became deeper and more gassy, workings were made larger and the danger from this inadequate ventilation increased, because the worked-out places became magazines for the accumulation of fire damp.

The improved method of ventilation, which was known as "coursing the air," consisted in so directing the air that the whole current passed through all the openings in the mine. While this method was effective in preventing the accumulation of standing gas, it introduced a great danger in that the air took up constantly increasing quantities of gas in its passage through the mine, and, since it was constantly exposed to the lights of miners, it became dangerous in the latter part of its course. It was, moreover, constantly contaminated by the breathing of men and animals and by the smoke from the candles. This method was introduced in the north of England about 1765 or 1766, and it was about this date that the steel mill also was introduced for the purpose of giving light.* Though this method was fairly satisfactory in small mines, it was very unsatisfactory in large ones. At Walker Colliery, although the pits were only half a mile apart, the air current traversed a line exceeding thirty miles in length. At Hebburn Colliery the air course was also said to be not less than the same length. Not only was it difficult to keep the air passages open and the doors and stoppings tight, but the friction of the air limited the velocity of the ventilating current, which would have been low at best since the force causing this current was supplied only by a furnace. At this colliery the circulation of five or six thousand cubic feet of air per minute was considered sufficient, and the velocity was about three feet per second.

45. The Panel System.—There was great difficulty in carrying on work in the deep collieries of the North, because squeezes occurred. A method of working described as common in the North at this period consisted in having bords 12 feet wide and 24 feet apart.

connected by headways 60 feet apart, thus leaving pillars of coal 24 by 60 feet. Another size of pillar given is 30 by 72 feet.*

Early in the nineteenth century, John Buddle, Jr., who had succeeded his father as manager at Wallsend and who was responsible for important improvements in coal mining methods, devised and put into practice improved methods of working and ventilation whereby squeezes were effectually kept in check, and the existing system of ventilation was greatly improved. He effected these improvements by dividing the workings into independent districts or panels, as Barnes had done. Buddle's idea, however, was to provide for confining the movement by separating the districts or panels with barriers of solid coal left in the first working. This method was adopted in developing the Wallsend G pit in 1810. Buddle's improvement in ventilation involved dividing or splitting the current. This method of ventilation proved successful and was quickly adopted at other mines to which it could be applied, but the air currents employed were still very feeble.

From the preceding descriptions it will be seen that all the essentials of the room-and-pillar system as now practiced in this country had been developed in Great Britain prior to 1810.

46. Square Work of South Staffordshire.—In the Thick seam of South Staffordshire where the coal varies in thickness from 18 to 36 feet, a method which bears a close resemblance to the panel method was developed. The district had been greatly troubled with fires due to spontaneous combustion, and in order to extinguish these fires easily or to confine them within the immediate vicinity of their origin this method, known as "square work," was developed. It consists in dividing the area to be worked into a number of large chambers termed "sides-of-work," surrounded on all sides by panels of solid coal known as "fire ribs." The only openings in these panels are those necessary for the extraction of coal and for ventilation. The panels are nearly square, and from four to sixteen pillars, the number varying according to the size of the chamber, are left to support the roof. Fig. 46 shows an old form of square work. Under the system in its simple form and in the first working, only from 40 to 50 per cent of the available coal is recovered, but the larger portion of that left is recovered by second or even third

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workings carried out after the lapse of some years. The final loss in working may, therefore, not exceed 10 per cent of the available coal; the coal recovered in these later workings, however, is frequently badly crushed.*

47. The Long-wall System.—The other general method of coal mining, the long-wall method, has been from early times prevalent in Shropshire, from which district it has spread into others. The date of the origin of this method is doubtful, but it is said to have been in general use in the Shropshire district about the middle of the nineteenth century.†

The long-wall method of mining has been highly developed in England and Scotland and has been applied at greater depths and to thicker beds of coal than it has been in this country. Considered from the point of view of completeness of extraction, the system fulfills the highest requirements: It not only permits, but requires the excavation of the whole bed of coal. Whether all the coal shall be taken out of the mine depends of course on whether it is marketable.

This method of working has not been as generally applied in the United States as have the various forms of the room-and-pillar system. There are, however, certain districts in which it is used almost exclusively. Among the most prominent of these is the long-wall district of Illinois which has been described as District I in Chapter II. The other districts in which the long-wall method is used are those of northwest Missouri, northeast Kansas, the

Osage district of Kansas, the Appanoose district of Iowa, the north-central district of Texas, and the Canyon district of Colorado. Scattering applications of the method are found elsewhere, but the physical conditions in the regions mentioned have been best suited to its use. It seems probable that the long-wall system, with modifications perhaps, will be more widely used in this country in the future.

48. Percentage of Recovery in England.—The methods followed in England have not been developed with the purpose of obtaining a high percentage of recovery. It was not until 1854* that a special department for collecting and publishing mineral statistics was created, and not until 1861 that any systematic estimate of coal resources was made. About this time predictions forecasting the exhaustion of the coal supply within a century caused a great disturbance, and a royal commission was appointed in 1866. A report of this commission was made public in 1871.

The part of this report which deals with waste in working is of special interest. The commission estimated the "ordinary and unavoidable loss" to be about 10 per cent, though they said, "In a large number of instances, when the system of working practiced is not suited to the peculiarities of the seams, the ordinary waste and loss amount to sometimes as much as 40 per cent." The principal part of this unavoidable waste arises from the crushing of pillars.

In addition to this unavoidable loss, there is waste or loss, variable in amount, but sometimes very great, arising from the following causes:†

1. The leaving below ground or consuming in large heaps of small coal on the surface (presumably the loss from this source is much less at present because of the greater consumption of small sized coal, as in this country).

2. Undercutting, often wastefully made, in good coal.

3. The leaving, either wholly or in part, of an adjoining or neighboring bed when it becomes crushed and unworkable, because it is not wanted at the time, or because if it should be worked, the cost per ton of the coal extracted is increased.

* Digest of the Evidence given before the Royal Commission on Coal Supplies, Vol. I., p. IX., 1905.
† Ibid, p. XXXIII.
(4) Existence of coal on properties which are too small to be worked alone or in small parts of collieries cut off by a large fault.

(5) Disputes over the cost of drainage.

(6) The breaking in of water from the sea or from a river estuary.

(7) The leaving of barriers around small properties or crooked boundaries.

(8) Lack of plans or records showing the extent of old workings, operations of seams not sufficiently proved to justify expenditure for sinking pits; sufficient information might have been obtained if records of previous explorations had been preserved in available form.

(9) The piercing of water-bearing strata by shafts and bore holes which are not protected by water-tight casings, or are not carefully filled and puddled when temporarily left or abandoned.

(10) The cutting through of main faults serving as natural barriers to keep back water and the consequent flooding of the coal.

(11) The leaving of large areas of coal in populous and manufacturing districts to support the surface and the buildings.

While some of the causes mentioned do not apply directly to conditions in this country, the list furnishes a complete synopsis of reasons for coal losses.

Since the issuance of the report of 1871, there have been great improvements in the methods of getting coal. At the present time the long-wall system is in general use, and the waste has been lowered; yet in some parts of the United Kingdom, notably Northumberland, the pillar-and-stall system is still in general use.

Among the factors contributing to a higher rate of recovery is the greatly increased value of small sizes of coal. It was computed in 1871 that the average value of the small coal mined in Great Britain was only 60 cents per ton, while in 1905 the small sizes of steam coal from the South Wales district brought about $1.90 per ton; in all the other coal fields the value has been doubled and even trebled. The principal cause of this change lies in the improved preparation of coal. The manufacture of producer gas on a large scale and the growth of the briquet industry have also increased the possible uses of the small sizes. One of the effects of the increase in the value of small coal has been some decrease of the comparative advan-
tage of the long-wall system, since the production of a large amount of fine coal with the pillar-and-stall system is less objectionable than formerly.*

Interest in the subject continued, and another investigation, more exhaustive than the earlier one, was made by the Royal Commission on Coal Supplies which organized in 1902 and presented its report in 1905. The Royal Commission of 1905 adhered to the limit of depth, namely 4,000 feet, established by the earlier commission. It was thought that, although there might be no insuperable physical or mechanical difficulties in the working of beds at greater depths, the expense would be so great that imported coal could be obtained more cheaply.

With regard to thickness, the commission which reported in 1871 had included seams exceeding one foot in thickness as workable. The question is largely a commercial one, and thinner seams are being worked now than formerly. Mr. Gerrard, inspector of mines for the Manchester district, obtained from all the inspection districts returns which showed that in 1900 17.7 per cent of the entire output was taken from seams not exceeding three feet in thickness.† In the United States, limits of 3,000 feet in depth and of 14 inches in thickness have been decided upon by the Department of the Interior as factors determining what portions of the remaining public lands shall be considered coal lands.‡

The Royal Commission took evidence also on the cost of working, and gave figures which show how greatly the labor cost rises and the individual output declines as thinner beds are mined. Mr. Gerrard gave the underground wages as ranging from $1.68 to $2.28 per ton in seams up to 12 inches, and from 63 cents to $1.36 in all underground seams in his district from 1 foot, 1 inch to 3 feet, while the daily output ranged from one-half ton to 3½ tons. It was estimated that the cost of digging, loading, and hauling in Scotland was $1.24 for a seam 14 to 15 inches thick, and 65 cents for one from 2 to 2½ feet thick, while the daily output varied from 22 hundredweight to 1½ tons. In Somersetshire the average cost of working thin seams has been about $1.92 per ton for a number of years, while

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* Digest of the Evidence given before the Royal Commission on Coal Supplies, Vol. I., p. XXV., 1905.
† Digest of the Evidence given before the Royal Commission on Coal Supplies, Vol. I., p. XXXV., 1905.
In Yorkshire the cost in 1900 varied from about 96 cents to $1.68.* The Commission of 1905 finally decided to retain the figure of one foot as the limit of thickness.

In connection with the subjects of depth and thickness, it should be noted that it is not the practice in Europe to work single thin beds at great depths. The thin beds are worked in conjunction with thicker ones, and it is the lower cost of production in the latter which makes the working of the thin ones commercially possible. The high cost of working thin beds is partly responsible for the high cost of European coal. The American practice is distinctly different, for there are few, if any, districts in this country in which any bed of bituminous coal is worked unless it is believed that such working shows a profit without reference to other workings. Instances of the working of more than one bed of bituminous coal from the same shaft are rare in the United States.

49. **Percentage of Coal Lost.**—A detailed inquiry was made by the Royal Commission into the various sources of loss. The points of greatest interest in connection with the present study were covered as follows:†

"**Coal left for Support.**—It is evident, that, except in very special cases, it is not possible to remove all the coal. A certain amount must be left in order to maintain shafts, etc., and to support the surface—as, for instance, under houses, railway, canals and rivers—and there seems little hope under existing circumstances of avoiding this source of loss. The amount of coal left for support depends largely upon whether its value is greater than the damage, which would be caused by its removal.

"**Barriers.**—We have evidence that much coal has been and is lost through the practice of leaving unnecessary barriers between royalties and properties; but the present tendency to take large areas under lease is reducing the loss from this cause, and in many cases barriers between properties are now worked out by mutual arrangements.

"**Thick Seams.**—Where the seams are of abnormal thickness much coal is, in some cases, wasted, and for various reasons. Sometimes it

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* Digest of Evidence given before the Royal Commission on Coal Supplies, Vol. I., p. 178 et seq., 1905.
† Digest of the Evidence given before the Royal Commission on Coal Supplies, Vol. I., p. XXXVI., 1905.
is considered that the whole seam cannot be taken out with safety, and part is therefore left to form a roof. Further, such thick seams are more difficult to work, and when the whole of the seam is not of the same quality, there is a temptation to take out the best coal first and to leave the rest for possible future working. Suggestions have been made by some of the witnesses as to the best method of working such thick seams, and there is little doubt that improved methods combined with the increasing use of inferior coal will to a large extent obviate the difficulties mentioned.

"Inferior and Small Coal Left in Mines.—According to the evidence inferior coal is frequently left in the mine owing to its being unsalable, and in some districts considerable quantities of small coal are also left. In recent years there have been vast improvements in the methods of, and the appliances for, preparing and utilizing small and inferior coal, and the higher appreciation of such coal should go far to put an end to this waste."

Table 10 presents the conclusions of the commissioners of different districts regarding the deductions which should be made to cover losses in calculating the amount of coal remaining available.* It is to be understood that the values given do not refer merely to the losses within a definite mined-out area but to the total losses which are to be expected in extracting the total coal remaining available. Since both amounts of losses and reasons for them are governed largely by local conditions, it is unnecessary to go into details, especially since it was found impossible there, as it has been here, to arrive at definite statement for the losses in all cases. Values, however, are founded upon the opinions of men familiar with the practice in the districts, and they are at least approximately correct.

<table>
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<td>Warwickshire</td>
<td>2.20</td>
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<td>22.61</td>
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<tr>
<td>and Monmouthshire</td>
<td></td>
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<td>26.00</td>
<td>Durham</td>
<td>20.25</td>
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<tr>
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<td>15.50</td>
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<td>20.70</td>
<td>Cumberland</td>
<td>28.20</td>
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<td>Cheshire</td>
<td>18.70</td>
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<td>13.00</td>
<td>Flintshire</td>
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<td>27.50</td>
<td>Denbighshire</td>
<td>33.30</td>
<td>Average</td>
<td>21.28</td>
</tr>
</tbody>
</table>

* Ibid, p. XXV.
In the introduction to the report of the Commission, prepared by the editor of the "Colliery Guardian," it is stated (p. xxvi), "Much of the evidence goes to show that the more general adoption of the long-wall system in recent years has resulted in an increased yield of coal. But there are many localities where the conditions are not considered favorable to long-wall working, and where pillars are still left. In the worst cases, in exceptionally bad ground, as much as 50 per cent of the coal is often left behind for this purpose, only to be crushed and oxidized and rendered unfit for future recovery. In the undersea workings in Cumberland as much as 75 per cent is thus left behind. Perhaps the most interesting point brought out in the evidence is that which concerns thick seams. It certainly does seem unfortunate that where there are 9 feet of good coal in a single seam, nearly one-third of this should be left behind." Yet this happens in many of our thickest seams, and the loss threatens to be still more serious as the depth increases."

50. Mining Conditions on the Continent.—In the Franco-Belgian basin the beds are for the most part thin, and they are worked, to a considerable extent, at greater depths than those reached in the United States. In Westphalia the beds are mostly steeply dipping, and in Upper Silesia there are combinations of steep dip with great thickness of coal. The development of mining methods in the United States up to the present time has not been affected by practice in these districts.

51. Percentage of Extraction on the Continent.—In France it is the custom to extract as much coal as possible from the bed and to fill the resulting space with rock or other material. The filling material is usually transported to its destination in cars, and the method of packing depends largely on the inclination of the bed. In steeply dipping beds the material is allowed to run into place by gravity, but where the slope is not sufficient to permit this method of packing, it is packed by hand. This custom does not entirely prevent subsidence, but it permits the extraction of nearly all the coal without serious disturbance of the surface. While the method of packing followed in these districts permits the removal of nearly all the coal, the removal is accomplished at an expense which would be regarded as prohibitive in the United States in view of the narrow margin between
cost of production and selling price here. The method of filling by flushing is coming into use in France, but has not yet displaced dry filling in most of the mines. Whatever system of filling is used, and whether the coal is taken out by pillar or long-wall method, the extraction is nearly complete.

Some of the most difficult problems found in any coal mining district have been encountered in Belgium. There is no other country in which such thin seams are worked and in which coal is generally mined at such great depths. At Quaregnon a series of thirty-three seams is worked, the average useful thickness being 1 foot, 3½ inches, while the greatest thickness is 2 feet, 2 inches. These beds vary in dip from 8 to 90 degrees. The flatter portions of the bed are worked by long-wall, and the steeper parts by inverted steps forming an interrupted long-wall face. Other beds of nearly the same thickness are being worked, and it appears in all cases that those thin beds are attacked by some form of long-wall working in which, of course, the extraction is practically complete.* The discussion of these districts is much briefer than their importance as coal mining districts would warrant were it not for the fact that the methods used would not in general be adaptable to physical and commercial conditions in this country. They furnish interesting illustrations of high percentages of extraction under difficult conditions, but can hardly be regarded as indicative of what it would be possible to do in the United States.

In the Westphalian district in Germany large amounts of coal have been lost, not so much as the result of poor mining methods or lack of attention to completeness of extraction as because of the necessity of preventing subsidence of the surface. This region is one of great industrial activity, and surface values have so increased within the last half century that high extraction without filling has become impossible. At first, hand filling was employed, the material used being the waste produced in the large amount of rock excavation necessary in beds lying at various angles combined with slack from collieries where coke was not made. More recently the method of hydraulic filling has been introduced. Where the packing is well done and the mining conditions are favorable, the loss of coal is possibly not more than five per cent, which may be considered a fair estimate of the

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loss even where the long-wall method is followed. There is, however, a greater loss in some of the thicker steeply dipping beds, though it has not been possible to obtain estimates of the amount.

The Upper Silesian coal field,* situated in the southeast corner of Prussia and extending into Austria and into Russian Poland, has an area of 2,160 square miles. The character of the seam varies considerably both in composition and in thickness, and thick seams occur only in the northern portion of the field where they are very numerous and many of which are of great thickness.

In this coal field, the problem of removing coal beds of great aggregate and individual thicknesses without serious disturbance of the surface has been met by the development of sand flushing processes of filling. This method of filling was borrowed from the anthracite district of the United States where it had first been used.

The mines are worked with and without sand filling. In the method without sand filling much coal is left unworked in the form of pillars and as support under towns or villages. There is a considerable loss resulting from the difficulty of extracting coal left as barriers between the working places and in the old workings. There is also a considerable loss because of fire. The estimated total loss under this method is 25 per cent.

At present sand filling is being used more or less extensively in most of the mines in the thick beds. It is especially advantageous where spontaneous combustion is prevalent and where surface support is necessary. With sand filling when only a part of the coal is replaced by sand it is estimated that the loss of coal is 10 to 15 per cent; with complete replacement of coal by sand filling, the loss is only from 3 to 5 per cent. Smaller and cheaper timber is used in this case, and the greater portion of this timber is recovered for future use. In four mines in Upper Silesia in which sand filling is used extensively and in sufficient quantities to suit the conditions of the mines, the cost in the seams is between 12 and 18 cents per ton. The cost is variable, however, and is calculated in different ways. The average working cost per ton of coal at the surface in this district is $1.51, of which 37 cents is for underground labor.

A report by J. B. Hadesty† shows that the sand filling system has not yet been adopted on a large scale in the western part of Europe.

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and the statements on cost of filling show that it would be impossible to adopt the process in the United States without materially increasing the cost of production.

It is unnecessary to go into the methods of mining and the results obtained in other coal producing districts. While there are great coal deposits in other parts of the world, and while large quantities of coal are produced, these regions have not been developed sufficiently to work out what may be called a settled practice. No other districts, moreover, are really large producers of coal in the same sense as those already considered. The problems to be considered in connection with districts only partially developed, or districts which though well developed supply only a limited market, are different from those in this country, and the results in such districts are no indication of what can be accomplished here.
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OTHER COUNTRIES

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