MECHANIZATION, EMPLOYMENT,
AND OUTPUT PER MAN IN

BITUMINOUS-COAL MINING

VOLUME I

E9

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WORK PROJECTS ADMINISTRATION
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DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

FEDERAL WORKS AGENCY
WORK PROJECTS ADMINISTRATION

F. C. HARRINGTON
Commissioner

CORRINGTON GILL
Assistant Commissioner

NATIONAL RESEARCH PROJECT
on
Reemployment Opportunities and Recent Changes
in Industrial Techniques

DAVID WEINTRAUB
Director

In cooperation with

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

JOHN W. FINCH, Director

Mineral Technology and Output Per Man Studies
O. E. Kiessling, Economist in Charge

MECHANIZATION, EMPLOYMENT, AND OUTPUT PER MAN IN BITUMINOUS-COAL MINING

by

Willard E. Hotchkiss,
F. G. Tryon, Charlotte K. Warner, L. N. Plein, Walter M. Dake,
R. L. Anderson, J. J. Gallagher, and Margaret H. Schoenfeld

VOLUME I

WORK PROJECTS ADMINISTRATION, NATIONAL RESEARCH PROJECT
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THE WPA NATIONAL RESEARCH PROJECT ON REEMPLOYMENT OPPORTUNITIES AND RECENT CHANGES IN INDUSTRIAL TECHNIQUES

Under the authority granted by the President in the Executive Order which created the Works Progress Administration, Administrator *Harry L. Hopkins* authorized the establishment of a research program for the purpose of collecting and analyzing data bearing on problems of employment, unemployment, and relief. Accordingly, the National Research Program was established in October 1935 under the supervision of *Corrington Gill*, Assistant Administrator of the WPA, who appointed the directors of the individual studies or projects.

The Project on Reemployment Opportunities and Recent Changes in Industrial Techniques was organized in December 1935 to inquire, with the cooperation of industry, labor, and governmental and private agencies, into the extent of recent changes in industrial techniques and to evaluate the effects of these changes on the volume of employment and unemployment. *David Weintraub* and *Irving Kaplan*, members of the research staff of the Division of Research, Statistics, and Finance, were appointed, respectively, Director and Associate Director of the Project. The task set for them was to assemble and organize the existing data which bear on the problem and to augment these data by field surveys and analyses.

To this end, many governmental agencies which are the collectors and repositories of pertinent information were invited to cooperate. The cooperating agencies of the United States Government include the Department of Agriculture, the Bureau of Mines of the Department of the Interior, the Bureau of Labor Statistics of the Department of Labor, the Railroad Retirement Board, the Social Security Board, the Bureau of Internal Revenue of the Department of the Treasury, the Department of Commerce, the Federal Trade Commission, and the Tariff Commission.

The following private agencies joined with the National Research Project in conducting special studies: the Industrial Research Department of the University of Pennsylvania, the National Bureau of Economic Research, Inc., the Employment Stabilization Research Institute of the University of Minnesota, and the Agricultural Economics Departments in the Agricultural Experiment Stations of California, Illinois, Iowa, and New York.

FEDERAL WORKS AGENCY
WORK PROJECTS ADMINISTRATION
1734 NEW YORK AVENUE NW.
WASHINGTON, D. C.

F. C. HARRINGTON
COMMISSIONER OF WORK PROJECTS

August 25, 1939

Colonel F. C. Harrington
Commissioner of Work Projects

Sir:

Although bituminous coal has been declining in importance as a source of fuel and energy, it is still this country's principal energy producer and it still employs as many workers as all of the other mineral industries combined. The average number of men employed reached an all-time peak of 705,000 in 1923. From that point on employment declined almost steadily until 1932 when it was down to 406,000 men; since then it has increased to 492,000 in 1937.

The fact that coal mining was one of our sick industries even during the prosperous twenties is attributable partly to the wartime inflation of capacity and partly to changes in demand. The high prices of the war led to the opening of new mines and further expansion of the capacity of an already overdeveloped industry. At the same time oil, gas, and hydroelectric power made inroads in the markets for coal and consumers turned to economies in the use of fuel. The former upward trend in coal demand flattened out. The combination of arrested demand and surplus capacity produced an inevitable readjustment and as early as 1924 the bituminous-coal industry experienced acute depression.

Technical advances underground and on the surface reduced the number of men required to mine a given volume of coal, though doubtless aiding coal to meet the competition of other sources of power. At underground mines the average output per mine worker per hour increased by 24 percent between 1920 and 1935. The continued spread of the mechanical devices that were available before the war, such as the undercutting machine; the electrification of underground transportation; and improvements in mine lay-out and management methods contributed toward the rising output per worker. Shortly after the war a new machine, the mechanical coal loader, was introduced. It is mainly with the progress of mechanical loading and its relationship to the other factors that influence production and employment in the industry that this report is concerned.

In a mine in which coal is loaded by hand, from one-half to two-thirds of the entire working force consists of miners who, in addition to undercutting the seam and preparing shot holes for blasting down coal, shovel the coal into mine cars. Most of their time is spent in loading coal and the mechanization of this process can obviously have an important effect on the amount of labor required by the mines.

Machine loading was adopted slowly in the early years of its introduction. Only 0.3 percent of all underground bituminous-coal tonnage was loaded by machine in 1923. By 1929 the percentage was 7.3 and in 1935 it was 13.5. Between 1935 and 1937 the machine-loaded tonnage increased from 47 to 83 million tons, or to 20.3 percent of all underground production, and it is estimated that in 1938 one-quarter of the output was loaded mechanically.

The installation of mechanical loaders has not taken place at an even rate in all producing areas. During the twenties and the years between 1930 and 1935 it had its principal acceptance in the great Illinois-Indiana producing district and in some of the less important producing States of the far West. In West Virginia, the country's leading coal producer, 21 percent of the output was mechanically loaded in 1938 as compared with 2 percent in 1935. While it was being adopted to an increased extent in other areas the coal loader also continued to be more extensively used in Illinois and Indiana.

It is estimated that within another decade as much as half of the total underground output may be mechanically loaded. How this will affect employment in the industry depends upon a multitude of factors. Between 1929 and 1935 output per man-hour in underground mines increased by 5 percent and production declined by 32 percent, but the average number of men employed declined by only 9 percent. The men have worked fewer hours per day and fewer days per year.

Technical progress has been a factor in aiding coal to meet its competitors in the market and offers one means of maintaining adequate wage rates and working conditions. No student of the coal industry, however, foresees a revival of demand such as to enable the industry to absorb any of the unemployed from other fields of labor. In fact, the most that can well be hoped for is to maintain the working force now employed at the mines.

If the cost of coal is reduced, new uses found, and former markets recovered, mechanical loading will result in the elimination of much of the backbreaking work of coal mining without exacting too great a price in terms of unemployment and reduced income. However, such a price has already been and is now being paid in some localities. Some mines and mining communities which by virtue of natural conditions or other factors have been unable to adopt mechanical loaders are being placed in unfavorable competitive positions and are finding their employment opportunities restricted. Some of the older miners, accustomed to the tempo of hand-loading mines, are finding themselves displaced and unable to gain a foothold in the mechanized mines. To many of these communities and for many of these older miners emergency relief measures of one type or another are the only alternative to destitution as long, at least, as mass unemployment remains a problem in the United States.

Respectfully yours,

Corrington Gill

Corrington Gill
Assistant Commissioner

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PREFACE

This study deals with the introduction of a new phase of machine technology into bituminous-coal mining, the largest employer of labor among the extractive industries. It illustrates the interaction between resource factors and changing economic conditions on the one hand and the process of technological advance on the other. The record is unusually complete. The spread of the technical change may be traced through large and small mines, strong and weak companies, union and nonunion working conditions, and through periods of declining and advancing wage scales.

The particular technological change under observation is the mechanization of the heavy labor of shoveling coal into the pit car underground. Machines adapted to this work emerged upon the commercial market about the year 1923, their appearance in practicable form following a long period of experimentation.

The mechanization of the loading process is but the latest in a long series of substitutions of more efficient forms of mechanical power for animal or manpower. Previous advances had centered around improvement of explosives, of the undercutting of the seam, and of hauling, hoisting, ventilation, screening, and washing. The mechanization of loading utilized these prior advances and in turn stimulated improvements in hauling, cutting, drilling, shooting, and mechanical cleaning of coal.

In the manufacturing and extractive industries the mechanization of conveying operations and of the handling of bulk materials seems in general to occur characteristically only after other production operations have been mechanized. It is probably for that reason that the mechanization of conveying and handling, in the form of loading devices and assembly belts, have occupied an important position among the types of technological changes that took place in American industry during the last two or three decades. The effects of these technological developments on labor requirements tended to be passed over lightly or dramatized depending on whether or not production and employment in the affected industries were expanding.

In the bituminous-coal industry the loading machine appeared at a time when the industry was undergoing a major economic readjustment, and the effects of this technological change are obscured by great changes in demand for the product, by the liquidation of mine capacity, and by declines in volume of employment due to external factors unrelated to the process of technical changes. The World War had intensified a chronic overdevelopment of mine capacity which had characterized the industry as far back as 1880. The war had likewise stimulated more efficient combustion, and technical advances in the arts of utilization of the product reacted sharply upon the conditions of its production. Meantime the competitive fuels made serious inroads upon the coal market.

This combination of factors brought on acute depression in the bituminous-coal industry as early as 1924. Between 1923 and 1929 more than 3,000 commercial mines were forced to close, 200 million tons of annual mine capacity was shut down or permanently abandoned, and over 200,000 men lost their jobs. In this readjustment, as indeed in many of the subsequent changes in employment, the effects of technical change tended to be overshadowed.

After the depression of the early 1930's had set in, still other external factors obscured the effects of technical change within the mines. Consumption declined, particularly in the heavy industries consuming the metallurgical and coking coals. The demand which had been comparatively stationary in the late 1920's fell from 535,000,000 tons in 1929 to 310,000,000 tons in 1932. Employment fell from 503,000 men to 406,000, the drop again reflecting chiefly factors of the market. From this depression low, production recovered to 442,000,000 tons in 1937 and employment to 492,000 men in the same year.

These sweeping changes make it difficult to ascribe to the single factor of technology either the debits of unemployment resulting from increased output per man-hour or the credits of employment resulting from retention of markets that, at higher levels of cost, might have gone to competing fuels. It is possible, however, to point out some of the effects which the new loading technique has tended to have and the points at which its impacts have been felt most keenly.

Mechanical loading of coal in underground mines cannot be introduced independently, without regard for the technological level of other operations. Loading is in fact closely related to all preceding and subsequent production steps and can be effectively mechanized only when properly geared to those other steps, providing seam conditions are favorable. Given proper physical conditions, mechanical loading proves most easily adoptable, from the engineering viewpoint, in mines which have gone furthest in mechanization before. Where the methods used on related operations are not suitable to mechanical loading, the installation of loading devices requires also appropriate changes in these other operations and the equipment used in them before the mechanization of loading can be carried through without causing costly breakdowns and bottlenecks. Individual mines and even districts do exist in which physical conditions prevent, at present, the mechanization of loading despite the fact that other operations are carried on along the most modern lines. To such mines the introduction of loading machines elsewhere may have meant some impairment of their competitive positions. In general, however, the availability of machines for the loading of coal provides a technical base for increasing the economic advantages of those mines which, by reason of financial ability, good management, or other factors, have been able to make use of the most modern techniques available before. Such advantages were in the past enjoyed primarily by the larger mines. This is partly reflected in the fact that for decades past mines with an annual production of 200,000 tons or more had an average output per man per day which was about 50 percent greater than that of mines producing less than 50,000 tons. In part, however, this difference also reflects the fact that the larger mines are, on the whole, working the thicker and therefore the less labor-consuming seams.

The mechanization of loading is, as already stated, the present phase of a long history of technological changes. Once the general technology of machine construction and power utilization had developed sufficiently to make mechanical loading possible, commercially feasible machines were bound to appear on the market. Moreover, there was considerable economic pressure to mechanize. Under the system of underground coal production using the hand-loading method, wages constitute about two-thirds of total production costs and the process of loading coal by hand consumes about half of the labor employed in a mine. Depending on the type of mechanical loading device installed, the resource conditions of the mine, and the efficiency with which a mine is managed, mechanical loading can displace from about 10 to 40 percent of the total mine labor used under hand loading.

By the time the first loading machines were put on the market these economic pressures toward mechanization, inherent in the character of the production process, had become augmented by others which flowed from the arrest of the growth of the demand for coal. Two factors in particular tended to determine the regions of mechanized loading activity. One was the suitability of natural-resource conditions to the available types of loaders; the other was the level of wage scales. The wage rates, never so high as to yield more than a meager annual income for the mass of the mine workers, had during and shortly after the war reached a point where, relative to the purchase price of the machines and the carrying charges, it would generally have been profitable to substitute mechanical loading for hand loading.

When, shortly after 1923, the wage scale collapsed in the Appalachian region, it was not profitable for the coal operators in that region to install the loading machines. This was especially true of the southern part of the region where wage rates eventually dropped to less than half of their former levels. The situation changed abruptly with the adoption of the NRA codes, the resumption of collective bargaining, and the elevation of wage rates to levels more nearly approximating those paid in the North. The fluctuations in wage rates and their incidence go far to explain the jerky and spotty way in which the mechanization of loading has thus far proceeded in the several producing areas of the coal industry: first the mechanization mainly in Illinois, Indiana, and the far West, then, since 1934, the extremely rapid mechanization in certain portions of West Virginia where seam conditions were most favorable to the new technique. For, in the face of overexpanded mine capacity, the mechanization of loading played an important economic role in the struggle for survival. The complicating factors that serve to obscure this role involve the simultaneous spreading of another technological change - strip mining, a method which is even more intensely mechanized and labor-saving than mechanical loading; wide variations in resource conditions and the degree of their adaptability to different types of mechanical loading and to strip mining; differences in the degree to which individual mines are controlled by their markets; wide variations in the size of mining enterprises; their financial and managerial resources; and their consequent abilities to adopt mechanical loading successfully.

The statistics for Illinois and Indiana indicate that the mines that mechanized their loading were chiefly the larger mines and that, so far as stability of operations and of the level of employment are concerned, they fared far better than those which continued to load by hand. However, for many coal operators the alternative to mechanize or not did not exist. The data on underground mining presented in this report show that when the coal mines of a particular region are classified according to whether or not they had successfully adopted mechanical loading by 1935, the result is a grouping of mines into what might loosely be called "good" mines and "poor" mines. By and large, the group which includes the mines that successfully mechanized their loading processes consists of those whose physical resources were peculiarly adaptable to mechanical loading, whose financial resources were superior, whose management was alert, or who were otherwise in a position to make effective use of the new technology, perhaps because their mine lay-out followed modern principles and was therefore more easily adaptable to modern techniques, or because their size made possible a more economical utilization of the new equipment. Mines with widely different financial and physical resources may be able to continue competing in the same market so long as all are on a hand-loading basis, but the introduction of mechanical loading in some may force the others into submarginal positions and lead to their eventual shut-down. In most instances the mines which mechanized had enjoyed more stable operations than the other mines even before the mechanical loaders were installed, and the very factors which enabled them to mechanize were also the ones that enabled them before to maintain a relatively stable level of employment.

It is not possible to determine the extent to which the stability of the mechanized mines was attained at the expense of those that either could not or failed to mechanize. The severe competition which set in shortly after the World War took its toll principally among the smaller mines of "commercial" size. While the total number of mines producing over 200,000 tons a year increased between 1923 and 1929, the number of mines producing from 10,000 to 50,000 tons a year declined about one-third between 1922 and 1924 and has continued to decline to date. The mushroom-like growth of truck mines in recent years has multiplied the number of mines producing less than 10,000 tons a year, but this growth is ascribable to technological developments outside the coal industry - the rise of hard roads and cheap trucks - rather than to improvements in the technology of mining. Much of the decline in the number of mines producing from 10,000 to 50,000 tons a year represented a liquidation of overcapacity, but some part of it was doubtless the result of inability or failure to mechanize and thus to compete effectively with the larger, mechanized mines.

When the coal industry ceased to expand its production, technological improvements had to result in a reduction of labor requirements, although failure to take advantage of the economies which could be effected by the mechanization of loading might itself have resulted in further loss of markets and jobs. Regardless of what the eventual or indirect results of mechanization may be, individual workers were bound to suffer unemployment as a result of technological displacement. Unless the rate of mechanization was geared to the number of job separations which normally occur as a result of voluntary quitting, retirement, death, and similar causes, some workers were displaced by machines even if they had been attached to the pay rolls of mines that were successfully mechanized. For those who remained on the rolls of these successfully mechanized mines, the change in technology meant an increased measure of immediate job security, but for those displaced and for many of those who were attached to mines that could not mechanize, the effect was just the reverse. As long as production did not expand, the total number of jobs available in the industry as a whole would have declined much more sharply than it did had not employment policies been adopted which involved both temporary and permanent reductions of standard working hours per day and per week.

This report was prepared under the administrative supervision of O. E. Kiessling as one in a series of studies conducted by the National Research Project in cooperation with the United

States Bureau of Mines. The factual information upon which the report is based is drawn largely from statistics collected by the Bureau over a period of many years. The statistical approach to the study and the handling of original data were directed at the start by Frederick G. Tryon, formerly Chief of the Coal Economics Division of the United States Bureau of Mines and now Director of the Division of Research of the National Bituminous Coal Commission, and by Fred E. Berquist, formerly Special Consultant to the National Research Project and now Special Assistant to the Attorney General, United States Department of Justice.

The outline followed, with some modification made in writing the report, was prepared largely by Mr. Tryon who also assembled the staff of authors and participants. Responsibility for writing the report was taken by Willard E. Hotchkiss, Consultant to the National Research Project, now Maurice Falk Professor of Social Relations at the Carnegie Institute of Technology. As author or joint author of individual chapters Mr. Hotchkiss contributed largely to the text of the final report.

Charlotte K. Warner, Assistant Economist of the National Research Project, was associated with the study from its beginning and was responsible for supervising the staff, assembling new materials, drafting much of the report, and editing copy. Responsibility for the accuracy of the statistical operations fell chiefly upon Mildred A. Keller, Research Assistant of the National Research Project.

Leo N. Plein, Senior Engineer-Economist, formerly of the Bureau of Mines and now of the National Bituminous Coal Commission, assembled materials and drafted the major portions of chapters III and VI. He reviewed all of the final copy. Joseph J. Gallagher, Assistant Statistical Analyst of the National Research Project, collaborated in the preparation of chapters V and VII and read critically many sections of the report, especially those dealing with labor conditions.

Walter M. Dake, Research Manager, Mining Publications, McGraw-Hill Publishing Company, New York City, as Consulting Engineer of the National Research Project, supplied information, gave generously of his time and advice, and reviewed the manuscript of the report. Mr. Dake is also joint author of chapters III and V. Robert L. Anderson, Engineer Economist of the National

Bituminous Coal Commission, collaborated in the preparation of chapter IV.

Indispensable data were drawn from Margaret H. Schoenfeld's unpublished monograph, "Physical Conditions in Bituminous Coal Mines." This study, prepared originally for the Brookings Institution in 1926 under Mr. Tryon's supervision, contains valuable descriptive material on resource factors and has been largely used in chapter III.

Former and present National Research Project staff members J. Edward Ely, Nicholas Yaworski, and D. C. Ashmead furnished access to some of the materials used, especially in chapters I, II, and VII. Cooke Settle is largely responsible for the design and lay-out of the graphic charts. Wilhelmina F. Whiting aided in the editing of the final draft of the report.

Invaluable assistance in meeting many of the problems which arose as the study progressed was also given by the following: M. van Siclen, Chief Engineer of the Coal Economics Division of the United States Bureau of Mines; Lida Mann, Staff Member of the same division; and Mary W. McMillan of the Division of Research of the National Bituminous Coal Commission. The completed manuscript was edited and prepared for publication under the supervision of Edmund J. Stone.

DAVID WEINTRAUB

PHILADELPHIA
August 22, 1939

CHAPTER I

INTRODUCTION*

The bituminous-coal industry has been the subject of many inquiries in past years. All efforts to diagnose the problem which reflects itself in the chronic meagerness of employment opportunity have shown that many complex forces have aggravated it; the problem's causes lie far deeper than its symptoms. This study is directed toward an examination of the effects of technology on employment in bituminous mining.

The timeliness of an inquiry into mechanization in the bituminous-coal industry derives in part from the importance of coal both as a source of energy and as a source of employment and in part from the decline which the industry has suffered since the World War. Coal is still the most important energy producer, and soft coal constitutes the dominant source of the coal-energy supply. Bituminous-coal mining still employs more labor than any single branch of manufacture. But in the years since the war a great change has come over the fortunes of the industry. From 1899 to 1919 the demand for soft coal grew steadily at the rate of 16,800,000 tons a year.[1] After 1918 the former growth disappeared under the combined effects of economies in use and competition of oil, gas, and water power. During the late 1920's, therefore, the total of consumption and exports fluctuated now above and now below a plateau of 531,000,000 tons a year. The total of consumption and exports in 1929 was 3 percent less than in 1918.[2] Comparing production alone the decline from 1918 to 1929 was somewhat greater, for in 1918 there were huge purchases for storage. Production in 1918 was 579 million tons; in 1929, 535 million.

After 1929 the factors of combustion efficiency and competing fuels were enormously intensified by the general depression of business. At the low point in 1932 production dropped to 310 million; it came back to 372 million in 1935; to 439 million in

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*By Willard E. Hotchkiss, Consultant to the National Research Project, now Maurice Falk Professor of Social Relations, Carnegie Institute of Technology; and Charlotte K. Warner, Assistant Economist of the National Research Project.

[1] F. G. Tryon and S. A. Hale, "Coal," *Mineral Resources of the United States: 1922* (U. S. Dept. Com., Bur. Mines, 1925), Part II, "Nonmetals," p. 482.

[2] F. G. Tryon and L. Mann, "Coal," *Mineral Resources of the United States: 1929* (1932), Part II, "Nonmetals," p. 772.

1936; and estimates for 1937 and 1938 are, respectively, 442 and 342 million tons.

Similar declines are shown by the trend of employment. The number of wage earners in the peak year 1923 was 705,000. This dropped to 503,000 in 1929 and to a low point of 406,000 in 1932. In 1935 the number had come back to 462,000, in 1936 to 477,000, and the official estimate of the National Bituminous Coal Commission for 1937 is 484,000.

Aside from the effects of the great depression upon the fuel requirements of general industry, the loss of bituminous tonnage during the past 2 decades was due, as just noted, to the competition of alternative sources of energy and to improved efficiency in use, which decreased the amount of coal required per unit of product. Whatever its causes, it placed the industry under the necessity of utilizing every possible means of securing and holding business.

The impact of declining markets fell with unequal force upon different mines and different mining areas. Areas working under union agreements with relatively high wage standards found increasing difficulty during the middle twenties in meeting competition from nonunion areas in which standards of wages and working conditions were often extremely low. Illinois and Indiana operators also encountered an expanding and highly efficient strip-mining industry in their own territories, with the result that they were caught in a network of forces which only those who were able to put their mines on a high plane of efficiency could combat. Study of mechanization in relation to employment must not only take account of any possible loss of jobs due to the greater output per man in mechanized mines but must also consider the influence that mechanization may have had toward reducing cost and thus helping to arrest loss of business.

Bituminous mining has been undergoing technological changes for many years. The last of the important mine processes to be mechanized is loading and, in spite of large advances made during the past decade, about three-fourths of the 1938 bituminous output of the country was loaded into mine cars by hand. This task of loading still accounted for more than half the total volume of employment in bituminous mines. The chief technical difference between important mines today lies in the extent to which they have introduced mechanical loading. The employment significance of loading coal and the speed with which transition from hand to machine loading[3] is going on make mechanization of this process by far the most important current item of mining technology. The direct influence of mechanical loading on employment is reflected in part by its effect on output per unit of labor time or, reciprocally, on labor requirements per ton of coal produced.

Analysis of past and current trends of unit labor requirements is the crux of the present inquiry. Data available for a study of such trends are found in the annual reports which coal operators for many years have made, first, to the United States Geological Survey and, in later years, to the United States Bureau of Mines. These records go back to the year 1890. Similar though less reliable data were reported for the census year 1880, and the analyses contained in the present study begin with that year.

This statistical record of bituminous operations was made possible by voluntary cooperation of thousands of coal operators throughout the United States. The accuracy and comparability of information under a system of mass reporting will obviously vary between concerns and between items in the schedule of information. Some of the time series carried for many years - for example, number of tons of coal produced - are accurate to a high degree; items relating to men employed and time worked are much less accurate in detail. The authors are well aware that the data do not permit a precise measurement of labor output, but they are the most trustworthy general information available, and it is believed that general trends are revealed with sufficient accuracy to make them a valuable guide in analyzing the relation of technology to employment. The best available measure of labor output in the bituminous-coal industry is average number of tons per man per day.[4] This figure is derived by dividing total tonnage by the number of man-days worked in any given period. Stated in terms which more directly suggest employment, the reciprocal of tons per man per day becomes man-days required per ton or, as referred

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[3] The terms "machine loading" and "mechanical loading" have been used interchangeably in this report. In the coal industry the term "machine loading" has often been used in the past to refer to loading coal by hand after cutting by machine.

[4] The following terms are used interchangeably to represent the output of labor employed directly in coal mines: labor productivity, labor output, man-day output, and output per man-day.

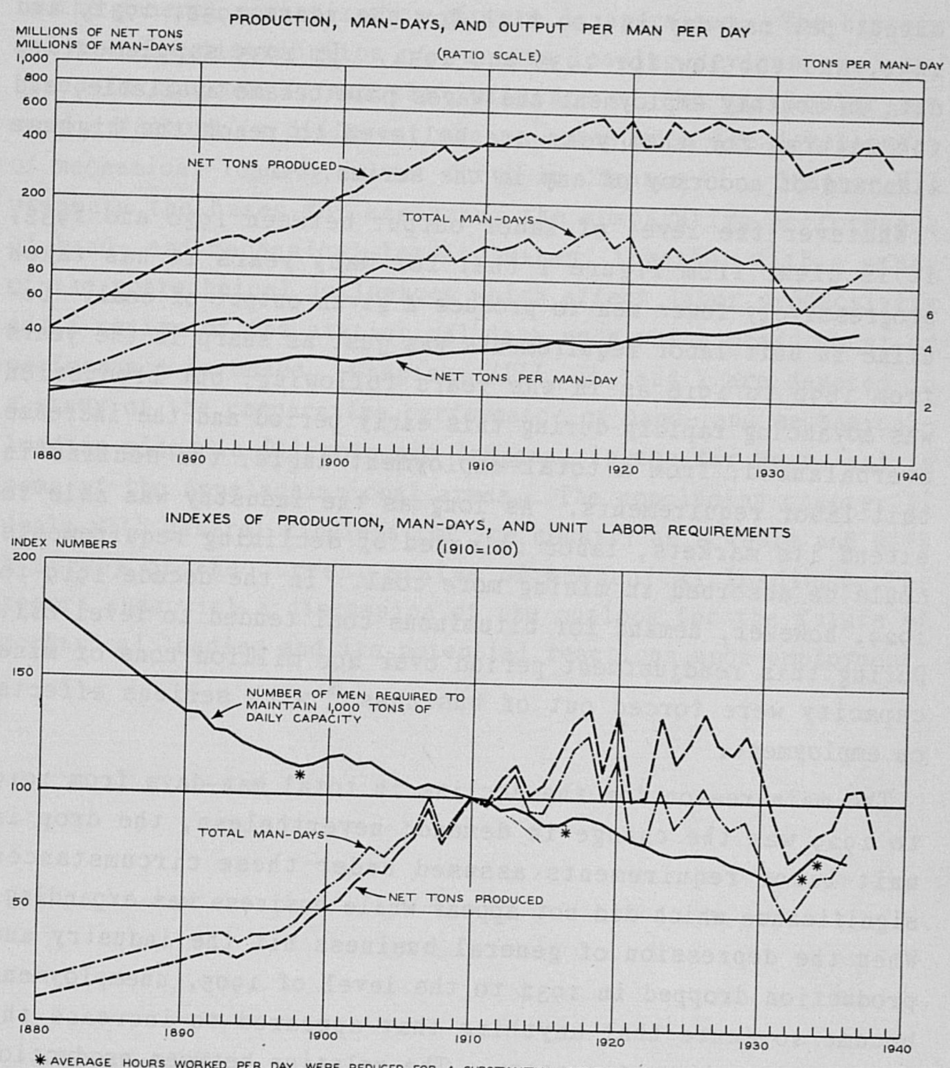
to frequently in this report, number of men required to maintain 1,000 tons of capacity.

Counting the average number of men employed in an industry presents great statistical difficulty. In the coal industry, because of intermittent operation, seasonality, and inadequate records, precise measurement of the working force becomes impossible. Precision is also lacking in the measurement of time worked by employees. The reported number of days worked in a mine in a given period is the number of days the mine tipple operated, but this may or may not vary from the number of days worked by miners. Figures for tipple operation have ordinarily been accepted as reasonably good indicators of man-time, and this no doubt is true in the great majority of cases. Although in some areas discrepancies have been considerable, for the industry as a whole they are not believed to be great enough to affect trends.

The most notable fact revealed by a study of labor output is its increase throughout the period from 1880 to 1931. Figure 1 presents graphically total production, total man-days, and labor-output data for all bituminous-coal mines in the United States. (See also tables B-1 and B-2.) In the upper panel of the chart these data are plotted on a ratio scale; in the lower panel they are shown as index numbers with the year 1910 as the base. It will be seen in the upper panel that net tons per man-day rose steadily throughout the period from 1880 to 1931 with only slight recessions. Average man-day output in 1880 was 1.90 tons; in 1890, 2.56 tons; and in 1931, 5.30 tons - almost a threefold increase in 51 years.

If these figures were translated to a man-hour basis, the increase in labor output would be somewhat greater inasmuch as the length of the working day was not the same over the period. In 1898 the United Mine Workers of America won the 8-hour day in the Central Competitive Field comprising the Illinois, Indiana, Ohio, and western Pennsylvania areas. Prior to 1898 the working day throughout the industry was probably close to 9 or 10 hours. Progress toward a universal 8-hour day was made slowly and received its greatest impetus during the World War. In 1920 practically all miners were employed at 8-hour mines. With the decline of union strength during the twenties average working hours increased, and during the depression years from 1929 to 1933 the trend toward longer

Figure 1.- LONG-TIME TRENDS OF PRODUCTION, MAN-DAYS, AND LABOR OUTPUT IN THE BITUMINOUS-COAL INDUSTRY, 1890-1936



* AVERAGE HOURS WORKED PER DAY WERE REDUCED FOR A SUBSTANTIAL PORTION OF THE WORKERS IN 1898, 1916-17, 1933, AND 1934.

BASED ON TABLES B-1, B-2

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hours was intensified. With the new rise of union strength to the extent of almost complete coverage of the bituminous industry at the time of the NRA, hours were again standardized. The official working day was changed from 8 to 7 hours in April 1934, and in that year the man-day output, which had started to decline in 1932, reached a low of 4.40 tons.

In addition to the effect that shortening the working day had on reducing output per man-day in 1934, errors of reporting associated with the depression introduced considerable bias into the series after 1929. These biases are discussed in detail in chapter VII; the available evidence indicates that output per man-day is too high for the years 1930, 1931, and 1932, and too low for 1933 and 1934. In 1935 supplementary data on monthly employment and wages paid became available, and the returns for that year are believed to reach the highest standard of accuracy of any in the series.

Whatever the level of labor output between 1930 and 1935, it is clear from figure 1 that for many years it has taken progressively fewer men to produce a given output of coal. Decline in unit labor requirements was just as sharp in the years from 1890 to 1918 as in the years following, but production was advancing rapidly during this early period and the increase overbalanced, from a total-employment angle, the decline in unit labor requirements. As long as the industry was able to extend its markets, labor released by declining requirements could be absorbed in mining more coal. In the decade 1919 to 1929, however, demand for bituminous coal tended to level off. During this readjustment period over 200 million tons of mine capacity were forced out of business,[5] with serious effects on employment.

The main reason for the decline in total man-days from 1919 to 1929 was the change in demand; nevertheless, the drop in unit labor requirements assumed under these circumstances significance which did not appear while business was expanding. When the depression of general business hit the industry and production dropped in 1932 to the level of 1905, unemployment became so acute that anything that appeared to increase the strain aroused great concern. The relation between production and the amount of employment during the period of revival of the past several years will be discussed in detail in succeeding chapters in connection with the analyses by areas, but in general employment during these recent years has not increased in proportion to the increase in production.

Chapter II outlines the history of mechanization of mining processes in underground mines. In chapter III the basic resource conditions which influence the development of mining

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[5] Net, not gross, number of tons forced out of business. See E. G. Nourse and Associates, *America's Capacity to Produce* (Washington, D. C.: Brookings Institution, 1934), p. 548.

technology are analyzed, and in chapter IV strip mining, which is a technical development in response to special resource conditions in certain areas, is described, and its significance in the general mechanization picture is appraised. The history and present distribution of various loading devices are outlined in chapter V, and the influence of the particular resource factors in different mining areas upon the development of mechanical loading is set forth in chapter VI. Chapter VII presents the bases for analyzing the comparative performance of hand- and mechanical-loading mines, together with a study of the nontechnical influences which affect labor productivity and a review of the statistical data upon which measurement of performance is based. Chapters VIII, IX, and X are devoted to a study of the comparative performance of hand- and mechanical-loading mines in Illinois and Indiana, in the far West, and in some of the Appalachian coal areas. The concluding chapter XI deals with general findings for the country as a whole and with a survey of the current status of mechanical loading. The report ends with a discussion of the outlook for the future of mechanical loading and its potential reactions upon employment.

CHAPTER II

MINING UNDERGROUND AND COAL PREPARATION, PAST AND PRESENT*

Improved mineral technology in general tends to make available resources that would not or could not be recovered otherwise, but in so doing it faces the prospect of increasing physical handicaps that are likely to offset any gains in labor output. As yet this has less significance in coal mining than in metal mining because of the great abundance of coal resources and their wide distribution. To a considerable extent, therefore, mechanization of coal mining brings about an increase in labor output and a reduction in unit labor requirements in much the same way that similar changes affect industrial operations. In strip mining, furthermore, the intense application of technology has enormously increased labor productivity. Although strip mining has been increasing in relative importance, by far the greatest part of the coal is still produced by underground mining, and the present chapter attempts merely to sketch briefly those aspects of the development of mining technology which help to explain current underground-mining practice and the more recent phases of mechanization.[1]

Modern coal mining involves coordination of power machinery in the recovery of deposits which are known as beds or seams. A mine resembles a factory in all its complexities, except that

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*By Leo N. Plein, Senior Engineer-Economist, formerly of the U. S. Bureau of Mines, now of the National Bituminous Coal Commission; Charlotte K. Warner; and Willard E. Hotchkiss.

[1] The history of coal mining in all its ramifications is recorded in widely scattered material. The principal source materials used in this chapter are as follows: H. M. Crankshaw, chapters on "History of Machine Mining," pp. 64-81, and "History of Explosives," pp. 82-8, *Historical Review of Coal Mining* (London: Mining Association of Great Britain, Fleetwood Press, Ltd., 1924); Edward W. Parker, "Coal-Cutting Machinery," *Transactions of the American Institute of Mining Engineers*, Vol. XXIX (1899), pp. 405-59; Edward W. Parker, "Recent Developments in the Undercutting of Coal by Machinery," *Transactions of the American Institute of Mining Engineers*, Vol. XLI (1910), pp. 677-708; unpublished article on coal-mining machinery by Joseph F. Joy, consulting engineer, Pittsburgh, Pa.; *Coal Age*, Vol. 41, No. 10 (Oct. 1936); *Mineral Resources of the United States* (U. S. Dept. Int., Geol. Survey, 1920-23, and U. S. Dept. Com., Bur. Mines, 1924-31). Also *Report of the United States Coal Commission* (S. Doc. 195, 68th Cong., 2d sess., 1925); E. N. Zern, ed., *The Coal Miners' Pocketbook* (12th ed.; New York: McGraw-Hill Book Company, Inc., 1925); Robert Peele, ed., *Mining Engineers' Handbook* (2d ed.; New York: John Wiley & Sons, Inc., 1927); *Transactions* and *Technical Papers* of the American Institute of Mining Engineers; *Coal Mine Mechanization Yearbook, 1929* (American Mining Congress); W. E. Fisher and Anne Bezanson, *Wage Rates and Working Time in the Bituminous Coal Industry* (Philadelphia, Pa.: University of Pennsylvania Press, 1932).

in underground mines activities are carried on in extensive subterranean areas. This necessitates a comprehensive system of transportation underground. Main haulage roads lead from the drift mouth or the shaft bottom to secondary roads which in turn connect with the active working areas known as panels. Room or butt entries are driven into these panels, and turned off from these are the "rooms" where the miners work.

Besides activities that have to do directly with recovery of the coal, mining includes auxiliary services necessary to the proper functioning of a mine. Deep or underground mining involves cutting, drilling, blasting, and loading the coal, and hauling it to the tipple where, in many mines, it is made ready for market in an elaborate preparation plant. In addition to these fundamental tasks other essential services must be performed such as timbering, ventilating, pumping, supplying power, and maintenance of machines and mine.

The first coal mined was that which outcropped on the surface of the ground, but as the supply of such coal was limited, the expanding uses of coal gradually gave rise to underground mining. Coal was mined in England by means of shafts and tunnels as early as the fourteenth century. The earliest mining tools were the shovel and pick, still widely used, and it was less than half a century ago that the dominance of the miner's hand tools was challenged by more complex mechanisms.

The most prevalent system of mining coal is known as room-and-pillar mining. As the name indicates, the miners work in rooms that are separated by pillars of coal left in place for roof support. In some seams the coal may be mined continuously from long faces instead of in rooms with intervening pillars. This method, known as longwall mining, has been used extensively abroad but has found little favor in the United States; in the future it may be used more widely. As the longwall advances (or retreats) the roof is allowed to cave, the haulageways and airways being kept open by packwalls of waste. The basic occupations in the two systems are similar.

Under the room-and-pillar system miners are isolated within the circumscribed space in which they work and are necessarily dependent upon their own initiative to complete the basic tasks of timbering, drilling, blasting, and loading. In the typical mine, undercutting is now performed by machines. The miners are responsible for cleaning the coal as they load it into cars and they must so plan their work that all the necessary auxiliary tasks are properly timed and performed.

In general, the miner is traditionally responsible for taking care of his working place as well as for mining coal. Important among his incidental responsibilities is the detection of weak places in the roof which create danger of cave-ins. Wherever bad roof is found it has to be supported with timber. If, in spite of precautions, part of the roof caves in, he has to move the rock fall and timber the room against repetition of the occurrence. Where animal haulage is still used and if the seam is too thin to permit the mule, horse, or pony to enter the room, the miner has to push the cars to and from the haulageways. If water comes into the room he has to bail it out.

In thin seams it is frequently necessary to remove material from either the roof or the floor in order to provide sufficient clearance in the haulageways. This is known as "taking up bottom" or "brushing roof."

In a typical mine consisting of numerous rooms or working places the total distances that have to be traveled in supervising the work of each individual miner are considerable. The result is that unless management is well organized a miner may work for hours or even for a whole day without being visited by any member of the supervisory personnel. Such conditions still prevail in mines in which a large part of the Nation's coal is produced. Even when management is on a high level hand miners do not work under the kind of direct supervision that obtains in factories.

The use of explosives for blasting rock and breaking coal loose from the solid seam dates from the seventeenth century, but both explosives and methods of firing have undergone great improvement. The work of drilling shot holes was formerly done exclusively by hand with a long steel auger. Power drills, first used about 1890, have now been extended to 27 percent of the bituminous output of the United States.

Prior to the invention of cutting machines the groove (or kerf, as it is called) under the seam had to be cut by hand, and the pick remained a major tool of the miners long after use of explosives became standard practice. Undercutting by hand is done today only to a limited extent.

Every time a new machine is installed the miner's work and his responsibilities are modified; as more and more of the processes become mechanized, synchronization of activities of machines and the men who work with them is essential if the best efficiency is to be obtained from each. Mechanization of loading especially necessitates a balanced cycle of specialized operations, each equipped, manned, and timed to the pace and performance of the others. Table 1 shows occupations in a hand-loading and in a mechanical-loading mine.

Steam was probably the first mechanical power used in mines. It has been used for over 200 years in pumping, and was introduced for hoisting in 1780 and for driving rope haulage units underground in 1812.

As the art of using electricity forged ahead toward the end of the nineteenth century, electrical power came to excel other forms of power in convenience, flexibility, and efficiency - both in transmission and in use. Compressed air failed to compete with electric power in coal mines, and steam and compressed-air power for underground uses have now been largely replaced by electricity.

The past half-century has probably witnessed greater technical changes in the bituminous industry than occurred in all preceding years. In underground mining nearly every phase of the operating cycle has been mechanized. In a highly mechanized mine today the coal is undercut by an electric machine and hauled by electric locomotives. Where animal power is still used it is confined largely to gathering the loaded cars from rooms and taking them to assembly points served by electric motors. Mainline haulage is almost universally electrified, except at small operations. Electrically operated pumps keep working places dry, power-driven drills are taking the place of the hand auger, and the shot which blasts the coal from the seam is electrically fired. Much of the responsibility for cleaning, which formerly rested on the individual miner, has now been transferred to a complex cycle of machines found in the modern coal-preparation plant on the surface. Last and most important, loading coal into mine cars - the last stronghold of hand labor - is now performed wholly or partly by power-driven machines for about 25 percent of the total underground tonnage of the country.[2] These changes from

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[2] "Mechanical Loading," *Coal Age*, Vol. 44, No. 2 (Feb. 1939), p. 28.

Table 1.- OCCUPATIONS IN A HAND-LOADING AND A MECHANICAL-LOADING MINE[a]

Occupation	100% hand-loading mine (1929)	100% mechanical loading mine (1937)
Total men employed	543	518
On surface	41[b]	124[c]
Underground	543	518
Supervisory	5	16
Mine foremen	1	1
Assistant foremen	4	3
Section foremen	-	12
Transportation	57	42
Haulage foremen or dispatchers	1	3
Motormen and trip riders	12	24
Mule drivers	26	-
Trappers (or doormen)	4	-
Trackmen	10	11
Wiremen	4	4
Maintenance, etc.	36	43
Timbermen	20	12
Bratticemen	2	3
Day laborers	14	2
Pumpmen	1	1
Shopmen (underground machine shop)	-	8
Supply men	-	6
Recovering material	-	11
Production - hand loading	403	-
Cutting-machine operators and helpers	40	-
Miners - coal loaders[d]	363	-
Production - mechanical loading	-	293
Loading-machine operators and helpers	-	38
Cutting-machine operators and helpers	-	50
Motormen and brakemen	-	50
Drillers and shooters	-	26
Preparation men	-	13
Stonemen (handle draw slate)	-	65
Track layers	-	25
Timbermen	-	26
Average production		
Per day	3,119[e]	3,670[f]
Per man per day	5.74[g]	7.08[h]
Per man per hour	0.72	1.01

[a] The two mines for which data are presented are highly efficient ones, both operating in No. 8 Seam in Eastern Ohio and having similar physical conditions. The material was derived from unpublished notes taken during field trips by L. N. Plein and R. L. Anderson and made available by the U. S. Dept Int., Bur. Mines.

[b] Includes tipple boss, tipple men, pickers, car droppers, mechanics, blacksmiths, carpenters, drivers, bit sharpeners.

[c] Includes, in addition to occupations listed in ftn. b, operators of mechanical cleaning equipment.

[d] Miners drill shot holes, fire shots, handle draw slate, lay track, and timber in their working place.

[e] One 8-hour shift.

[f] Three 7-hour shifts.

[g] Per 8-hour shift.

[h] Per 7-hour shift.

hand to machine mining as applied to underground processes are outlined in the following sections.

MACHINE CUTTING

When a mine has been developed to the point at which it is a going concern, the coal face toward which the mining process is directed constitutes a solid vertical wall, the height being equal to the thickness of the seam. The coal can be blasted from the solid face of the seam without any advance preparation of the seam itself. However, the heavier charge and the greater resistance when seams are blasted uncut increase the shattering effect and result in an excessive amount of fine, unmarketable coal. Also, the heavy charge always creates danger that the shots will blow out and ignite coal dust or gas at the face, or that they will weaken the roof. This method, called "shooting off the solid", is still used to some extent, although certain States have prohibited the practice.

Dangers incident to shooting off the solid, together with the degradation resulting from using a large charge of explosive, led to the practice of cutting under or across the coal seam in order to give room for expansion when the blast by which the coal is to be loosened is fired. This not only lessens the danger and minimizes the shattering effects of the explosive but also reduces the amount of explosive required. When no machinery was available for cutting it was necessary for the miner to perform the task with a pick, and undercutting by hand was one of the most arduous and time-consuming operations in mining. In some cases the top of the seam was cut, in others a shearing cut was made from top to bottom, but the most frequent practice was to cut under the seam. The only way this could be done by hand was for the miner to lie on the floor of the room and gradually pick away a slot under the coal. This cut was known as a kerf, a name which it still bears when cut by machine. It usually extended back under the seam for a distance of 2 or 3 feet and was wedge-shaped, a foot or more high at the front and several inches high at the back. While the cutting was proceeding, the overhanging coal was propped up or "spragged" with timber posts or blocks so that it would not break loose and crush the miner working beneath it. Cutting across the face of a 20-foot room usually required 2 to 6 hours of backbreaking work; it was to be expected that inventive talent would be directed toward obviating such a task.

The earliest types of cutting machines had a percussive action in imitation of the hand pick. The first patent of a percussive machine operated by hand levers was recorded in England in 1761, but the first really successful machine in the United States was a compressed-air machine called the puncher, patented in 1877 by J. W. Harrison. The air-driven puncher continued in use until about 1910 and was reported to have achieved considerable success in increasing productivity and in reducing costs.[3]

As usually happens in the development of technology, the perfection of early inventions came only when imitation of the hand process was discontinued. A machine consisting of a horizontal rotating wheel with projecting teeth and operated by manpower was patented in England in 1852. Later adaptations of this disk-type machine enjoyed considerable popularity abroad but made little headway in this country because it was suited primarily to longwall mining.

The bar-type cutter was another early departure from the percussive type developed in England and on the Continent for longwall mining, the first machine being patented in 1856. It remained, however, for the chain-type machines developed in this country to fill most adequately the early needs of a coal cutter in the United States.

The first breast[4] machine, a contemporary of the puncher, was placed on the market in 1876. Originally the machine consisted not of a chain but of a revolving bar on the front of a cutter frame.[5] This bar, on which were mounted teeth or bits, was constantly forced against the coal, the depth of the cut being limited by the length of the cutter bar. When the cut was completed the machine was withdrawn and started in again.

In 1894 three manufacturers brought out chain-breast machines which almost immediately drove the bar-type machine off the

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[3] For further details concerning the results achieved with puncher-type machines consult the following documents: *Thirteenth Annual Report of the Commissioner of Labor, 1898: Hand and Machine Labor* (1899), vol. II, pp. 1578-81; J. G. Hudson, "Notes on Coal Cutting Machinery at the Collieries of the Dominion Coal Co., Ltd.," *Transactions of the Mining Society of Nova Scotia*, vol. III (1894-95), pp. 94-103.

[4] Breast is another name for the face of a room.

[5] The principle of this machine was different from that of the English bar-type machine, and it is a forerunner of the chain-type one.

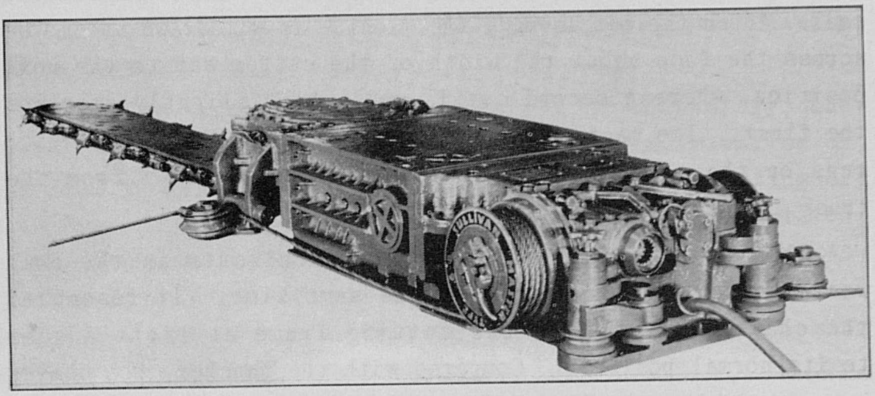
market and which, as they were gradually improved, began to replace the puncher machines - the principal type in use at the end of the century.

The cutter element of the breast machine is a heavy plate about 44 inches wide, known as the cutter bar, which projects about 6 feet in front of the machine. Around the outer edge of the plate is an endless chain fitted with removable steel bits. When the machine is started the endless chain revolves, and the cutter bar is automatically fed forward against the coal. After the cut is made the machine is withdrawn and moved across the face about the width of the cutter bar to the next position, where a second cut is made which slightly overlaps the first. The machine moves about the mine on a truck which runs on the mine track, but it has to be removed from the truck and skidded up to the face for operation.

A shearing machine for making vertical cuts in the coal was also brought out at about the same time. It resembled the chain cutter, with the cutting frame at right angles to its normal position. Compared with the puncher, the chain-breast machine nearly doubled the speed of undercutting and greatly reduced the strain on the operator.

The first modifications of the chain-breast machine were made in order to permit continuous operation for the full width of the working face. The longwall and shortwall machines were the first continuous cutters, the chief difference between them being the position of the cutting device. In the longwall machine the cutting arrangement is in position at the side of the machine during the cutting operation, whereas in the shortwall machine it is fixed longitudinally with the body of the machine. The shortwall machine was patented in 1900 and put on the market in 1906. It was not until about 1910 that it came into general use, but from that time on it rapidly replaced both the breast machine and the compressed-air puncher. With its adoption the speed of undercutting increased greatly. A series of observations made by the United States Coal Commission of 1923 revealed that the shortwall machine would do nearly two-thirds more work than the breast machine.

A later stage in the improvement of the cutting machine dealt with ease of manipulation. Track-mounted machines, introduced about 1911, operate without being removed from the track and cut at any elevation in the coal face. Machines are now available that will top-cut, center-cut, under-cut, and shear in either rib or at any point in the coal face. The flexibility of the modern machine permits the cutting of the coal in such a way as to reduce to a minimum the amount of jar in blasting, an important advantage where roof is tender and subject to cave-in. Center cutting makes it possible to take out bands of impurities before blasting and thus to avoid mixing them with the coal. Various estimates have placed the



Sullivan Manufacturing Co.

Shop View of Shortwall Undercutting Machine

Sullivan Manufacturing Co.

Shortwall Machine Undercutting in Thin Seam

FIGURE 2.— CUTTING MACHINES

capacity of track-mounted machines at three times that of the chain-breast and twice that of the shortwall machines.[6]

Improvements since the World War have pertained chiefly to the improvement of existing types of cutting machines, with great advances in power, flexibility, and capacity. In addition, two entirely new developments may be mentioned. The pick hammer, widely used in Europe and gaining increased attention in America since 1929, is a pneumatic-puncher type of machine which picks down the whole face of the coal without undercutting or explosives. The coal saw, introduced in 1931, makes thin horizontal and vertical cuts that leave the face in blocks; the coal is then loosened by hydraulic pressure applied between the cuts. Both of these have had limited use up to the present time.

The last few years have witnessed a widening in the field of cutting because of the evolution of machines designed to load the cuttings and the development of track-mounted machines with double bars for cutting out refuse bands and of other devices for performing specialized tasks. The length of the cutter bar has been increased and the cutter bits, because of improved quality of steel, are slower to dull and have to be changed less frequently. The time required to change the bits has, moreover, been reduced from about an hour to as low as 8 minutes.

Considerable change is taking place in the relation of cutting to other operations in the mine. With the heavier types of cutting machine, which were costly to move from place to place, two men constituted the crew which operated a machine, and their labor was confined to the actual cutting of coal. With the introduction of mechanical loading, especially of the conveyor type, the loading equipment interfered with the movement of the cutter from place to place. To meet this problem a lighter and cheaper cutting machine has been designed for use with a crew of three or four men who are responsible not only for cutting but for shooting, timbering, and loading. This type of organization may show a decrease in the output per day of the cutting machine in order to increase the efficiency

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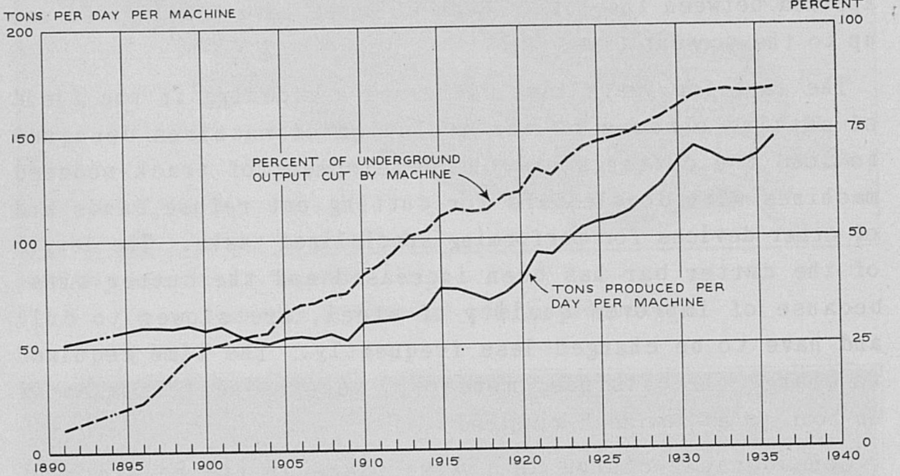
[6] The quantity of coal cut depends upon a dozen or more variables other than the kind of machine - notably, thickness of seam; length of cutter bar; feed of machine; expertness of the machine runners; absence of delays; constancy and abundance of power; quality of mine management; hardness of the coal; absence of rolls, clay veins, and sulphur balls; and width of working place.

of the conveyor unit - an illustration of the balanced operation which a high development of mechanization necessitates.

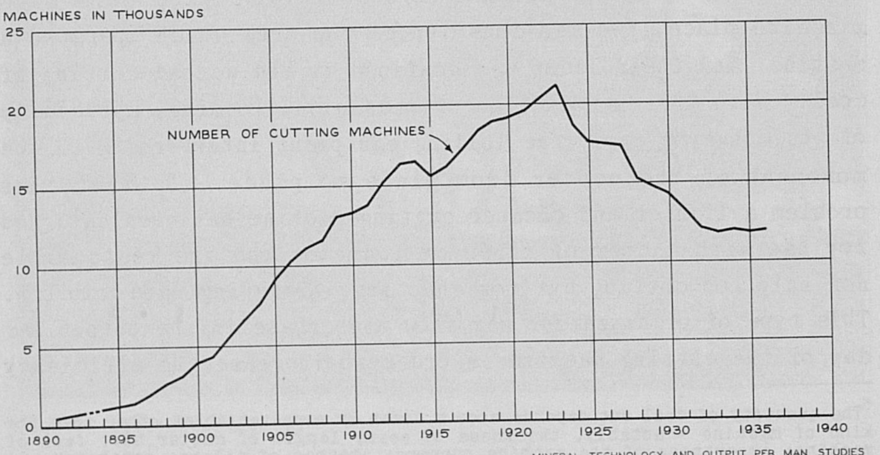
Figure 3 and table B-3 present a summary of statistical data on machine cutting. In 1891, the first year in which data on undercutting became available, 545 machines (mainly punchers) undercut 6,211,732 tons of coal, or 5.3 percent of the total United States production. The average yearly production per machine was 11,398 tons, or 51.11 tons per day per machine.

Figure 3.- LONG-TIME TRENDS IN MACHINE CUTTING OF BITUMINOUS COAL, 1891-1936

PERCENT OF UNDERGROUND OUTPUT CUT BY MACHINE AND OUTPUT PER MACHINE



NUMBER OF CUTTING MACHINES IN USE



BASED ON TABLE B-3

MINERAL TECHNOLOGY AND OUTPUT PER MAN STUDIES
WPA-NATIONAL RESEARCH PROJECT E-142

Although no data are available after 1912 on the types of cutting machines in use, the bottom panel of figure 3 shows that the total number increased rapidly up to 1923, except in the years 1915 and 1916. The decline thereafter is a reflection of the large number of mine closures and also of replacement of older types by newer machines of larger average capacity.

From 1891 to 1910, the period when punchers and breast machines were flourishing, the tons of coal produced per machine per day, as seen in the upper panel of figure 3, varied little, but with the introduction of the shortwall machine tonnage showed a perceptible increase. Except during the war years and 1922, output per machine per day increased materially up to 1931, with an increase of 136 percent over 1910. A new record of daily output was established in 1936.

The percentage of production cut by machine increased steadily year after year to 84.7 percent in 1933. Since 1933 the curve has shown a tendency to level off, indicating an approach to the saturation point. In most districts the cutting machine is now about as widely used as conditions permit. In Iowa and Kansas, where very thin seams are mined and where the bottom is rolly, the use of the cutting machine has been limited. In Maryland, where a great deal of second and third mining of coal originally left in place is now being done, hand undercutting is used when necessary. In longwall mining the pressure of the roof is sometimes utilized to bring down the coal, and undercutting is not required.

In the past few years a new, small type of undercutter for use in particularly thin seams has been developed. Attention has been given to producing a machine which will be economical for use in mines with a low daily output. Machines of this type already on the market have extended the field of undercutting in small mines. Although this will furnish a new market for machines, it will add little to the percentage of deep-mine tonnage cut by machine since the total output of these small operations is almost negligible when compared with the total bituminous production of the country. The future of machine cutting lies chiefly in improvements in design and in the replacement of earlier machines with superior models.

DRILLING AND BLASTING

Although drilling is directly a part of the mining process, it does not occupy a major position like that of cutting, loading, and hauling. Drilling is usually done by miners who are occupied with other processes, and it is chiefly in very large mines that it constitutes a separate occupation.

Installation of power drills for use in bituminous mines began as early as 1890. Compressed-air drills were used in the nineteenth century, and as early as 1911 electrically propelled augers, including types which were mountable on cutting machines, were placed on the market. Not until the period of the World War was the industry particularly concerned with power drilling in coal. One-man portable drills came into use in 1917 and 1918, and from 1919 until 1925 a gradual increase occurred in the number of power drills placed in service. Hand augers, however, predominated, and it was not until mechanical loading made it necessary to put all operations on a balanced cycle that the wider use of power drilling became essential. From 1925 to 1936 the use of power drills gained steadily, except during the depths of the depression, and the impetus from 1934 to 1936 was greater than at any other time. The following extract taken from a weekly coal report of the National Bituminous Coal Commission shows the importance of power drilling in 1936:

> A preliminary survey covering the year 1936 indicates that 27.2 percent of the deep-mined bituminous coal output was produced from working places in which the shot holes were drilled by mechanical power drills as contrasted with hand drills. The tonnage amounted to 111,950,000 tons. Power drills are in use or on trial in nearly every important coal-producing county in the nation. . . . The conditions under which this kind of labor-saving device is used are widespread, not only geographically but also in thick and thin beds, in pitching seams, in flat beds, and in coals of varying degrees of hardness.[7]

Table 2 shows the coal produced by power drilling and a comparison of the percentages power-drilled, cut by machine, and mechanically loaded. The States showing the highest percentage

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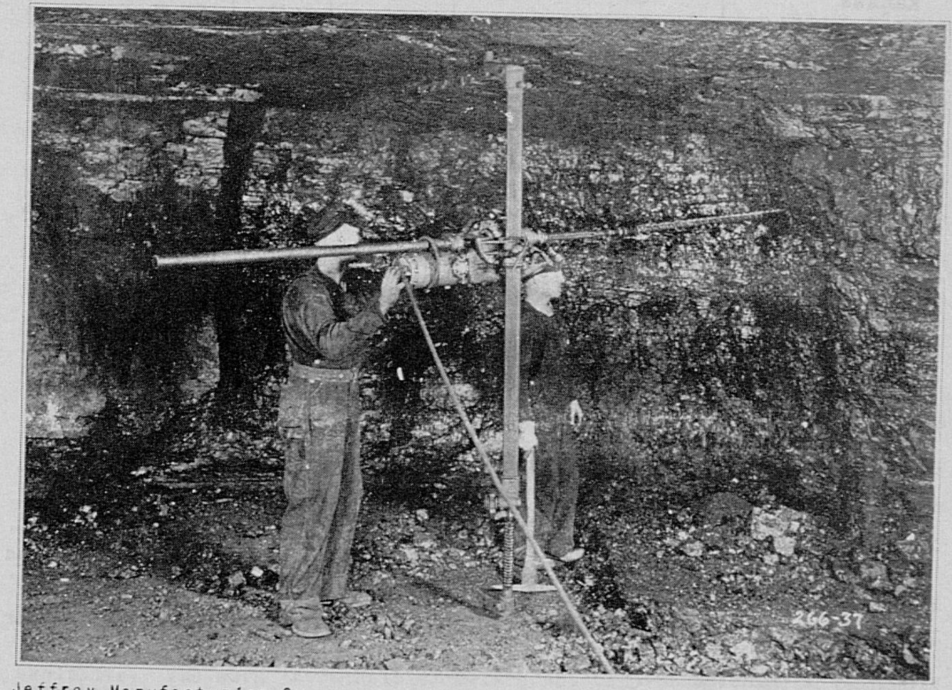
[7] J. J. Gallagher and L. N. Plein, "A Reconnaissance of Power Drilling in Underground Bituminous Coal Mines in 1936," *Weekly Coal Report No. W. C. R. 1118* (U. S. Dept. Int., Nat. Bituminous Coal Com., mimeo., Dec. 17, 1938), p. 4.

Van Dorn Electric Tool Co.

Hand-Operated Electric Power Drill



Jeffrey Manufacturing Co.

Post-Mounted Electric Power Drill

FIGURE 4.- POWER DRILLS

Table 2.- COAL PRODUCED IN UNDERGROUND BITUMINOUS MINES IN WORKING PLACES WHERE SHOT HOLES WERE POWER-DRILLED AND PERCENTAGE OF TOTAL UNDERGROUND OUTPUT POWER-DRILLED, CUT BY MACHINES, AND MECHANICALLY LOADED, 1936[a]

State	Thousands of net tons produced by power drilling			Percent of total tonnage		
	Electric drills	Compressed-air drills	Total	Power-drilled	Cut by machines	Mechanically loaded[b]
United States	100,050	11,900	111,950	27.2	84.8	16.3
Alabama	3,810	160	3,970	23.0	72.8	14.3
Tennessee					70.0	5.7
Arkansas	240	0	240	6.8	81.2	33.3
Oklahoma					78.4	(c)
Texas	780	10	790	11.6	0	0
Colorado					68.6	8.2
Illinois	27,110	10	27,120	64.9	88.4	62.4
Indiana	8,010	0	8,010	79.0	90.3	70.5
Iowa	80	0	80	1.3	35.7	(b)
Kansas					28.3	0
Missouri					58.6	0
Kentucky	12,490	0	12,490	26.3	93.7	1.4
Maryland	(c)	0	(c)	(c)	35.6	(c)
Michigan	(c)	0	(c)	(c)	98.3	0
Montana	1,200	120	1,320	75.0	92.9[d]	83.2
New Mexico	160	0	160	10.0	25.8	(c)
North Dakota	(c)	0	(c)	(c)	68.0[d]	(c)
Ohio	4,800	0	4,800	22.2	94.6	9.5
Pennsylvania	10,380	10,860	21,240	19.5	76.9	8.3
Utah	2,400	10	2,410	74.2	87.4	41.8
Virginia	2,830	10	2,840	24.4	90.2	6.7
Washington	490	560	1,050	57.9	35.9	33.6
West Virginia	19,530	110	19,640	16.7	92.0	7.4
Wyoming	5,180	50	5,230	92.8	94.5	92.0[e]
Other States	–	–	–	–	20.6	–
Undistributed	560[f]	0	560[f]	17.6[f]	0	12.6[g]

[a] J. J. Gallagher and L. N. Plein, "A Reconnaissance of Power Drilling in Underground Bituminous Coal Mines in 1936," *Weekly Coal Report No. W. C. R. 1118* (U. S. Dept. Int., Nat. Bituminous Coal Com., mimeo., Dec. 17, 1938), pp. 4-6.

[b] Includes mobile loaders, scrapers, duckbills, other self-loading conveyors, pit-car loaders, and hand-loaded conveyors.

[c] Included in "Undistributed."

[d] Includes lignite figures published by U. S. Bureau of Mines, "Lignite Tables, 1936."

[e] This figure does not agree with that shown in table B-34 because stripped tonnage only from mines whose total tonnage was produced by stripping was subtracted in order to obtain the underground production used in computing the above percentages.

[f] Includes Maryland, Michigan, and North Dakota.

[g] Includes Oklahoma, Iowa, Maryland, New Mexico, and North Dakota.

of deep-mined production power-drilled are Wyoming, Indiana, Montana, Utah, Illinois, and Washington. With the exception of Washington these were the areas with the highest percentage of their tonnage mechanically loaded in 1936. Electric power drills accounted for about 90 percent of the tonnage power-drilled. Pennsylvania was the only important State where compressed-air drills were used in substantial numbers.

Parallel with the improvement in methods of drilling have gone improvements in explosives and methods of shooting.

The use of gunpowder as an explosive for blasting coal was introduced in Europe during the seventeenth century, but methods of use remained clumsy and dangerous until the development of the safety fuse in 1840. The next great advance was the invention of dynamite in 1867, and, from 1870 on, types of dynamite especially adapted for use in coal mines were rapidly developed.

The frequency of mine disasters caused by explosions led in 1872 to the English Coal Mines Regulation Act which, among other things, controlled the use of powder in mines. Toward the end of the nineteenth century a number of so-called flameless explosives were introduced, but they proved unsuccessful for use in places where explosive gases were present. These difficulties finally led to the erection of a testing station at Woolwich, England, which by 1901 had placed 25 types of explosives on a "permissible" list. In the United States the Bureau of Mines, which was established in 1910, has pioneered in the study and approval of permissible explosives.[8] These so-called permissible explosives, when used under proper conditions, are much safer than the earlier types.

When loading machines are introduced, it becomes necessary to revise blasting practices because the efficiency of the mechanical loading device depends upon the maintenance of an adequate supply of loose coal in sizes convenient for the

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[8] "A permissible explosive is one that has passed certain tests conducted by the United States Bureau of Mines at the Explosives Experiment Station, Bruceton, Pa. After the explosive has passed these tests it is placed on the official list of explosives permissible for use in coal mines and may be sold as a permissible explosive. The word 'permissible' refers not only to the explosive itself but also to the method of using the explosive underground. Thus, in addition to specifying that the explosive actually used should be similar in all respects to the sample submitted by the manufacturer for test, the Bureau specifies the use of electric detonators and states that the explosive must not be used in a frozen condition, that the quantity used for a shot must not exceed 1½ pounds, and that the charge must be confined properly in a borehole with clay or other incumbustible stemming." (D. Harrington and S. P. Howell, "How to Use Permissible Explosives Properly," [U. S. Dept. Int., Bur. Mines I. C. 6871, mimeo., Jan. 1936], p. 2.)

machine to handle. The first modifications generally included a heavier blast, with the result that higher proportions of less saleable coal were produced. This situation, coupled with safety requirements, focused attention on improved blasting practice, which has developed along two separate lines. The first involves drilling more shot holes in the face and using lighter charges in each hole, thus reducing degradation. The second has been the application of mechanical force to replace the chemical explosive.

Several methods of using mechanical force were tried before any were found that seemed to meet all the requirements of practical operation. One of the earliest devices was the hydraulic blasting barrel inserted into a drill hole in the face and expanded under hydraulic pressure by a hand-operated pump. A somewhat similar principle was embodied in a device by which a rubber tube was placed in a drill hole and inflated by hydraulic pressure of 5,000 or 6,000 pounds per square inch, which was sufficient to break down the coal. Hydraulic pads were tried in the thin kerfs cut by mechanical saws. Such devices have had limited use as they are practical only under favorable conditions. The possibility of using hydraulic power to break down coal has not been abandoned, however, and experiments are being carried on which may yet lead to successful applications.

The cardox system is a method of dislodging coal by use of liquid carbon dioxide charged into steel shells. The slow heaving action of the carbon dioxide gas is employed as the blasting force. Cardox first underwent an operating test in Illinois in 1926 and since then has met with considerable success in several fields. Airdox, introduced in 1933, uses a cartridge in the drill hole charged with compressed air which, when released at high pressure, dislodges the coal in substantially the same way as the chemical explosives. Compressed air or harmless gases have advantages over chemical explosives from the standpoint of safety, and they appear to minimize the shattering effect of blasting. For these reasons they are making substantial headway.

UNDERGROUND HAULAGE

Mine transportation in 1880 was done chiefly by animals. The mule is the animal most frequently associated with underground haulage, but horses, ponies, and even dogs were used. Animal haulage was a distinct improvement over the human effort previously expended in carrying sacks, dragging tubs, and pushing cars of coal. With production mounting steeply from 1870 to 1900 and mines increasing in size, distances underground likewise increased and created a serious need for better transportation.

About 1870 rope haulage patterned after English experience, replaced mules for mainline haulage in a considerable number of mines. One great advantage of rope haulage is that it can be used in seams in which the pitch is relatively steep;[9] on the other hand, it can be used advantageously only along relatively straight entries. On the whole, it increased the haulage output per man-hour, but the saving was limited by the fact that the speed with rope haulage was usually no greater than with mules. For the most part, rope haulage disappeared with the advent of electric-motor haulage.

Steam locomotives were first used at approximately the same time that rope haulage was introduced. Though their main use was in surface haulage, a few were also installed underground. Compressed-air locomotives were introduced in 1875, and after some experimentation a number were installed, particularly in West Virginia and Pennsylvania. Within limits they were satisfactory, but they were bulky and required frequent recharging, which limited their radius and time of operation.

At the end of the century experiments were made with gasoline locomotives, the earliest installation being in Kentucky in 1898. In mobility the gasoline engine had the advantage of a self-contained unit, but it gave rise to problems of noxious gases, air pollution, and fire hazards which greatly restricted its use underground. Some few were installed underground but their chief use was on the surface.

Diesel engines have been used successfully in German, Belgian, and French mines, and during the past few years engineers have again considered their use in America. Diesels would be expected not only to reduce power cost but also, by eliminating trolley wires, to reduce electric hazards. Current Diesel designs are said to avoid the dangers of monoxide gas

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[9] Rope haulage units are still used effectively in mines that have dips too steep for mules and not steep enough for gravity chutes (7° to 17°).

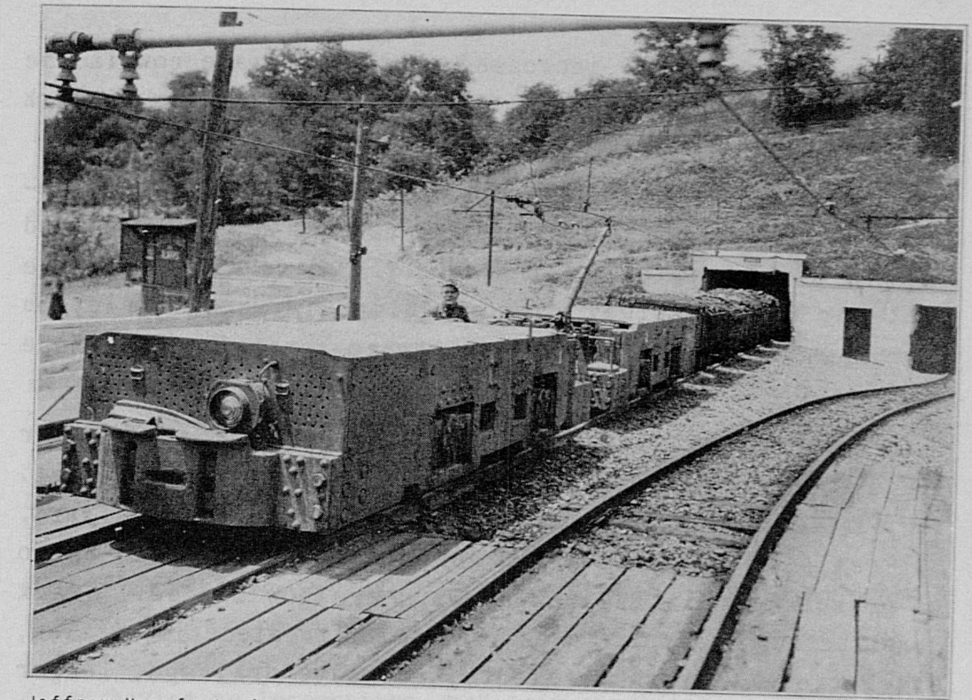
and of explosions which constituted serious objections to the use of gasoline for locomotive power underground.

During 1887 and 1888 electric mine locomotives were used in individual mines in Pennsylvania, Ohio, and Illinois. All the early experiments were with the trolley type of locomotive and were confined to mainline haulage. Skepticism and mechanical limitations of design retarded the introduction of electric locomotives until about 1900, but as improvements were made and their advantages tested in practical operation, the number of electric locomotives in use increased rapidly, especially after 1905.

Mainline haulage was fairly well advanced before attention was directed to motorizing gathering haulage. With animal haulage the size of a mine car is restricted, particularly where there are steep grades. Also, in thin seams the head room between roof and floor may be so low as to prevent the animal from entering, and the necessity of brushing the roof or taking up floor to provide greater height adds to expense. After the practicability of electric motors had been demonstrated, designers began to create models low enough to permit travel into rooms where animals could not enter.

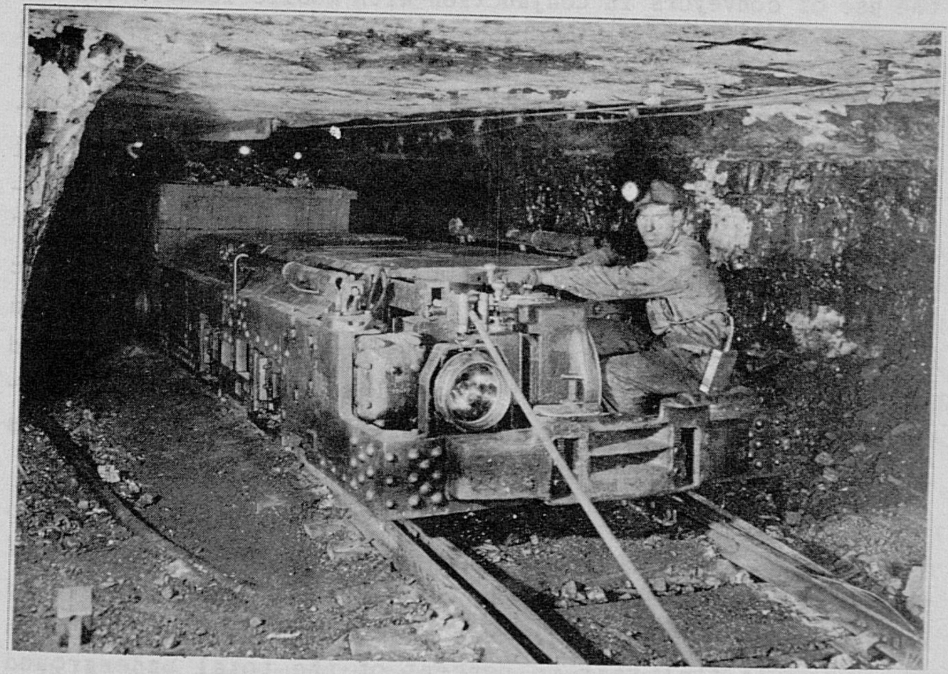
Difficulty arose in extending operation of the trolley type of locomotive into mine rooms. Such a locomotive can go only where trolley wire has been strung, and the temporary, frequently unbonded tracks in gathering haulageways and rooms are not suited to trolley operation. These difficulties were met by different types of cable operation used as a substitute for hanging trolley wire. The introduction of the storage-battery locomotive at about the turn of the century further increased the scope of mechanical haulage in gathering service. Storage-battery traction was initiated in the Pocahontas field. Progress was slow at first, but improvements in design and development of the alkaline battery with steel jars resulted in a rapid increase of this form of haulage in the years following 1911.

Since the success of motorized transportation was established, improvements in design directed toward increasing the power and speed of locomotives have been continuous. Originally locomotives weighed from 3 to 5 tons, but some of the recent models used on long hauls for heavy loads weigh as much as 45 tons. The power of locomotives per unit of



Jeffrey Manufacturing Co.

Tandem Locomotive Consisting of Two Primary Units Used for Mainline Haulage



Jeffrey Manufacturing Co.

Cable-Reel Gathering Locomotive

FIGURE 5.- MINE LOCOMOTIVES

weight has constantly increased, and motors are now in use which transport 300 to 400 tons per trip at speeds as high as 15 miles per hour.

Powerful electric traction has made possible great improvements in mine cars. In 1911 cars in general were made of wood and had a capacity of $1\frac{1}{2}$ to $2\frac{1}{2}$ tons. Modern mine cars have cast- or wrought-steel wheels equipped with antifriction bearings, and their capacities run to several times those of the old wooden cars.

In order to permit the hauling of larger cars and heavier loads the original wooden rails have given place to steel. The earlier steel rails weighed from 8 to 16 pounds per yard, but rails as heavy as 35 to 40 pounds in rooms and 80 to 90 pounds in mainline haulageways are now in use. Track construction today includes the use of treated timber ties, steel ties, uniform gradients, adequate drainage, longer curves, better ballasting and signaling, and dispatching systems similar to those used in surface transportation.

A significant recent advance in mine transportation has been the use of conveyors in conjunction with mobile loaders for the sole purpose of permitting a continuous flow of machine-loaded coal from the working faces[10] to central loading points in the mine or even to the surface. In some installations the mobile loaders place the coal on conveyors which move it to a central loading point where it falls into mine cars; in others, hand-loaded conveyors in rooms deliver the coal to "mother belts" on the entry. There has been developed also an electric storage-battery truck, mounted on pneumatic tires for operation on the mine floor, which may consist of a single integrated unit or of a power unit hauling trailers and which, like conveyors, is used for transporting coal from the mobile loaders at the working faces to a central loading station.

Statistical data on the subject of haulage are meager, and no time series can be constructed to trace the development of mechanical haulage as was done for machine cutting. The only complete survey of haulage was made by the Bureau of Mines in 1924. In that year 12 percent of the total underground production was taken from mines in which haulage was exclusively

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[10] Such conveyors are sometimes referred to as "gathering conveyors" or "mother belts" and should not be confused with hand-loaded face conveyors.

by animal power, 34 percent from mines using locomotive power exclusively, and 54 percent from mines using both animals and locomotives. (Table B-4 shows the same information for individual States.) Locomotives of all types used underground numbered 14,723, of which 14,280 were electric, 226 gasoline, 132 steam, and 85 compressed-air. The total number of animals in use was 36,352, and there were 649 rope-haulage units.[11]

Under increasing pressure to reduce costs, improvements in haulage since 1924 have been very substantial. State Mining Departments of some of the important coal States have published haulage data covering varying periods of years. Computations based on these data showed that after 1925 motor haulage in Illinois had advanced to the stage at which 2 percent or less of underground shipping-mine tonnage came from mines where haulage was performed exclusively by animals.[12] As early as 1925 only 3 percent of the tonnage in West Virginia came from mines having no locomotives, and only 5 percent of Pennsylvania tonnage came from such mines in 1930.[13]

Mechanical power has now superseded animal power for mainline-haulage work in all but the very smallest mines, and motorized gathering haulage is rapidly advancing. However, no data are available which measure directly the effect of mechanized haulage on labor output for the United States.

MECHANIZATION OF AUXILIARY SERVICES

Auxiliary services incident to deep mining include safety, ventilation, pumping, underground lighting, maintenance, and repairs of machinery. Some engineers place ventilation as the prime task in operating a mine. Although safety is a basic human requirement, accidents also can become a heavy burden from a pecuniary cost angle. Both pumping and ventilation have reached a high degree of technical perfection.

Ventilation involves two problems: (1) choice of proper ventilating fans and (2) maintenance of airways so that the air

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[11] These data are summarized by H. O. Rogers, "Exit the Mule," *Coal Age*, Vol. 32, No. 2 (Aug. 1927), pp. 84-8.

[12] In 1937 about 9 percent of the total underground production in Illinois came from local mines where animal haulage was probably still in use.

[13] Tables B-5 and B-6 show for a series of years the number of animals and different types of locomotives in service in the coal mines of West Virginia and Pennsylvania. The increasing predominance of the electric locomotive relative to other forms of mechanical power and the decline in the number of animals are the significant facts revealed by these tables.

can be directed at minimum cost and maximum efficiency to every place where men work. When mechanical loading is used ventilation becomes vitally important because of the rapid sequence of operations in the working place. Fresh air must be supplied constantly to the face to sweep away mine gases and fumes from explosives. Great advances have been made in ventilation engineering but improvements are still possible at many mines.

Progress in underground lighting has proceeded from the oil to the carbide lamp and, finally, to the electric cap lamp. Illumination by electric lighting along haulage roads can be made as efficient as the lighting upon our best highways. Electric cap lamps used by miners at the face are light in weight, highly efficient, and safe. Future progress will no doubt revolve around more adequate lighting at the working face where loading machines are in use.

Dangers from falling rock, from gas and dust explosives, from high voltage electricity, and from moving machinery in dark and cramped quarters make underground coal mining hazardous. Although the industry is "safety-minded" and for many years has made progress in reducing accidents, much still remains to be done. The following tabulation shows the ratio of fatal accidents to man-hours and to tonnage:[14]

Year	Fatal accidents per million man-hours	Fatal accidents per million tons
1925	1.975	3.53
1926	2.002	3.60
1927	1.899	3.36
1928	2.015	3.45
1929	1.910	3.19
1930	2.158	3.46
1931	1.812	2.83
1932	1.998	3.09
1933	1.476	2.50
1934	1.621	2.67
1935	1.673	2.60
1936	1.639	2.52
1937	-	2.70
1938	-	2.64

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[14] U. S. Dept. Int., Bur. Mines. Data for 1925-36 were published in annual Bulletins of the Bureau of Mines entitled *Coal-Mine Accidents in the United States* (Bulls. 380, 387, 397, 409, 420); for 1937-38, by D. Harrington, "Safety Trends in Coal Mining," *Coal Age*, Vol. 44, No. 2 (Feb. 1939), p. 72.

MECHANICAL LOADING

During the past two decades devices have been introduced for mechanizing the heavy task of shoveling coal into mine cars. These devices are of two types: those that practically eliminate hand shoveling and those that leave loading largely a hand process but greatly reduce the labor involved. The devices of the first category are designated as mobile loaders, scrapers, and duckbills; those in the second, pit-car loaders and conveyors.

Of the devices which practically eliminate hand loading, scrapers and duckbills have been found adaptable to physical conditions of relatively few areas, with the result that the intensive form of mechanization has been brought about chiefly through the use of mobile loaders. Of the less intensive types of loading device, the pit-car loader has been used extensively in the past, especially in Illinois and Indiana, but its use is at present on the decline. Conveyors represent a type of equipment which is similar to that widely used in industry, and because of their flexibility they are adapted to a wide variety of conditions. The present advance of mechanical loading is concentrated largely in mobile loaders and conveyors. The operation of the different loading devices will be outlined in chapter V, which discusses the history and present distribution of loading devices.

COAL PREPARATION

Since the beginning of the century coal preparation has changed from a simple task to a process involving heavy capital investments and complex applications of mechanical and electrical energy. Because buyers have become more discriminating and competition between different coals and with other fuels more severe, operators have become sensitive to market appeal, and they find it necessary to pass their product through intricate preparation facilities at added expense in order to improve quality and physical appearance. Mechanization of mining has, in general, reduced cost, whereas mechanization of coal preparation has increased cost.

The simplest system of preparation involves casting the impurities aside by hand as mine cars are loaded underground and later as railroad cars are loaded on the surface. Hand cleaning can be effective, depending largely upon the kind and amount of impurities present. Such methods must be employed at mines with limited tonnage that cannot afford modern preparation plants and at mines whose customers do not demand and are unwilling to pay the added cost of preparation.

In the more elaborate preparation plants coal is screened into numerous sizes, the larger sizes are hand picked, the smaller sizes may be dedusted, and certain sizes are mechanically cleaned by wet-washing systems and others by pneumatic processes. Some of the washed sizes are dried. Oil and chemical treatments are given to reduce dustiness of the final product and to eliminate freezing while in transit. Not all tipples handle coal with such care, but screen sizing is general and mechanical cleaning and dust-allaying treatments are spreading rapidly. There are three phases in the operation of a modern preparation plant: screening, cleaning, and special treatments.

Screening

The separation of mine-run coal into sizes is now common practice. A Bureau of Mines study found that 80 percent of the bituminous output in 1927 came from mines equipped with some type of screening equipment.[15] All the important coal fields reported that between 70 and 100 percent of the product was from mines with screening equipment. Official information on a national scale is lacking for later years, but it is probable that fields that were in the 70- and 80-percent brackets in 1927 have advanced by about 10 percent since that date. The three types of mines that do not ordinarily use highly mechanized screening equipment are truck mines which use simple bar screens, some captive mines which ship run-of-mine coal to parent concerns, and mines which produce friable, low-volatile coals that suffer damage from too much handling.[16]

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[15] Although 79.6 percent of the production came from mines equipped with screens, only 49.8 percent was shipped in screened sizes. See H. O. Rogers and F. G. Tryon, "Nation-wide Increase in Use of Screening Equipment: Shows Progress in Bituminous Preparation," *Coal Age*, Vol. 34, No. 8 (Aug. 1929), pp. 475-8; H. O. Rogers and F. G. Tryon, "Fitting Product to Consumer's Needs: How Bituminous Coal Met the Issue in 1927," *Coal Age*, Vol. 34, No. 1 (Jan. 1929), pp. 30-2; *Mineral Resources of the United States:* 1929 (U. S. Dept. Com., Bur. Mines), Part II, "Nonmetals," pp. 384-94.

[16] Early history of screening is obscure. The simple bar screen was the first device used to make a separation of sizes. Mechanization has advanced from the [*Con.*]

The most important advance in size separation during the past decade was the perfection of the vibrating screen. Following similar lines, improvement is still possible in screening particles of less than $\frac{1}{4}$ inch in size and in the wider use of high-grade alloys in construction. Limitation on further mechanization of screening is found in the fact that compared with most metals coal has a low value per unit of weight. For that reason expense which might be justified in the treatment of gold or even of copper ores would be out of place in the preparation of coal. All things considered, improvements in screen design are probably approaching the saturation point.

Cleaning

The importance of cleaning depends on the original quality of the coal and on the demands of customers. Accessibility to river transportation was a determining factor in the opening of early American mines. As rail transport expanded, quality of coal became an increasingly important factor in seeking new fields for development. As time went on, price considerations were emphasized and areas with low freight rates to consuming centers came to have an advantage over less accessible coals which might be of higher quality. Users of coal were not willing to spend their money for excessive impurities, and even before the practice of purchasing coal by heat units developed it was necessary for most operators to bring their product up to some minimum standard of cleanness. As the practice of buying heat units has grown and as competition between coals and with other fuels has enlarged, efficient cleaning has become a necessity in major sections of the bituminous-coal industry.

Response to the demand for clean coal is focused first on the removal of impurities underground. This covers instructions to the machine runners not to cut bottom rock with the coal and, under hand loading and simpler forms of mechanized loading, it covers hand picking and discarding of impurities

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16 [*Con.*]
bar screen until today numerous types of screens are in use which vary both in respect to the screen itself and in the way it is motivated. There are wire-mesh, round-hole, square-hole, and elliptical-plate screens, and there are rotating, revolving, and shaker screens, some vibrated by electrical and some by mechanical power. See E. A. Holbrook and Thomas Fraser, *Screen Sizing of Coal, Ores and Other Minerals* (U. S. Dept. Int., Bur. Mines Bull. No. 234, 1925). This volume contains a brief resume of the history of screening and lists volumes containing a more detailed history.

as coal is loaded into mine cars. These precautions are supported by provisions in union contracts that miners shall load clean coal. The dim light in mines, however, limits the possibility of hand picking underground, and concerns that lack mechanized cleaning plants usually supplement underground cleaning with a further discarding of impurities on the surface as coal is loaded into railroad cars. When highly developed types of mechanized loaders are used - mobile loaders, scrapers, duckbills - hand picking underground is impracticable and hand picking on the surface ordinarily does not meet the requirements.

Building on helpful precedents in ore dressing, mechanical cleaning of coal has been practiced for more than a century, but the greatest advances have occurred during the past 15 years.[17] Growth of mechanical loading underground and of strip mining has given a decided stimulus to these advances.

All the common mechanical-cleaning devices utilize the difference in specific gravity between coal and the impurities to be removed. Substances of differing specific gravity become separated when subjected to certain mechanical or hydraulic actions and, with suitable mechanisms, can be separated as desired. A clean and rapid separation of coal and shale can be accomplished by using the principle of passing the mixture through a rising current of water so controlled that the upward force is strong enough to lift the coal, which has a specific gravity of 1.3, but too weak to lift the shale, which has a specific gravity of 2.6. The coal is carried over a discharge point and the shale sinks to a trap in the bottom where it is removed.[18]

Since the World War the principle of gravity separation has been embodied in numerous types of equipment for the purpose of increasing capacity per hour and perfecting the elimination of impurities. Some devices have introduced refinements in the basic idea of water separation, others use sand and water,

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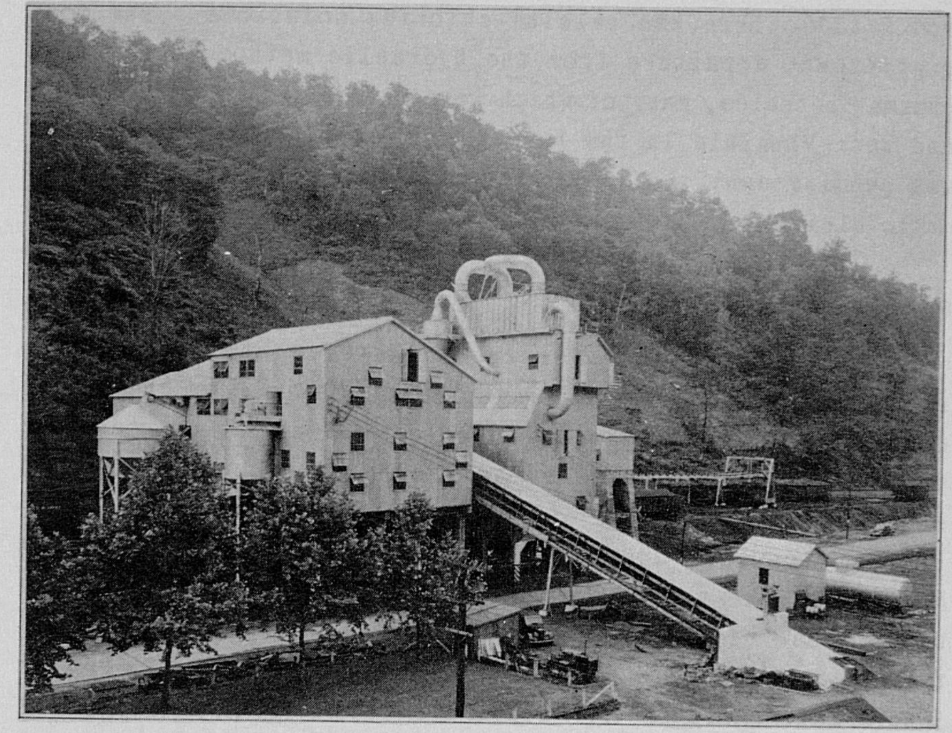
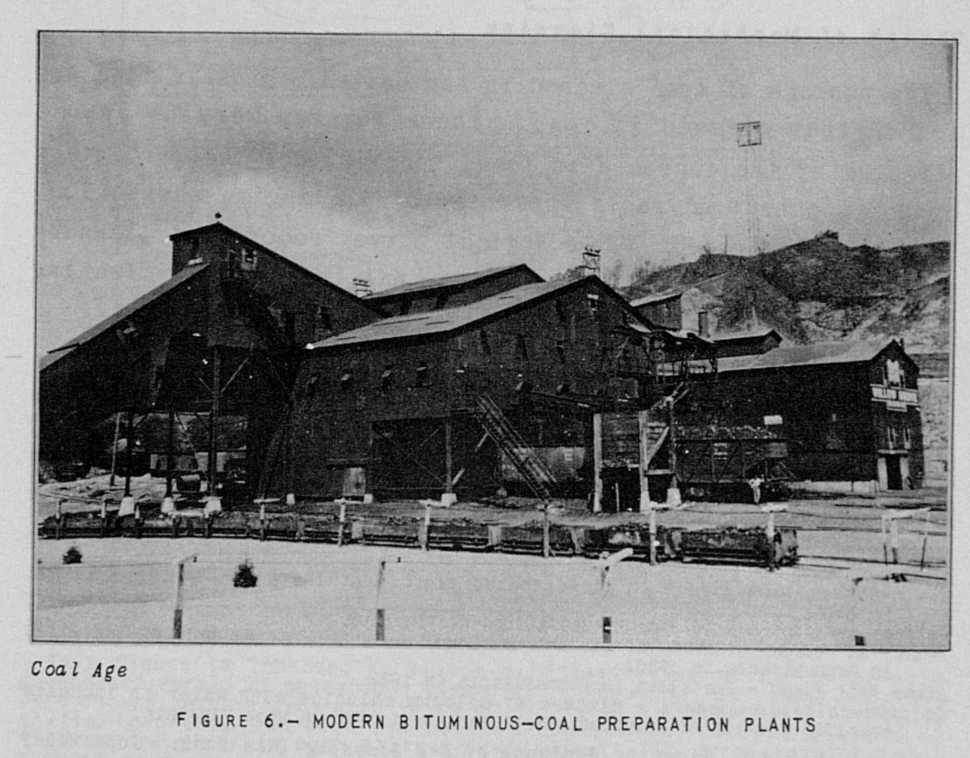
[17] A washing device was installed in Saxony in 1830 and jigs were introduced into the Pennsylvania anthracite fields about the time of the Civil War. Installations were later made in western Pennsylvania bituminous fields and in southern Illinois. See W. R. Chapman and R. A. Mott, *The Cleaning of Coal* (London: Chapman and Hall, Ltd., 1928), pp. 94-124.

[18] Gold placer deposits in the West and river coal near Harrisburg, Pennsylvania, are examples of nature's efforts at mechanical separation. Mechanical cleaning does in limited space and in a brief interval of time what a river or stream does over miles of flow in years or centuries.



Roberts and Schaefer Co.



Coal Age

FIGURE 6.– MODERN BITUMINOUS–COAL PREPARATION PLANTS

and still others use calcium-chloride solutions. The most significant departure from the hydraulic method is found in pneumatic tables, many of which were introduced in Pennsylvania and West Virginia in the twenties. Patent litigation, which was pending until 1938, has hampered the development of pneumatic cleaning in recent years.[19]

Special Treatments

Preparation of coal for the market frequently includes such treatments as dedusting, spraying with oil or chemicals, crushing, and rescreening of sized coal after it has undergone the intermediate processes between original screening and shipment. The purpose of oil and chemical treatment is to prevent freezing and to allay the dust which results from handling. The use of aspirators for dedusting is also for the purpose of minimizing the disadvantages that come from the pulverizing effect of handling. Rescreening is done to insure uniformity in the various sizes. All these treatments are carried out with highly mechanized equipment.

Growth of Mechanical Cleaning

The tonnage of coal cleaned in the United States in 1936 was double that cleaned in 1932. These figures were of course affected by the increase in total tonnage, but the percentage of total output advanced from 9.8 to 13.9 during the period. From the time the U. S. Geological Survey records of cleaning were begun in 1906 there was a gradual increase in cleaning

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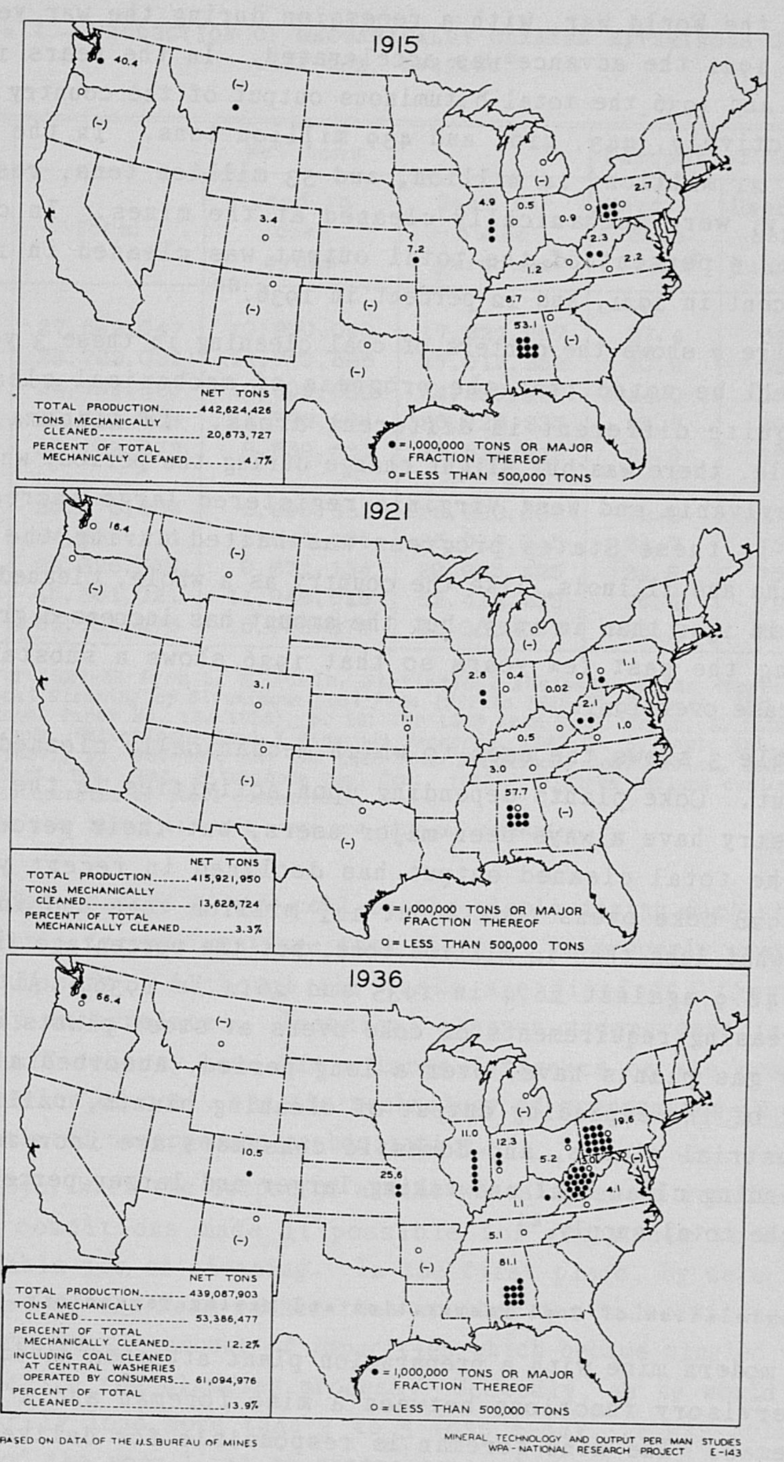
[19] Following is a selected chronological list of cleaning devices:

Piston jigs - Adopted from metal-mining practice.
Wet concentrating tables - Adopted from metal-mining practice.
Pneumatic tables - Similar in principle to the wet table, but air instead of water is used as the separating medium; introduced in 1919 in the West and 1922-24 in West Virginia and Pennsylvania.
Chance cones - Introduced in Pennsylvania bituminous mines in 1925; uses a mixture of sand and water as separating medium.
Rheolaveur launders - Introduced from Belgium in 1926 in Colorado; essentially a flowing stream of water.
Menzies hydroseparators - Upward-flowing water currents; first installed in West Virginia about 1927.
Simon-Carves Baum jigs - An air-operated jig; first installed in Pennsylvania in 1928.
Jeffrey-and-Norton Baum jigs - Adaptations of the Baum jig.
Fraser air-sand - Mixture of air and sand used as a separating medium; installed in Pennsylvania in 1930.
Stump "Air Flow" - Installed in Pennsylvania in 1932.
Calcium-chloride washers - Mixture of calcium chloride with water to increase specific gravity of solution; installed about 1935 in West Virginia.

See also Arthur F. Taggert, *Handbook of Ore Dressing* (New York: John Wiley & Sons, Inc., 1927).

Figure 7.- CENTERS OF MECHANICAL COAL CLEANING IN 1915, 1921, AND 1936



BASED ON DATA OF THE U.S. BUREAU OF MINES

MINERAL TECHNOLOGY AND OUTPUT PER MAN STUDIES
WPA - NATIONAL RESEARCH PROJECT E-143

This figure is intended to give a bird's-eye view of the remarkable growth and spread of mechanical cleaning. The years 1915, 1921, and 1936 were chosen because they were years of nearly equal production. However, shifts in production occurred between the several States; therefore, figures are given in each State which indicate the percentage of total production mechanically cleaned. The figures given in 1936 for Colorado and Pennsylvania represent coal cleaned at the mines and at consumer washeries. The symbol (–) indicates that the percentage cannot be given without revealing data for individual operations. Data for Kansas and Missouri are combined.

until the World War, with a recession during the war years; after 1921 the advance was accelerated. In the years 1915, 1921, and 1936 the total bituminous output of the country was, respectively, 443, 416, and 439 million tons. In the same years 21 million, 14 million, and 53 million tons, respectively, were mechanically cleaned at the mines. In other words, 5 percent of the total output was cleaned in 1915, 3 percent in 1921, and 12 percent in 1936.[20]

Figure 7 shows the centers of coal cleaning in these 3 years. It will be noted that the progress of mechanical cleaning was quite different in different areas. In Alabama, for example, there was but slight change during the period, whereas Pennsylvania and West Virginia registered large increases. Even in these States progress was halted during the war. Indiana and Illinois, like the country as a whole, cleaned less coal in 1921 than in 1915, but the amount has increased greatly during the past few years so that 1936 shows a substantial increase over 1921.

Table 3 shows the uses to which mechanically cleaned coal is put. Coke plants depending upon activities in the steel industry have always been major users, but their percentage of the total cleaned output has declined in recent years. In 1928 coke ovens took about 11¾ million tons and in 1935 somewhat less than 12 million tons, but the percentage in 1928 was 40.9 against 26.4 in 1935 and 26.2 in 1936. Although increasing requirements of coke ovens at steel plants and at city gas plants have, over a long period, absorbed a large part of the expanding output of cleaning plants, railroads, industrial plants, and domestic consumers are increasingly demanding clean coal and taking larger and larger percentages of the total supply.[21]

Interrelation of Coal Preparation and Mining Technology

A modern mine with a preparation plant attached divides its supervisory functions between a mine foreman and a tipple foreman. The mine foreman is responsible for delivering a

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[20] This comparison does not include the coal cleaned at consumer-operated washeries.

[21] See tables B-7 and B-8 for a summary of the growth of mechanical cleaning, by wet and dry methods and by States.

Table 8.- PRODUCTION OF MECHANICALLY CLEANED BITUMINOUS COAL, BY USE, 1927-36[a]

Year	Net tons			Percent of total	
	Total	Used in coke ovens[b]	Used for other purposes	Used in coke ovens[b]	Used for other purposes
1927	27,692,047	10,370,090	17,321,957	37.4	62.6
1928	28,783,039	11,770,686	17,012,353	40.9	59.1
1929	36,799,120	12,509,683	24,289,437	34.0	66.0
1930	38,799,619	11,873,284	26,926,335	30.6	69.4
1931	36,172,373	8,639,561	27,532,812	23.9	76.1
1932	30,278,369	6,895,333	23,383,036	22.8	77.2
1933	34,558,211	8,541,166	26,017,045	24.7	75.3
1934	39,826,559	9,871,134	29,955,425	24.8	75.2
1935	45,361,021	11,948,618	33,412,403	26.4	73.6
1936	61,094,976	16,028,879	45,066,097	26.2	73.8

[a] Data for 1927-34 from L. N. Plein, *Statistical Analysis of the Progress in Mechanical Cleaning of Bituminous Coal From 1927 to 1934* (U. S. Dept. Int., Bur. Mines Econ. Paper No. 18, 1936), p. 19; for 1935 from F. G. Tryon, L. Mann, and W. H. Young, "Bituminous Coal," *Minerals Yearbook, 1937* (U. S. Dept. Int., Bur. Mines, 1937), pp. 787-867; and for 1936 from *Bituminous Coal Tables, 1936-1937* (U. S. Dept. Int., Nat. Bituminous Coal Com., 1938). Figures include coal washed at plants operated by steel companies.

[b] Includes coke plants at steel works and city gas companies.

specified tonnage of raw coal to the tipple during each shift. The tipple foreman must see that the coal is properly prepared for shipment. Although the tasks are distinct, they are closely interrelated. Technical changes underground in the past half-century have had a large influence on the present preparation of coal, and the technology of preparation in turn has assisted underground mechanization.

In 1890, when the output of a mine was shipped as run-of-mine coal, conditions made it possible for the miner to do an acceptable job of cleaning. In the first place, by selecting one part of the seam rather than another for undercutting, he could reduce the amount of impurities which became mingled with the coal in the blasting process. Secondly, as he would not ordinarily load more than 3 to 5 tons a day, he was able in spite of the poor light to remove most of the impurities as he shoveled the coal into the mine car. Finally, the organization of the tipple was such that a good part of the impurities that remained could be removed by members of the crew as the railroad cars were loaded. Introduction of the cutting machine tended to increase the amount of foreign substance that became mixed with the coal and also to increase the proportion of fine sizes produced by the cutting bits.

By 1920 machine cutting had become standard practice, electrical haulage was highly developed, and underground operations generally were speeded up, with consequent reduction in the opportunity for hand picking. The effect of mechanization underground in accelerating the tempo of operations was greatly accentuated by the introduction of mechanical loading. Unless seam conditions are exceptionally favorable or market demands lenient, a modern preparation plant is a corollary of the higher types of mechanized loading; even the use of pit-car loaders or conveyors impairs opportunity for hand cleaning.

As mechanization underground advanced, more and more coal had come to be sold by sizes and consumers were demanding better quality. In these circumstances, insistence of discriminating buyers on clean as well as sized coal was a factor that could not be ignored, and it was obvious that responsibility for providing clean coal had been largely shifted from the mine to the tipple. With the larger sizes - lump and egg - cleaning could be done with reasonable effectiveness by hand pickers as coal traveled on conveyors from screens to railroad cars. The number of pickers could be adjusted to requirements, depending on the type of coal, the speed of operation, and the demands of the market. The smaller sizes could not be cleaned effectively by hand and, in the absence of a washing plant, were shipped without cleaning.

Separation of Mining and Preparation

Although a preparation plant serving a single mine is essentially an integral part of the mine, its technical and managerial organization is such that its operation could be detached without serious disturbance of the preparation process. There are several concerns in which a single preparation plant serves more than one mine.[22] The custom washery is another form in which separation of mining and preparation functions occurs. At the Acme plant near Avella, Pennsylvania,

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[22] The Clairton plant of the Carnegie-Illinois Steel Company in western Pennsylvania, the Champion No. 1 plant of the Pittsburgh Coal Company, and the Ziegler plant of the Bell and Zoller Coal and Mining Company in southern Illinois are notable examples of preparation plants serving more than one mine.

and at the Universal plant at Pinkneyville, Illinois, coal is cleaned not only for affiliated mining companies but for independent companies at a specified service charge. These custom plants also buy raw coal which they clean and sell in the regular course of trade. Some of the examples of separate preparation have been in operation for many years.

Considering the heavy investment in a preparation plant, it would appear that considerable advantage to the industry, especially to moderate-sized producers, might accrue by having one plant prepare the product of several mines for market whether or not they were all a part of the same corporate structure. Probably the greatest offset to such potential advantages would be added transportation costs. Whether the future will reveal an increasing trend toward separating the functions of mining and preparation cannot be predicted.

Coal Preparation and Employment

If there should be a future trend in the direction of separating mining and preparation functions, the effect of technology in preparation plants on employment would be an appropriate subject of study, distinct from technology in mining. Even in that case, however, employment opportunity in the preparation of coal would depend in large measure upon what happened in respect to mining.

In the typical case today, preparation plants are directly connected with mines. Although their supervision and technology are different from those of the mine, employment in the preparation plant is an integral part of the employment opportunity furnished by the particular mine. Because preparation advances alongside of mining in the same concern it is impossible to measure separately the direct effect on employment of each advance in the process of preparing coal for market. Other things being equal, if a given quantity of coal is subjected to an additional process - be it screening or cleaning - either hand workers or machine operators are required to do the work and thus employment opportunity is increased. As long as the preparation of coal is confined to relatively simple methods of screening and hand picking, the effect of preparation for market as contrasted with shipping run-of-mine coal is to increase employment.

In general a preparation plant cannot be considered apart from other technical appointments with which it is coordinated. If a mine having its underground operations of cutting, drilling, blasting, and hauling already mechanized and its tipple equipped for screening and hand picking installs both mobile loading and a modern preparation plant, it is the effect of the whole installation, not of one part of it, that is significant. Quite often the mechanical-cleaning plant makes possible the use of the high-speed loader. Such installations usually occur under pressure of competition and are motivated by a desire to increase output per man and either to make more profit or to forestall loss. Should a particular operator secure the desired result from such technical changes he will probably increase his tonnage beyond what he would have produced with his former methods. When that occurs, total employment in the concern will either decline less than it would have if the operator had continued as he was and lost business, or employment will remain stationary and in some cases even increase. When such results are realized, increased sales may offset or even overbalance the adverse effect which a drop in unit labor requirements has on employment, and if this occurs, employment opportunity in the concern may be enhanced.

In the case of unsuccessful installations, the employment situation both before and after is likely to be highly unfavorable and the influences of technology become merged with those of business decline. In the case of a preparation plant which is a unit in the balanced operation of a mine it is impracticable to analyze the effects of the plant on employment except in connection with the other operations of the mine. Preparation plants are part and parcel of a move to make technical advance a means of expanding business or of arresting its decline. The effect of the movement in general as well as in the specific case depends in considerable measure on the degree to which it succeeds.

TECHNOLOGY IN BURNING COAL

Mechanization in bituminous mining has a counterpart in the technology of combustion. Advances in the science and art of burning coal do not fall within the scope of the present study, but their reactions upon demand relate them to employment. Information disseminated as a result of scientific studies in combustion has made buyers increasingly discriminating about the energy value of coal. The practice of selling coal in prepared sizes was advanced on the assumption that it would enable the purchaser to utilize the size best adapted to the conditions of combustion in his plant.

In respect to the larger sizes, it was also assumed that he would obtain reasonably clean coal, impurities having been cast aside by hand picking. In the case of slack, it was recognized that it might contain a substantial amount of impurities, but this was offset by the lower price at which it was sold. Ashes were a necessary incident of burning coal, and under a price appeal a few ashes more or less were considered inconsequential. As combustion research has advanced, buyers and sellers alike have gradually shifted emphasis from price per ton to net cost for fuel. Industrial coal is now bought largely on the basis of heat units, and there is an increasing tendency to buy domestic coal on that basis.

Technology in combustion affects not only the amount of coal used to provide a given amount of energy but also the form in which it is used. Automatic stokers adapted to the use of screenings have become standard equipment in industrial plants, and this has shifted emphasis from the sizing to the cleaning aspects of coal preparation. In turn, some of the requirements in mining are undergoing modification. Hitherto the assumption that mechanical loading would increase degradation and reduce the amount of prepared sizes obtainable from a given output of mine-run coal has tended to retard mechanization, expecially among producers of soft, friable coal.

By way of contrast it was found at several of the highly mechanized mines inspected during the process of this study that the whole output at the time the mine was visited was being crushed into screenings on the tipple. In one case inability of the crushers to take the coal as fast as the mine could supply it was slowing down mining operations. General introduction of automatic stokers for domestic use would cause further shift of emphasis toward providing clean coal. The advantage of using coal that costs less than prepared sizes is lost to the extent that the consumer pays for impurities instead of for heat units. Discriminating buyers whose purchasing departments are equipped with definite specifications concerning the physical and chemical composition of the coal desired insist upon having clean coal.

Even in cases in which lump coal is still considered essential, the tendency to measure its value in terms of thermal units is growing. Since the purpose of burning coal is to provide energy in the form of heat, the practice of buying coal on that basis will probably come to dominate the market. Technology in combustion has advanced both with technology underground and with technology in the preparation of coal, and this has been responsible for the nation-wide improvement in preparation facilities above outlined.

A few of the factors involved in the technology of combustion have been outlined. Coal is used under a variety of conditions and the consumer, besides giving weight to price, quality, and size, must often give consideration to factors such as softening temperature of ash, slacking and storage characteristics, grindability, coke- and gas-making qualities, and the suitability of the coal to the equipment available at the plant where the coal is to be used.

Improved technology in mining lowers the ratio of labor units to coal units. Improved technology in combustion lowers the ratio of coal units to energy units.[23] The cumulative effect is lower cost of energy. Unless this lower cost can be translated into demand for enough coal-generated energy so that the product of man-hours per 1,000 tons of coal mined times the number of tons used increases or remains constant, employment opportunity must decline.

EQUIPMENT PRODUCTION

Another important accompaniment to mining technology is found in the application of science to the design and manufacture of mining machinery. This subject, like technology of combustion, is outside the scope of the present study, but its influence cannot be overlooked in analyzing the effects of changing technology in mining. Achievements in this field obviously stimulate mechanization and in large measure determine the conditions under which it advances.

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[23] For a study of progress in the efficiency of fuel consumption see Nicholas Yaworski and Others, *Fuel Efficiency in Cement Manufacture, 1909-1935* (WPA National Research Project in cooperation with U. S. Dept. Int., Bur. Mines, Report No. E-5, Apr. 1938).

When new machinery is introduced for performing a mine process, the aggregate cost of producing it has to be met by the operators who install it, and this cost is chargeable against savings in labor cost. Cost in relation to savings is a crucial item in determining the wisdom of an installation, especially when old equipment, still usable but not fully amortized, has to be scrapped. Both the initial cost and the carrying charges on new equipment serve as a moderating influence upon the tempo of mechanization, and this influence is accentuated when experimental installations are abandoned, as has frequently occurred in the bituminous industry.

Progress of mining technology is developed in part by experiments within mines and in part by experiments in drafting rooms, laboratories, and factories of industrial concerns. Such experiments have an important influence upon the investment aspect of mechanization. If it were known that the performance of a particular machine would justify using it until it was worn out, its cost could be covered by charges for maintenance and amortization. For operating purposes, however, the life of a machine dates from its installation to the time it gives way to a new machine which will do its work more economically. In a period of rapid change, therefore, obsolescence may become a heavy burden, and that is one of the imponderables of the mechanization problem.

Just as an important cost item must be set off against the labor saving from new machinery, so, likewise, there is some set-off against the direct loss of employment resulting from mechanization. Evaluation of direct and indirect labor, which goes into the production of different types of machinery, is a highly intricate problem and one that in most cases is insoluble on the basis of convincing statistical data. No data have been compiled from which to estimate the labor content of the machinery with which bituminous mining is conducted.[24] In any case, the labor that goes into the production

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[24] A recent study of the beet-sugar industry calculated that between 1927 and 1935 the labor utilized in the production of machinery for that industry averaged about ½ man-hour per ton of beets sliced. See Raymond K. Adamson and Miriam E. West, *Productivity and Employment in Selected Industries: Beet Sugar* (WPA National Research Project in cooperation with National Bureau of Economic Research, Report No. N-1, Oct. 1938), p. 117 ff.

In the National Research Project study of phosphate-rock mining the question of labor content of the industry's purchases was discussed at some length and the conclusion was reached that this labor did not constitute a significant offset against reduced unit labor requirements. See A. Porter Haskell, Jr. and O. E. Kiessling, *Technology, Employment, and Output Per Man in Phosphate-Rock Mining, 1880-1937* (WPA National Research Project in cooperation with U. S. Dept. Int., Bur. Mines, Report No. E-7, Nov. 1938), p. 118 ff.

of mining equipment does not accrue directly to miners and the amount of employment that would filter back to them because of the added coal used in manufacturing the machinery would be extremely small.

Advance in the design and construction of mining machinery, as well as progress in the science and art of burning coal, links development of technology in the bituminous industry with the technical revolution of the past half-century of which it is a part. The current phase of the movement within deep mines is seen in the rapid spread and intensification of mechanical loading following its notable growth in the late twenties.

CHAPTER III

RESOURCE CONDITIONS: THEIR INFLUENCE ON MECHANIZATION AND PRODUCTIVITY*

Some of the primary factors by which future progress of mechanization will be conditioned are economic, some are engineering and managerial, and some geologic. Under economic factors are included competition between fields, competition with other energy producers, wage rates and differentials between fields and with foreign sources, wage differentials between machine and hand operations, price levels, freight rates, extension of markets through sales effort, growth of population, industry, and commerce, and changes in standards of living. Any other forces, voluntary or involuntary, which influence the relationships of the bituminous industry in the United States to national or international economy are within the scope of economic factors. Factors like these, predictable only to a limited extent, will be controlling in determining the future of the bituminous industry and the pace of mechanization.

Engineering and managerial influences are less complex than economic factors but almost equally difficult to predict. One of the chief determinants of engineering progress is ability of management to adapt the operation of machines to the physical setting of different coal deposits. Engineers are seeking to suit the design of loading equipment to a wider range of conditions and, at the same time, managerial skill in utilizing machines is improving. A case in point is the advance in design of mobile loaders for use in thin seams and the concurrent improvements in management to facilitate their use.

Such movements greatly enlarge the utility and range of choice of equipment under given resource conditions. However, the human factors of tradition and habit have a large influence on the equipment used. When operators in a field have been successful in using a particular machine, they tend to continue

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*By Leo N. Plein; Margaret H. Schoenfeld, Economist, U. S. Bureau of Labor Statistics; Willard E. Hotchkiss; and Walter M. Dake, Consulting Engineer, National Research Project, now Research Manager, Mining Publications, McGraw-Hill Publishing Co., New York, New York.

its use although another machine might give equal or better results. The rapidity with which mining methods in many areas will change under pressure of technical advance can scarcely be forecast.

Geological factors which affect mechanization are not entirely constant since depletion and shifting of operations between seams and areas alter conditions actually encountered in mining. These shifts to other seams and areas, however, will not greatly alter in our time the resource factors. In final analysis, seam conditions constitute the basic factors to which engineering, management, and economic factors are related. For that reason they are made the focal point around which the discussion is developed.

No effort will be made in the following pages to make an exhaustive survey of all resource conditions or to give accurate weight to such conditions in the various areas. Attention will be focused on fields that have been important mechanization centers in the past and on probable future centers, with minor emphasis on less important areas which have succeeded in overcoming difficult conditions. Although geological conditions indicate the approach to the subject, the viewpoint sought is that of the mining engineer and the practical coal operator rather than that of the geologist. The relative importance of areas in the future, as in the past, will be determined by a complex of factors of which resource conditions are only one.

COAL RESOURCES

Coal Areas

American coal fields can be grouped roughly into three major geologic and economic divisions - the Appalachian, the Mississippi Valley, and the Rocky Mountain.

The Appalachian division is the geologist's Eastern Province and includes the coal fields from Pennsylvania and Ohio on the north through West Virginia and eastern Kentucky to Alabama on the south.[1]

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[1] For an excellent description of coal provinces, fields, reserves, quality, rank, and analyses of coal from the geologist's viewpoint, see M. R. Campbell, "Our Coal Supply: Its Quantity, Quality, and Distribution," *Proceedings of the International Conference on Bituminous Coal, Nov. 15-18, 1926* (Pittsburgh, Pa.: Carnegie Institute of Technology), pp. 5-64 and map in folder at back of book.

The Mississippi Valley division includes the geologist's Eastern Interior Region (Illinois, Indiana, and western Kentucky), the Western Interior Region (Iowa, Missouri, Kansas, Arkansas, and Oklahoma), the Northern Interior Region (Michigan), the Southwestern Region (Texas bituminous), and the Gulf Province (Texas lignite).

The Rocky Mountain division includes the Rocky Mountain Province (New Mexico, Colorado, Utah, Wyoming, parts of Montana, and small scattered areas in Idaho, Nevada, and Arizona), the Northern Great Plains Province (parts of Montana and all North and South Dakota), and the Pacific Coast Province (Washington and small scattered areas in Oregon and California). North and South Dakota, although geographically Mississippi Valley States, are included in this division because their lignite fields are adjacent to the lignite and sub-bituminous fields of Montana and Wyoming.

Topography

Appalachian topography is the result of erosion of plateau land forms caused by elevation of horizontal rock formations and subsequent stream erosion. Such topography, depending upon the stage of erosion, varies from distinctly mountainous surfaces in parts of southern West Virginia to the rolling country of eastern Ohio. Broad, flat prairie lands characterize the Mississippi Valley, although in some sections stream erosion has resulted in low, rolling hills. In Arkansas earth movements which formed the Ozark and Ouachita Mountains and subsequent stream erosion have resulted in hilly topography. In the Rocky Mountains topography is rough as the result of the bending and tilting of the earth's surface during the formation of these mountains.

Cover

The depth of cover overlying the coal deposits of the United States ranges from zero along the abundant outcrops to a probable maximum of 6,000 feet or more in certain fields of the Rocky Mountains. Over huge areas, however, workable beds lie within a few hundred feet of the surface, or can be reached under greater depth of cover by horizontal drifts, entering along a valley bottom and extending back under the hills. In practice, therefore, there has been little occasion as yet to attempt the working of coal at great depth. At the mines now developed, cover is shallowest in the stripping areas of the Mississippi Valley. It is greatest at individual mines in eastern Kentucky and in Utah.

Structure

When originally deposited all coal beds were flat, but subsequent geological processes have modified this to varying degrees. Although dipping beds do not in themselves seriously handicap mechanization, they require at times modifications in mining practice. The coal formations in the Mississippi Valley occur in broad, shallow basins which are of such dimensions that the seams for all practical purposes are thought of as being flat. The exceptions to this rule are the more steeply dipping beds resulting from mountain-making movements in Arkansas and Oklahoma.

In the Appalachians the beds are practically level except along the eastern flank of the coal measures. There is considerable variation, however, and average conditions are not comparable with the level seams of the Mississippi Valley. In western and central Pennsylvania there are coal basins which are only moderate in width. Most of the coal in these basins is level or dips only slightly, but on the edges the seams are tilted more sharply. In the Broad Top field of central Pennsylvania, in the semianthracite district of Virginia, and in the Coosa and Cahaba basins of Alabama, the coal beds dip sharply in some of the operating mines.

The geological forces which created the Rocky Mountains tilted the coal formations to angles varying from only a few degrees of dip to the point where they stand on end. On the other hand, the lignite beds of the Great Plains are conspicously flat.

Rank

The rank of coal defines the degree of metamorphism (or geologic change) through which it has passed from the time of its original deposition to the present. Rank has no direct bearing on the problem of mechanization or output per man, but indirectly, since rank is to some degree associated with heating value and coking properties, it influences the marketability of the coal and the running time of the mine. The number of days a mine is in operation is a very important factor in reducing costs and in adapting loading machines to economic operation.

Scientifically, coal is divided into the following ranks: anthracite, semianthracite, low-volatile bituminous, medium-volatile bituminous, high-volatile bituminous, sub-bituminous, and lignite.[2] Trade usage, however, recognizes two grand divisions in the coal trade of the United States - Pennsylvania anthracite and bituminous. The bituminous-coal industry, as ordinarily understood in the trade, includes the production of lignite and of the small quantities of anthracite and semianthracite mined outside of Pennsylvania. From the viewpoint of wage scales, freight rates, distribution, and general competitive relationships, these other hard coals are commonly grouped with bituminous coal, and they are so grouped in the tables of this report. Low-volatile bituminous has the highest heat value, and lignite the lowest.[3] Low-volatile, medium-volatile, and the top divisions of high-volatile bituminous coals can generally be coked.

Bearing in mind that the value of coal depends upon its heat content and the variety of uses to which it may be put, it is clear, other factors being equal, that the areas possessing coals with higher heating values and with good coking and gas-making qualities have a twofold market. When demand for coals

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[2] Anthracite is mined in eastern Pennsylvania; a very small production comes also from Colorado and New Mexico.

Semianthracite is mined in Pennsylvania, Arkansas, Colorado, New Mexico, and Virginia.

Low-volatile bituminous (often referred to as semibituminous and smokeless) comes from Pennsylvania, Maryland, Virginia, West Virginia, Alabama, Arkansas, and Oklahoma. It is mined in such well-known fields as central Pennsylvania, Georges Creek, Upper Potomac, Pocahontas, and New River.

Medium-volatile is an intermediate rank and is mined principally in West Virginia and Pennsylvania.

High-volatile bituminous coal is mined in all coal-producing States except North and South Dakota.

Sub-bituminous is produced chiefly in Montana, Wyoming, Colorado, New Mexico, and Washington.

The chief lignite production comes from the Dakotas, Montana, and Texas.

[3] Heat values within each rank vary considerably, depending upon the amount of moisture and impurities included in the coal. A rough measure of the range of B. t. u. per pound of coal of the various ranks would be as follows: anthracite, 12,700 to 13,830; semianthracite, 12,340 to 13,870; low-volatile bituminous, 13,120 to 14,860; bituminous, 10,040 to 14,490; sub-bituminous, 8,300 to 11,230; and lignite, 5,650 to 8,000. Within the bituminous rank is included a wide range of varieties. In general, coal decreases in heat value as it is mined farther west of the Appalachians.

of these special uses declines the mines can continue to market their product for steam and domestic use, whereas the areas with noncoking coals must always rely on the steam and domestic trade. These resource advantages are particularly valuable to many of the coal fields within the Appalachian region.

Besides the disadvantage of low heat value associated with sub-bituminous and lignite coals, such coals have an additional drawback in that they slack or disintegrate very rapidly when exposed to the atmosphere. Storage at points of consumption is therefore difficult; when mines producing these coals must depend on domestic trade, running time becomes highly seasonal.

In 1935 roughly three-quarters of the mechanically loaded coal came from mines producing sub-bituminous and noncoking high-volatile bituminous coals. By 1937 the proportion had dropped to three-fifths because of the rapid increases in the high-volatile and medium-volatile coking coals in the Appalachians. The shift has therefore been from coals with limited ranges of use to coals with wider ranges.

Quality

Quality refers to purity, which is dependent upon the ash, sulphur, and moisture content of the coal. For metallurgical coal low ash and low sulphur content together with the right combinations of coke-forming constituents, are a prime requisite. For steam and domestic use the percentage of ash is the chief determinant. Burning equipment, however, can be designed to utilize any quality of coal if the price factor is right. Probably the best over-all measure of quality is heat value as measured in B. t. u. Rank should not be confused with quality although heat values are used in classifying coals by rank.

Heat value, therefore, is one of the resource factors associated with any coal deposit. Relative heating values explain part of the competitive position of all coal fields. Table 4 is a rough indicator of the average heating value of coal produced in each of the States; it does not attempt to show the wide differences which may be found in any State. It represents what is considered to be a conservative estimate, based upon reliable data, of the average heat value per pound of coal produced in 1936.

Table 4.– AVERAGE BRITISH THERMAL UNITS PER POUND OF COAL PRODUCED, BY DIVISION AND STATE, 1936[a]

(These values are averages, and individual mines in any State may produce better coal or considerably inferior coal.)

Appalachian		Mississippi Valley		Rocky Mountain	
State	Average B. t. u. per pound	State	Average B. t. u. per pound	State	Average B. t. u. per pound
Virginia	14,350	Arkansas	13,990	Utah	12,900
West Virginia	14,200	Oklahoma	13,430	New Mexico	12,280
Pennsylvania (bituminous)	13,950	Kansas	12,850	Washington	11,900
Eastern Kentucky	13,950	Western Kentucky	12,250	Wyoming	11,610
Tennessee	13,820	Michigan	11,780	Colorado	11,260
Alabama	13,750	Indiana	11,730	Montana	9,690
Maryland	13,630	Missouri	11,640	North Dakota	6,980
Pennsylvania (anthracite)	13,300	Illinois	11,410		
Ohio	12,760	Iowa	10,790		
		Texas	7,600		

[a] These averages were computed from data in M. R. Campbell, "Our Coal Supply: Its Quantity, Quality, and Distribution," *Proceedings of the International Conference on Bituminous Coal, Nov. 15-18, 1926* (Pittsburgh, Pa.: Carnegie Institute of Technology), pp. 49-57. In compiling these data Campbell's heat values, by county, have been weighted by the county production in 1936 in order to obtain the average for each State. In a few cases, where representative analyses were not available for important producing counties, estimated heat values were added.

"The figures given are those obtained by the analysis of individual samples of coal, but each sample has been so selected that it represents the average composition of the coal of a certain district or field, or the composition of a certain rank of coal. Most of the analyses given in the table were made by the Bureau of Mines or the United States Geological Survey, and so are strictly comparable; but for a few coals, ... such analyses are not available and the figures given are taken from State reports." (*Ibid.*, p. 48.)

The figures quoted by Mr. Campbell represent mine or face samples rather than car or delivered samples. Mine samples are obtained by making a vertical cut up and down the face of the coal seam and carefully rejecting all partings of rock or impurities which it would be feasible to throw out in the operation of hand mining. In general, mine samples will run lower in impurities and higher in heat value than samples of the product as it is actually shipped to market. The difference between the two has been frequently described in the technical papers of the U. S. Bureau of Mines. It is necessary to use mine samples for such purpose because they are the only ones systematically available for all fields in the country. The records publicly available on car or delivered samples do not yet cover many of the coal fields adequately.

Reserves

The United States possesses tremendous reserves of coal sufficient to last for centuries. The original reserves before mining began are estimated at 3,215 billion tons.[4] It has been estimated that by the end of 1936 the amount mined plus that lost or wasted during the mining process amounted to slightly more than 1 percent of the original total.

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[4] T. A. Hendricks, "Coal Reserves," *Report to the President on Energy Resources and National Policy* (H. Doc. 160, 76th Cong., 1st sess., 1939), ch. I, sect. I, pt. II.

Depletion in certain areas, nevertheless, is approaching a point where serious thought must be given to the problem. Mining operations always concentrate on the thicker, better quality coals, and the problem should be thought of not in terms of that indefinite time in the future when complete exhaustion is reached but in terms of increasing mining costs as more and more difficult physical conditions are worked.

The highest degrees of depletion are found in certain Appalachian districts containing the thickest- and highest-rank coals, from which the Nation draws the major portion of its annual supply.[5] Mechanization, therefore, has a distinct function to perform in such areas to enable the mines to produce a cheap fuel under increasing physical handicaps.

Table 5 shows the relation between reserves of the principal ranks and production, by State. All relationships are calculated as a percentage of the national total.

INTERRELATION OF RESOURCES, TECHNOLOGY, AND MANAGEMENT

The influence of resource factors upon labor output in bituminous mining depends in large measure upon the skill with which management employs and coordinates technology. If it were possible to conceive of all the factors except resource conditions remaining constant, labor output would tend to vary as resources are favorable or unfavorable. Similarly, with factors other than technology constant, output would tend to vary according to the effectiveness of the equipment used. Technology is obviously outstanding among the variables that affect labor output; technology, resources, and management are mutually complementary in the practical operation of bituminous mining.

Changes in the national average of unit labor requirements during recent years are not attributable to any over-all change of resource conditions. To be sure, large tonnages of coal have been taken from the earth since 1880, the year in which the records of labor output with which this study is concerned began, but the effect on total bituminous deposits has been

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[5] G. S. Rice, A. C. Fieldner, and F. G. Tryon, "Conservation of Coal Resources," *Transactions, Third World Power Conference* (Washington, D. C.: 1938), vol. VI, sect. IV, paper no. 11, pp. 679-80.

Table 5.- PERCENTAGE DISTRIBUTION OF COAL RESERVES AND COAL PRODUCTION, BY DIVISION AND STATE, 1936[a]

Division and State	Percent of total coal reserves					Percent of total production[b]
	Total	Anthracite[c]	Bituminous[d]	Subbituminous	Lignite	
United States	100.000	0.485	44.259	25.720	29.536	100.00
Appalachian	17.168	0.474	16.694	0	0	76.23
West Virginia	4.643	0	4.643	0	0	23.89
Pennsylvania	3.708	0.459	3.249	0	0	33.32
Ohio	2.890	0	2.890	0	0	4.88
Eastern Kentucky	2.097	0	2.097[e]	0	0	7.93
Alabama	2.094	0	2.094	0	0	2.48
Tennessee	0.797	0	0.797	0	0	1.03
Virginia	0.665	0.015	0.650	0	0	2.36
Maryland	0.243	0	0.243	0	0	0.34
Georgia	0.031	0	0.031	0	0	0
Mississippi Valley	16.842	0.007	16.111	0	0.724	18.78
Illinois	6.218	0	6.218	0	0	10.32
Missouri	2.629	0	2.629	0	0	0.81
Western Kentucky	1.723	0	1.723[e]	0	0	1.70
Oklahoma	1.722	0	1.722	0	0	0.31
Indiana	1.633	0	1.633	0	0	3.61
Texas	0.973	0	0.252	0	0.721	0.17
Kansas	0.929	0	0.929	0	0	0.60
Iowa	0.903	0	0.903	0	0	0.80
Michigan	0.062	0	0.062	0	0	0.13
Arkansas	0.050	0.007	0.040	0	0.003	0.33
Rocky Mountain	65.990	0.004	11.454	25.720	28.812	4.99
Wyoming	19.501	0	0.952	18.549	0	1.17
North Dakota	18.861	0	0	0	18.861	0.45
Montana	11.977	0	0.084	1.975	9.918	0.61
Colorado	9.958	0.003	6.683	3.272	0	1.38
Utah	2.928	0	2.766	0.162	0	0.66
Washington	2.004	0.001	0.354	1.649	0	0.37
New Mexico	0.652	(f)	0.593	0.059	0	0.32
Ariz., Calif., Idaho, Oreg., S. Dak.[g]	0.109	0	0.022	0.054	0.033	0.03

[a] Derived from T. A. Hendricks, "Coal Reserves," *Report to the President on Energy Resources and National Policy* (H. Doc. 160, 76th Cong., 1st sess., 1939), ch. I, sect. I, pt. II.

Reserves and production are shown in percentages so that comparisons can be more readily made. Thus, Wyoming produced only 1.17 percent of the total coal output but it contains 19.501 percent of the total reserves, whereas Pennsylvania's production was 33.32 percent with 3.708 percent of the reserves.

[b] Computed from M. E. McMillan, R. L. Anderson, and Others, "Bituminous Coal," *Minerals Yearbook, 1938* (U. S. Dept. Int., Bur. Mines, 1938), pp. 687-745. For comparability with figures on reserves, total production includes all ranks, anthracite to lignite inclusive.

[c] Includes anthracite and semianthracite.

[d] Includes low-, medium-, and high-volatile bituminous.

[e] Partly estimated.

[f] Less than 0.0005 percent.

[g] Data for Alaska are included only in last column.

slight. Yet, the resource factor has affected labor requirements in actual mining operations and has had an influence on labor output through shifts in production between areas and between mines. Such a shift occurred with the opening of new mines in southern West Virginia, eastern Kentucky, and southern Illinois coal fields prior to the World War. Resource conditions in these newer fields are quite different from those in the older fields of Pennsylvania, Ohio, and Maryland. Another example of significant change in the resource setting of coal actually mined is found in the rapid development of strip mining in recent years. Prior to the World War the over-all effect of strip mining was negligible, and its influence, even in areas where it was concentrated, was relatively small. A further example of a shift of production between mines is associated with the development of mechanical loading. Centers of mechanical loading tend to develop where resource factors are favorable and management is progressive. The more favorable the conditions are, the more effective is the type of equipment used.

The joint influence of resources and technology is strikingly illustrated in the use of cutting machines. With the same expenditure of energy, one undercut by a machine will produce twice as much coal in a seam 9 feet thick as it will in a seam half as thick. Accordingly, a shift of operations from a thin seam to a thick seam immediately increases labor output. If, however, machines with longer cutting bars are installed in the thinner seam, with operations skillfully managed output can be materially increased despite the resource handicap.

Among other factors that determine the way in which the joint influence of resource conditions and technology finds expression in actual development of mining are proximity to markets, the level of engineering and managerial talent, relations with labor, and competition between areas and between varying technologies. Competition of coal with other forms of energy likewise has an important influence both locally and nationally.

Although a study of the effect of resource factors upon productivity takes account of all the other influences with which resources are associated, this does not in any way imply lack of importance in the resource factor itself. Iowa is a case in point. In regard to the all-important economic factor, proximity to markets, the situation of the coal industry in Iowa is somewhat similar to that in Illinois, yet resource factors in Iowa have deterred progress of mechanization and labor output has lagged. On the other hand, progress has been outstanding in those Illinois fields that enjoy more favorable natural conditions.

Although the influence of other factors must not be minimized, a large part of the reason for differing degrees of mechanization and different labor output in the several bituminous fields is found in resource conditions which distinguish them. One coal mine in Williamson County, Illinois, has an output of 2.5 tons per man-day, whereas another mine in the same county has, in the same year, an output of 8.5 tons. Output in LaSalle County, Illinois, averaged 3.19 tons per man-day during a period in which output in Franklin County averaged 7.85 tons. The over-all average of Michigan mines is 2.73 tons against an average of 5.70 tons for Utah mines. Numerous factors in addition to resource conditions, such as management, technology, corporate strength, size of operations, attitude and skill of labor, and market outlets, have important influence in determining varying levels of labor output like those just stated. In last analysis, however, resource factors are important determinants of productivity both directly and through their influence upon technology and, in turn, upon other factors.

From considerations such as these it becomes clear that, in the main, conditions surrounding coal resources in their natural state exert an influence upon labor output that is relative to several other factors. Mining technology has advanced to a point at which low output resulting from adverse physical factors can be raised materially by the use of suitable machinery. When installation of machinery is accompanied by other favorable elements, including a high degree of managerial skill, its effects on output are greatly enhanced, but whatever the results obtained, their ultimate limits are determined by the resource conditions under which all the other factors operate.

MAJOR RESOURCE FACTORS

Among the major natural factors that influence output of labor are depth of cover, thickness and character of the coal seam, character of roof and overlying strata, character of bottom of floor, dip or pitch of seam, mine gases, and mine water. Topography and climate are natural factors of minor importance.

Depth of Cover

Aside from the fact that depth of cover may have a bearing upon the kind of opening, which will be discussed later, it has a direct bearing upon the methods of development that can be used. A depth of 50 feet or less is ideal from the standpoint of labor productivity because the deposit can then be worked by stripping, which results in a greater output per man-day than can be attained in deep mining. Some stripping is now being done at depths of 55 feet and the future seems to hold possibilities of stripping at greater depth.[6]

For underground mining it is largely immaterial whether the cover is 150 or 350 feet. Between 350 and 600 feet consideration must be given to ample pillars, and between 600 and 1,000 feet proper roof control is imperative. Difficulties of mining at a depth of 1,000 feet are somewhat greater than at 200, but they are not so important as the problems associated with such factors as managerial skill, roof strata, method of mine development, kind of opening, and mine gases.

In an unpublished study by Margaret H. Schoenfeld it was found that the average depth of cover in 1926 for all underground bituminous mines was 321 feet (see figure 8[7]). Utah shows the highest average cover, 734 feet, largely because of operations in the Book Cliff Mesa of Carbon County, whereas Texas and North Dakota lignite mines show the lowest averages of 67 and 74 feet, respectively. The value of lignite is at present so low that it would be unprofitable to mine it at any great depth.

Depth of cover must not be confused with depth of shaft. Although the average depth of cover in Utah was 734 feet, 0.1 percent of the coal was produced at shaft mines (see

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[6] See chapter IV for discussion of output records achieved and factors affecting labor productivity in strip mining.

[7] The bar charts in this chapter have been prepared from statistical tables in an unpublished study by Margaret H. Schoenfeld on Physical Conditions in Bituminous Coal Mines. The data were based on U. S. Geological Survey and Bureau of Mines annual questionnaires to operators during the years 1920-26. See also F. G. Tryon and Margaret Schoenfeld, "Comparison of Physical Conditions in British and American Coal Mines," *Coal and Trade Journal*, Vol. 57, Nos. 35, 36, 40, 44 (Sept. 1, 8, Oct. 7, Nov. 4, 1926), pp. 934, 965-7, 1087-9, 1202-6.

figure 11). In the Texas bituminous mines, as distinguished from Texas lignite mines, the average cover was 149 feet, but all the product came from shaft mines. In the mountains of the far West many mines have been opened by drifts or slopes, and as the mine development proceeds into the mountain side the cover increases very rapidly because of the ruggedness of the topography. In flat country the cover for any one mine tends to be uniform because, in general, the plane of the coal bed is parallel with the surface. In the Appalachian areas cover for a single mine may range from 200 to 1,000 feet, depending upon topography. The variations in depth of cover in American mines are relatively small when compared with those in European mines where coal deposits are worked at depths as great as 3,800 feet. Depth of cover alone has not materially influenced labor output - other factors have been more important.

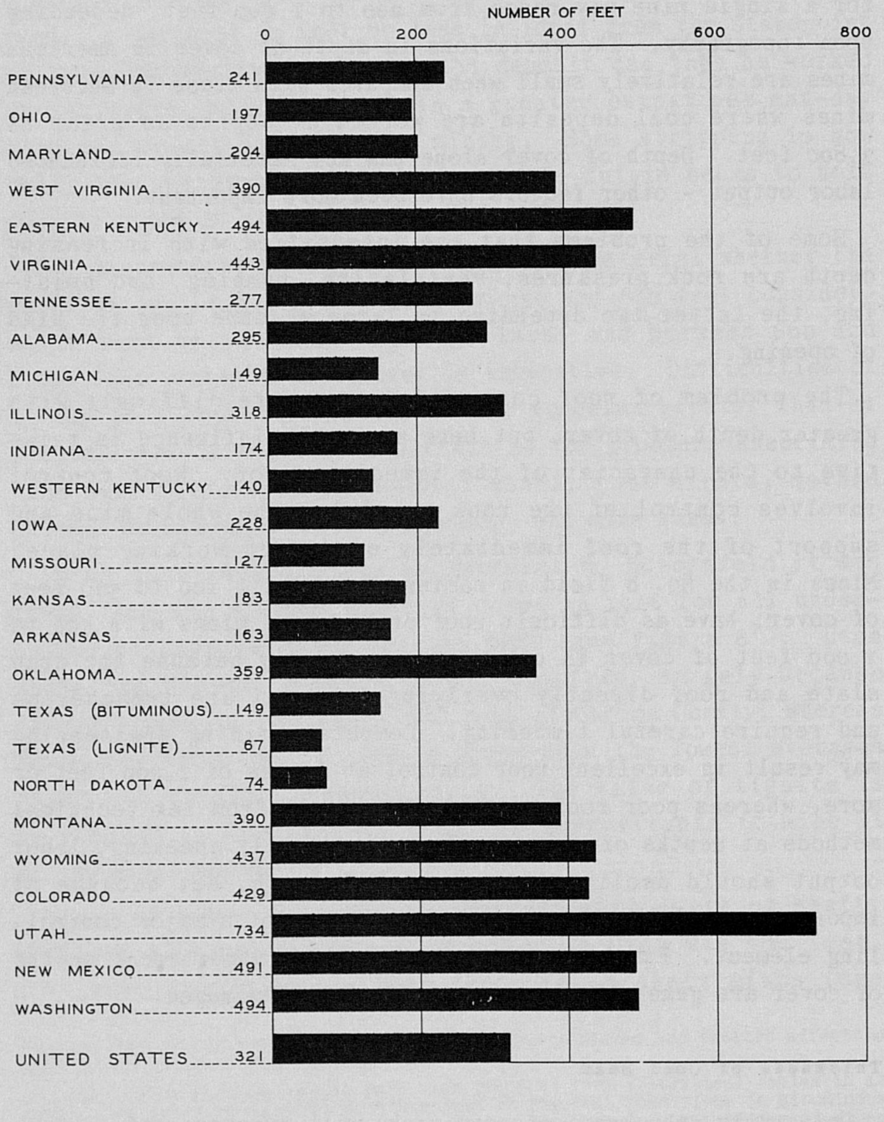
Some of the problems that are intensified with increasing depth are rock pressures, ventilation, pumping, and hoisting, the latter two depending in large measure upon the kind of opening.

The problem of roof control becomes more difficult with greater depth of cover, but here again the influence is relative to the character of the immediate roof. Roof control involves control of the rock overlying the whole mine and support of the roof immediately over each working place. Mines in the No. 8 field in eastern Ohio, with 100 to 500 feet of cover, have as difficult roof problems as mines with 500 to 1,000 feet of cover in other areas, chiefly because the draw slate and roof directly overlying the coal are treacherous and require careful timbering. Competent mining engineering may result in excellent roof control at depths of 1,000 feet or more, whereas poor roof control may result from lax technical methods at depths of only 100 feet. Generally speaking, labor output should decline with increased depth, but because of important modifying factors depth alone is not a major controlling element. Furthermore, mines operating under great depths of cover are generally large and efficiently managed.

Thickness of Coal Seam

Ordinarily, thickness of seam ranks with character of roof as one of the most important resource conditions affecting unit labor requirements. A mine with a 7-foot seam can weather degrees of adversity such as bad roof, clay veins, dip, mine gases, and mine waters which might prohibit profitable working of a 4-foot seam. High-capacity equipment designed for thick seams cannot well be used in thin seams. The example previously cited of greater output in cutting thicker seams applies to drilling, shooting, loading, and hauling. Hardness

Figure 8.- AVERAGE DEPTH OF COVER OF UNDERGROUND BITUMINOUS-COAL MINES, BY STATE, 1926



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of coal, depth of the machine-cut, width of room, location of binders, and need for greater or lesser production of lump coal, however, quickly modify the relation of seam thickness to labor output.

Thicker seams offer definite advantages whether hand or machine loading is practiced. For the hand loader it is a problem of working in cramped quarters in thin seams compared with freedom of movement in thicker deposits. When machine loading is introduced, differentials in productivity caused by variables of seam thickness tend to narrow.

Mechanical loading in thin seams hitherto has chiefly utilized conveyors, but low-built mobile loaders are now on the market and are being used in seams 36 inches or less in thickness.

Thickness of seam controls the size and hence the capacity of the loading device. The mobile loader operating in a 6-foot seam has available 50 percent more coal to load per operating cycle than one operating in a 4-foot seam. A machine designed for use in a 6-foot seam, moreover, can be built with greater capacity in tons loaded per minute and can be served by larger mine cars. Because of these differences in capacity, the loading machine in the thicker seam may load the full cut of coal (involving 50 percent more tonnage) as rapidly as one operating in a 4-foot seam. During the course of a day, therefore, both machines may move an equal number of times from room to room, but the larger machine will handle greater tonnage.

The relative disadvantage of thin coal may be greatly modified by efficient management. By carefully scheduling the cycle of operations, by driving wider rooms where possible, by increasing depth of cut, by replacing mine cars with conveyors behind the loading machine, and by improving other details of mine operation, the daily output of the mobile loader in the thin seam may approach or even exceed the daily output of the larger machine in the thicker bed when the latter is operated by inefficient management.

Thick seams also have definite advantages in mine haulage because larger mine cars can be used with less shifting. Also, less room track per ton of coal removed is needed. In a 6-foot seam with a room 25 feet wide and a machine cut with an effective depth of 6 feet, about 36 tons of coal will be produced for every 6 feet of track laid, whereas with a 4-foot seam a similar set-up will produce only 24 tons. Haulage in thin seams results in a choice of using mine cars of limited capacity, taking down some roof (or taking up bottom) to permit using higher-capacity cars, or installing conveyors. To produce a daily capacity of 2,000 tons the mine with the thicker seam needs fewer working places than the mine with a thin seam. This influences the size of mine with its attendant problems of long haulage roads. Management here exerts its influence by using the best technology to concentrate the active workings and by obtaining a maximum production from each working face.

A survey covering 1920 found that 25 percent of United States bituminous-coal production came from seams less than 4 feet thick, 45 percent from seams 4 to 6 feet thick, 25 percent from seams 6 to 8 feet thick, and 5 percent from seams over 8 feet. The average seam thickness for all mines was 63 inches. Average thickness of seams worked in Utah, Wyoming, and North Dakota exceeded 100 inches. Average thicknesses of 50 inches or less were reported for Tennessee, Alabama, Michigan, Iowa, Missouri, Kansas, Arkansas, Oklahoma, and Texas (bituminous). The remaining States fell within 52- to 75-inch averages, with none in the 76- to 100-inch range. Figure 9 gives a detailed break-down of the percentage of coal coming from various intervals of seam thickness and the average seam thickness, by State.

Character of Roof and Overlying Strata

Support and control of the roof material overlying working places, haulage roads, and air courses are extremely important for safe and efficient operation. Rock strata overlying a seam may be divided into two parts, the immediate roof and the main roof. The immediate roof material may have a thickness from a few inches to 20 feet or more. Control of the main roof centers in methods of development, whereas support of the immediate roof depends upon methods of timbering.[8]

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[8] Methods of development refer to dimensional distances, such as width of rooms and room pillars; length of rooms; size of panals; width of barrier, entry, and chain pillars; and methods of pillar recovery. Methods of timbering include size of posts and cross bars used, distance between posts, and sequence of setting timber with reference to other details of operation at the working face. Considerable information is given on roof control in a series of reports issued by the U. S. Bureau of Mines. See the following publications of the Bureau [*Con.*]

Character of roof, unlike thickness, cover, and dip, is not measurable in quantitative values. Although experimentation may lead to definite quantitative values, at the present time no measures are available which permit a comprehensive comparison of roof conditions in the many coal fields of the country. Description of them by mining men is generally qualitative and has reference to their own experiences. Roof conditions are sometimes measured in terms of safety, sometimes in terms of timber costs, and sometimes in terms of a combination of factors. It is, of course, possible to characterize roof in certain areas as excellent and in other areas as bad. Bad roof implies that considerable time and money must be spent in setting timbers and in cleaning up rock when falls occur. Excellent roof implies absence of these difficulties and corresponding savings in time and money. Between these limits are found innumerable gradations.

A type of rock strata known as draw slate, which immediately overlies some coal seams, requires careful timbering to avoid falls and has to be taken down as the working face advances. It may vary in thickness from 6 inches to 6 feet, and where it occurs miners must handle an equal area of draw slate for every cut of coal mined. This has a marked effect upon labor output. Volume of coal and slate is in proportion to the relative thickness of the two. Managerial skill can contribute greatly toward lessening the burden of dead work involved in handling draw slate.

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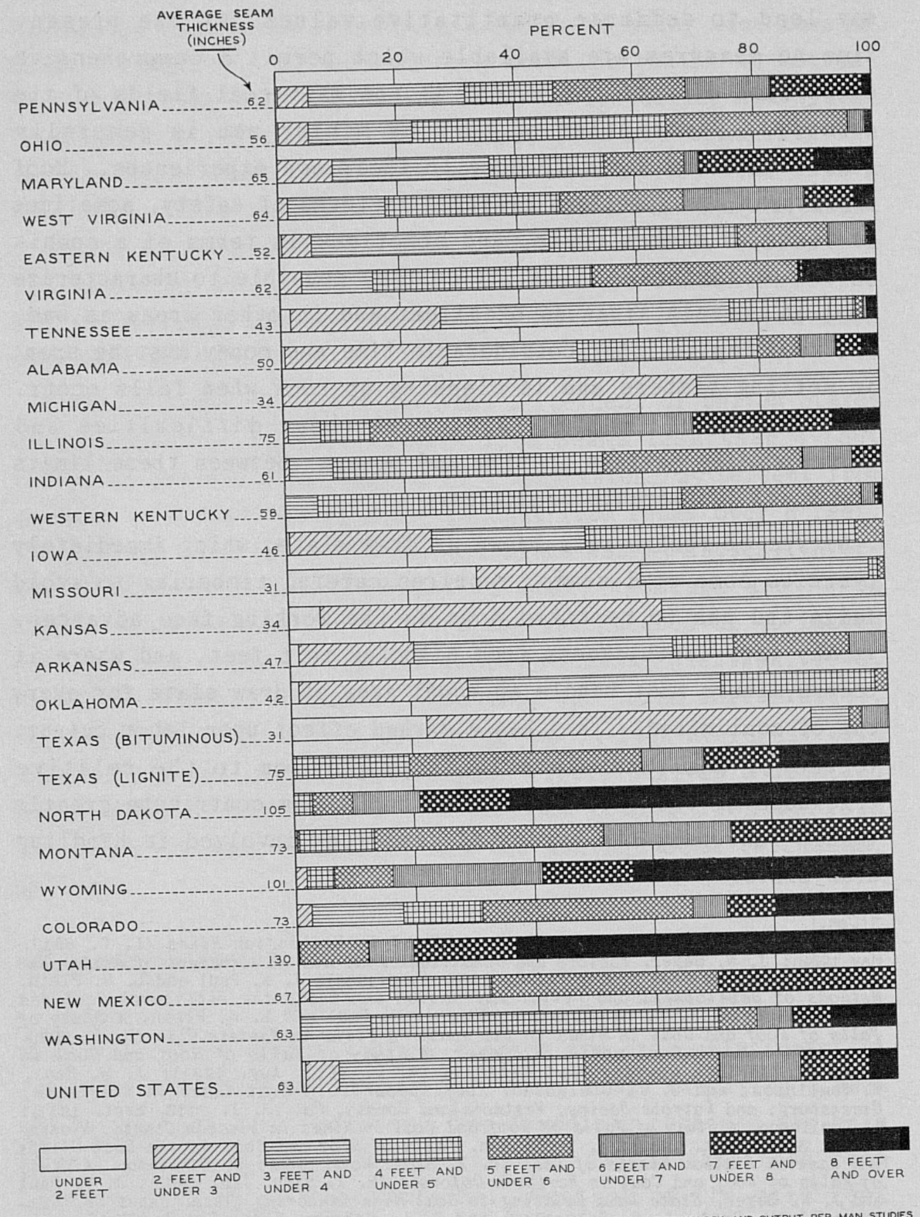
[8] [*Con.*]
of Mines: S. H. Ash, *Falls of Roof and Coal in Washington Mines* (I. C. 6617, May 1932); J. N. Geyer, *Factors and Conditions That Aid in Alinement of Pillar Extraction Lines in Coal Mining* (I. C. 6727, June 1933); J. W. Paul and L. N. Plein, *Methods of Development and Pillar Extraction in Mining the Pittsburgh Coal Bed in Pennsylvania* (I. C. 6872, Dec. 1935); J. W. Paul and L. N. Plein, *A Study of Falls of Roof and Coal in Mines in the Number 8 Field in Eastern Ohio* (R. I. 3070, Mar. 1931); J. W. Paul and J. N. Geyer, *A Study of Falls of Roof and Coal in Mines of Harrison County, West Virginia* (R. I. 3110, Aug. 1931); J. W. Paul, H. Tomlinson, and S. J. Craighead, *Roof Supports in Coal Mines in the Irwin, Greensburg, and Latrobe Basins, Westmoreland County, Pa.* (R. I. 3113, Sept. 1931); H. Tomlinson, *A Study of Falls of Roof and Coal in Mines in Lincoln County, Wyoming* (R. I. 3188, Sept. 1932); H. Tomlinson, *Falls of Roof and Coal in the Book Cliffs and Wasatch Plateau Fields of Utah* (R. I. 3189, Nov. 1932); H. Tomlinson, *A Study of Falls of Roof and Coal in Northern Colorado* (R. I. 3199, Jan. 1933); J. W. Paul and J. N. Geyer, *State Laws Relating to Coal-Mine Timbering* (Tech. Paper No. 421, 1928); J. W. Paul, J. G. Calverley, and D. L. Sibray, *Timbering Regulations in Certain Coal Mines of Pennsylvania, West Virginia, and Ohio* (Tech. Paper No. 485, 1930); J. W. Paul and J. N. Geyer, *Falls of Roof and Coal in Mines Operating in the Sewickley Coal Bed in Monongalia County, West Virginia* (Tech. Paper No. 520, 1932); J. W. Paul and J. N. Geyer, *Falls of Roof and Coal in Mines Operating in the Pittsburgh Coal Bed in Marion and Monongalia Counties, W. Va.* (Tech. Paper No. 522, 1932); J. W. Paul and J. N. Geyer, *Falls of Roof and Coal in Mines Operating in the Pittsburgh Coal Bed, Panhandle District, West Virginia* (Tech. Paper No. 534, 1932); J. W. Paul and L. N. Plein. *A Study of Mine Roof of the Pittsburgh Coal Bed in the Pittsburgh Mining District* (Tech. Paper No. 541, 1932); J. W. Paul and J. N. Geyer, *Falls of Roof in Mines Operating in the Pittsburgh Coal Bed, West Virginia* (Tech. Paper No. 547, 1933); J. W. Paul and J. G. Calverley, *A Study of Roof In Pennsylvania Mines Contiguous to the Monongahela River* (Tech. Paper No. 550, 1933); J. W. Paul and L. N. Plein, *A Study of Mine Roof in the Coking District of Western Pennsylvania* (Tech. Paper No. 563, 1935).

Figure 9.- PERCENTAGE DISTRIBUTION OF BITUMINOUS COAL MINED, BY NET SEAM THICKNESS AND STATE, 1920



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Roof conditions influence output through the time spent in timbering - a nonproductive, time-consuming operation which, except to a limited extent, is not susceptible to mechanization.[9] The best mining practice today sets up definite timbering standards which must be followed irrespective of roof conditions, with stipulation that additional timber must be set when necessary. Not only must face workers spend part of their time setting posts, but daymen must be used to maintain a service of supply from the outside timberyard into the mine and thence to every individual working place. Additional men must be employed to inspect haulage roads and airways and to set whatever permanent or semipermanent roof support is needed to insure safe and efficient mine operation. Character of roof determines the spacing of timbers, and this in turn places certain limitations on the use of machinery. The strength of the immediate roof, the width of working places, and the amount of artificial support needed to hold and control the roof are interrelated items in their influence on mechanization and labor output.

The character of roof support and control is a primary factor affecting the installation of mechanical devices. Because of advancing technology in this subject, timbering requirements no longer present an insurmountable barrier to the use of cutting or loading machinery. If the character of the roof is such that by proper roof control relatively large working places in close proximity to each other can be secured, greater tonnage per machine can be provided and less time will be lost in moving equipment.

Considerable progress has been made in both the practical and the theoretical study of roof support. If results of laboratory studies prove successful in practice, long-face operations may become possible which will permit loading machines to function continuously throughout a shift with tonnages far greater than any yet realized.[10] The conclusion is obvious that here, as in other resource conditions, physical factors are interlocked with the principles of management. Bad roof is a handicap to labor output, but skillful management can, to a great extent, offset its disadvantages.

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[9] Prepared timber sets for use in seams of more or less uniform thickness can be delivered underground with varying-sized wedges which greatly reduce man-hours needed to place them. Also, timbering by so-called hitch-drill methods decreases labor requirements.

[10] See Philip B. Bucky, "Roof Control Problems in High-Speed Mechanization Answered by Barodynamics," *Coal Age*, Vol. 43, No. 1 (Jan. 1938), pp. 61-6; "Putting Theory to Work," *Coal Age*, Vol. 43, No. 3 (Mar. 1938), p. 42.

Character of Bottom or Floor

The rock strata immediately below the coal seam may impose burdens upon coal-mine operations, but in general their effect on unit labor requirements in American coal mines is not so important as in European mines where seams are worked at much greater depths. The most serious difficulties are with bottoms that are rolling or soft, on which cutting machines cannot be used to full advantage. Rolls and pitches also place additional burdens upon haulage, although the use of conveyors (which, aside from loading, complete the transportation from the room face to the room entry) may assist in overcoming the disadvantages of rolling bottom.

A floor that is soft or that weathers easily, and is relatively weaker than the roof overlying the coal seam, may heave or rise in the working places, sometimes filling them as completely as if the roof had caved. In the case of a heaving bottom the stress of overlying rock pressures is relieved by the rock beneath the coal, instead of the roof above the coal, giving way. Heaving bottom is expensive to handle and obviously reduces output. It is comparable to mining thin seams in which the bottom must be taken up to give haulage clearance. Engineering skill can minimize some of the effects of heaving bottom by proper spacing and size of pillars in relation to the width of the room opened.[11] Conveyors have been successfully used in working places with bad heaving conditions in which the cost of hand loading would probably have been prohibitive. Soft bottom is generally considered a bar to the use of scrapers because of the impurities that are scraped up with the coal. Better coordination between the productive and dead-work cycles in scraper practice would probably improve performance.

Character of the Seam

Aside from thickness of seam, physical factors inherent in the coal itself have a bearing upon labor output. These variables are hardness, quality, distribution of impurities,[12]

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[11] Many heaving-bottom conditions are overcome by taking only a small percentage of the total coal as the room advances and increasing the amount of extraction on the retreat.

[12] Following are special forms of impurities: (1) *Binders*, impurities in the coal seam found in bands parallel to the bedding of the coal; (2) *clay veins*, impurities usually consisting of shales or sandstones varying in thickness from [*Con.*]

irregularities in seam thickness, and benches or double bedding.[13] The importance of these resource factors is that they have a direct influence upon the efficiency of the most labor-consuming task - loading - and if adverse will decrease output whether machine loading or hand loading is practiced.

Hardness of coal has a bearing on cutting and drilling, although its effect on labor output is slight at the present time. Before the introduction of cutting machines hardness impeded cutting and was a drag on output. Most of the bituminous coal is now cut by machines and hardness ceases to be a great liability. The cutting time may be greater and the machine bits may have to be resharpened more frequently, but these handicaps are now largely obviated by use of alloy steels. Furthermore, improvements in design have made the task of changing bits less time-consuming than it was in earlier years. Approximately three-fourths of the bituminous coal is still drilled by hand, and hardness necessarily retards the drilling time. However, power drilling is increasing rapidly.

At the other end of the scale, softness or friability of coal may be a deterrent to the use of loading machines. Under present marketing conditions larger sizes of coal ordinarily command the highest prices,[14] and it is important to load the softer coals with great care in order to minimize degradation. This has been offered as a reason for the infrequency of mechanical loading in the Pocahontas field, although it appears that hand-loaded conveyors would be feasible since they cause a minimum of degradation.[15] Degradation resulting from mechanical loading is a factor to be considered in any coal regardless of its hardness. Quite often the reductions in mining costs are offset in part by decreased realization resulting from the degradation.[16] Quality, in itself, should have little effect on labor output, except as it affects

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[12] [*Con.*]
a few inches to several feet and extending from the top to the bottom of the seam; (3) *wants*, areas in the coal seam which were eroded at the time of deposition and were then filled in with sand or mud which consolidated to sandstone or shale; and (4) *horsebacks*, irregularities of shale or sandstone found in top or bottom of the seam, extending across the seam, and generally a few feet thick and several feet wide.

[13] Benches or double bedding refer to variations in some seams in which the top half and bottom half of the deposit have distinct differences in physical characteristics, such as hardness and quality.

[14] With the development of automatic stokers and their increasing entry into the field of domestic consumption, coal is coming more and more to be sold on the basis of B. t. u. and impurity content; large sizes are becoming less important.

[15] Coal from the Pocahontas seam breaks down under the most careful hand loading. Case histories are offered by machinery manufacturers in which mechanical loaders are shown to cause less degradation than hand loaders.

[16] See pp. 23-4.

marketability and thus controls the running time of the mine. Dead work normally is greater at the mine with limited running time, and therefore output per man-day is usually less.

Various types of impurities that become mingled with coal in mining obviously affect labor output to the extent that miners are occupied in removing rock or bone while the coal is being loaded. This is important in hand loading and in mines where pit-car loaders and conveyors are used. With mobile loaders, scrapers, and duckbills, cleaning as the coal is loaded becomes impracticable.[17] Thus, although the distribution of impurities has an important bearing on the quality of coal that can be produced from a given seam, the presence of impurities, except in extreme cases, does not greatly affect output under mechanical loading. Irregularities in seam thickness, variations in physical characteristics of top and bottom, and, in some seams, the form in which impurities appear, introduce burdens that tend to reduce output by upsetting the normal sequence of operations. In general the influence of the quality is reflected in the selling price and presumably in net return rather than in labor output. The rank of the coal, whether it be bituminous or lignite, has no bearing upon output except as to certain physical characteristics and marketing conditions associated with rank.

Dip or Pitch of Seam[18]

The dip of a coal seam is the measure of the angle between a horizontal plane and the plane of the seam. In general, the effect of dip on output is not great in American mines. In the study by Schoenfeld already cited it was found that 65 percent of bituminous production in 1920 came from seams with less than a 2-degree dip, 20 percent from seams dipping 2 to 4 degrees, 8 percent from seams dipping 4 to 7 degrees, and the remaining 7 percent from seams with greater dip. Figure 10 shows the percentage distribution of tonnage produced in 1920 by degree of dip for the United States and for individual States. If similar data were available for 1938 it is probable that little if any change would have to be made in the chart.

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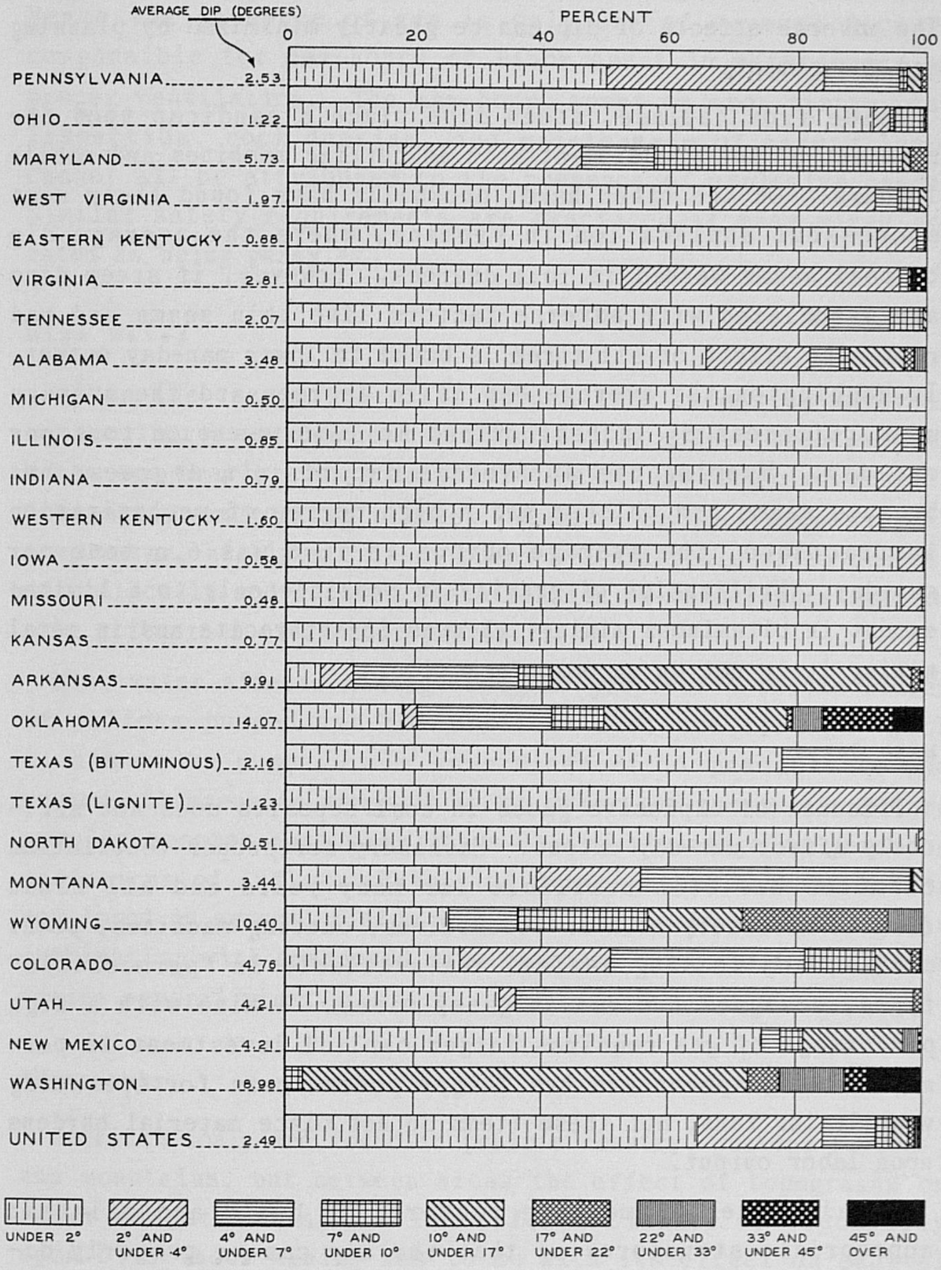
[17] See section on Coal Preparation in chapter II for discussion of interrelation of mining and cleaning.

[18] For the purposes of this report the terms "dip" and "pitch" are used interchangeably.

Figure 10.- PERCENTAGE DISTRIBUTION OF BITUMINOUS COAL MINED, BY DEGREE OF DIP OF BED AND STATE, 1920



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Increasing degrees of dip affect car haulage adversely. Seams with dip of about 2 degrees or less are considered flat because such a dip does not add appreciably to the burden of mainline haulage.[19] Labor output is sacrificed when seams dip too much to be disregarded and at the same time too little for the advantages of the force of gravity to be reaped. The adverse effects of dip can be greatly minimized by planning and management.

Aside from haulage, steep dips place a handicap upon the movement of heavy equipment such as cutting machines and mobile loaders. On the other hand, duckbills have found their most successful application in Wyoming, where the average dip of coal seams worked is 10.4 degrees. However, if steep dips are associated with adverse factors like thin seams and bad roof, the effect of all three is bound to lower man-day output. In Washington the average dip is 19 degrees and the average seam thickness 63 inches; output in 1936 was 3.46 tons per man-day. Wyoming has an average dip of 10.4 degrees, but because seams are thicker and a high degree of mechanization is practiced, the average output in 1936 was 6.0 tons per man-day. Utilization of gravity is possible only to a limited extent in bituminous mining, whereas in anthracite and in metal mining it is not an uncommon practice.

Mine Gases

Presence of explosive gases in coal deposits does not seriously affect man-day output. Machinery for proper ventilation of mines has been available for many years and all kinds of mine machinery such as locomotives, cutting machines, power drills, and loading devices are available in "permissible" types, designed for use in gassy mines. A mine with a high percentage of gas requires larger capital investment in permissible equipment and has larger power costs for operating ventilating fans, but these items do not place material burdens upon labor output.

In all mines daymen are required to build and maintain appropriate structures so that the air can be properly directed, at minimum cost, to the individual working places throughout the mine. The importance of this work, and the

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[19] Haulage grades up to nearly 4 degrees for locomotives and 6 or 7 degrees for animals are usually practical in gathering haulage, since the locomotive or animal usually handles but one car at a time. Above these limits rope haulage becomes necessary. When a 17-degree dip is reached the force of gravity may be utilized. Between 17 and 22 degrees coal can be pushed downhill by shovels, above 22 degrees it slides freely on a metal surface, and above 25 or 30 degrees it will slide on a rock surface.

man-hour requirements for it, depend not only upon the amount of gas present but also upon the size of mine, height of coal, development system, and size and number of ventilating fans. Hence the presence of gas is only one of several factors responsible for man-hours of labor spent in maintenance of proper ventilation. The man-hours spent in shot firing, gas inspection, rock dusting, and maintenance of safety lamps cannot all be attributed to the presence of explosive gases. Similar safety requirements are practiced at many mines not rated as being gassy.[20]

Mine Water

As in the case of gas, the burden from excessive water in a mine increases overhead but has little effect upon output. Mines are nearly always laid out to take advantage of gravity drainage from working places. When it becomes necessary to pump water, highly efficient pumps are available which operate automatically and require the attention of maintenance men for only a fraction of an hour per shift.

Mine water affects mining costs in proportion to the number of gallons pumped and the vertical distance through which it has to be pumped. In some mines it is possible to use worked-out areas as sumps in which water can accumulate before pumping becomes necessary, thus taking advantage of periodic variations of inflow. Extensive drainage projects have been developed in several fields in which, by use of rock tunnels in combination with abandoned mine entries, a single installation drains several mines.

Topography

American coals are found in prairie country, plateau regions, and mountains, but between areas the effect of topography on labor output is small. The chief influence of topography upon bituminous mining has to do with its effect on capital investments. A single illustration will make this point clear. A shaft mine located on the Illinois prairie has ample space for tipple, machine shops, wash house, refuse disposal, and mining town, if needed. Roads and other connections on the

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[20] See section on mechanization of auxiliary services in chapter II for further details about auxiliary services.

surface are inexpensive to build. Compare this with a mine located in a narrow, V-shaped, West Virginia valley. A stream, a railroad track, and a highway use practically all the space in the valley bottom. Within this narrow confine must be located a tipple with one to four or more tracks, machine shops, a company store, and a mining town which must literally hang on the hillside. Roads about the camp are expensive to build and to maintain, and disposal of waste material from the mine may become a serious problem as the mine ages. On the other hand, the Illinois mine in the same location is put to heavy capital investment in the sinking of a shaft, whereas the West Virginia mine may be able to reach the coal seam by a horizontal drift. Although these costs are not reflected in unit labor requirements, differences in carrying charges on capital investment enter into total costs and so affect profits.

Climate

The advent of modern machinery has practically eliminated the effect of climatic conditions upon coal mining. Severe winter weather with extreme cold and heavy snowfalls has some slight effect upon tipple operation, but the number of days of such weather occurring even in our northernmost latitudes is not serious enough to affect an industry that at best operates only part time. Even in strip mines the effect of severe winters or torrential summer rains has been minimized. In areas of heavy rainfall strip mines require a complete system of ditching and ample pumping equipment. In contrast, the small amount of rainfall in arid regions raises a problem of water supply for mining towns and washeries. Variations in climate, like those in topography, cause some differences in capital investment but do not greatly affect labor output.

CONTINGENT FACTORS

Resource conditions discussed in the preceding pages pertain to coal deposits in their natural state, and although choice may be exercised in methods of handling them, the conditions themselves cannot be changed. In contrast to such physical factors as depth of cover, thickness of coal seam, character of roof and floor, and dip, other physical conditions incident to coal mining result from choice, exercised either currently or in the past. Current options include the way in which a new mine is opened and the size of the mine as reflected in the extent of workings and scheduled tonnages. Results of past options are found in the age of mines and the degree to which their resources are depleted. Resource factors amenable to choice may be designated as physical conditions associated with development and operation. The four factors noted will be considered in the order indicated.

Type of Opening

Coal deposits are worked either from the surface or by deep mining underground. Recovery of coal from the surface, known as strip mining, is discussed at length in chapter IV. Types of opening used in deep mines are controlled largely by topography and depth of cover and are designated as drift, slope, or shaft openings. A drift is a level opening through which the coal is moved to the tipple in cars by motor or animal power. A slope is an inclined opening that may be at almost any angle from the horizontal. When slope openings are used, cars are pulled by a rope operated from a hoisting engine or, in some cases, the coal is carried up the incline by conveyors. A shaft is a vertical opening in which the loaded cars are hoisted one or two at a time within a cage or, in occasional operations, in which the coal is lifted in a skip (or bucket). Drifts or slopes may be driven either in coal or rock, but ordinarily are driven in the seam itself. Shaft openings must always be sunk through rock to reach the seam of coal.

Basically, drift openings should be the most efficient type and shaft openings the least, with slopes occupying an intermediate position. In actual practice, however, the disadvantages due to hoisting from shaft or slope mines have been greatly minimized by technological advances. Sometimes other factors - proximity to railroad transportation, for example - may even give to a shaft opening an advantage not possessed by a drift or slope opening.

The initial investments in sinking shafts and installing machinery represent a charge upon operations but do not affect labor output. Certain drift mines in the Appalachian field have been opened high on the hillsides with tipples located in the valley bottoms alongside a railroad. In these cases coal must be lowered by various devices such as aerial trams, conveyors, or monitors (buckets of 5- to 15-ton capacity which run on rails and are raised and lowered by ropes). Such equipment represents a substantial investment and tends to minimize the advantage of a drift mine over a shaft mine.

As in other phases of operation, technology is effectively employed to overcome disadvantages in connection with types of opening. Output per man-day of employees engaged in transportation in a shaft mine equipped with a high-speed hoist is far greater than that realized in a small drift mine using less efficient animal or motor haulage.[21] The type of opening has a marked effect on the transport phase of coal mining, but the number of men occupied with moving coal from the mine to the tipple is small in relation to the total mine force. Accordingly, the effect of the kind of opening upon over-all labor output is limited.

From figure 11 it may be seen that in 1926 about two-thirds of the deep tonnage of the United States came from slope and drift mines and one-third from shaft mines.

Size of Mine

The size of a mine is greatly influenced by resource conditions in the particular seam in which it is opened. Management exercises control, however, in adapting size to these conditions and to the scheduled daily and annual output. For many years the Bureau of Mines has published measures of the size of mines based upon annual output. A more accurate measure would be daily output, or daily capacity, but data for such measurement are not available. Another significant measure of size would be areal extent of mine workings in relation to daily output.

The average annual output of bituminous mines in 1936 was 64,000 tons; this average, however, is heavily weighted by a great number of small mines. Of the total 1936 production

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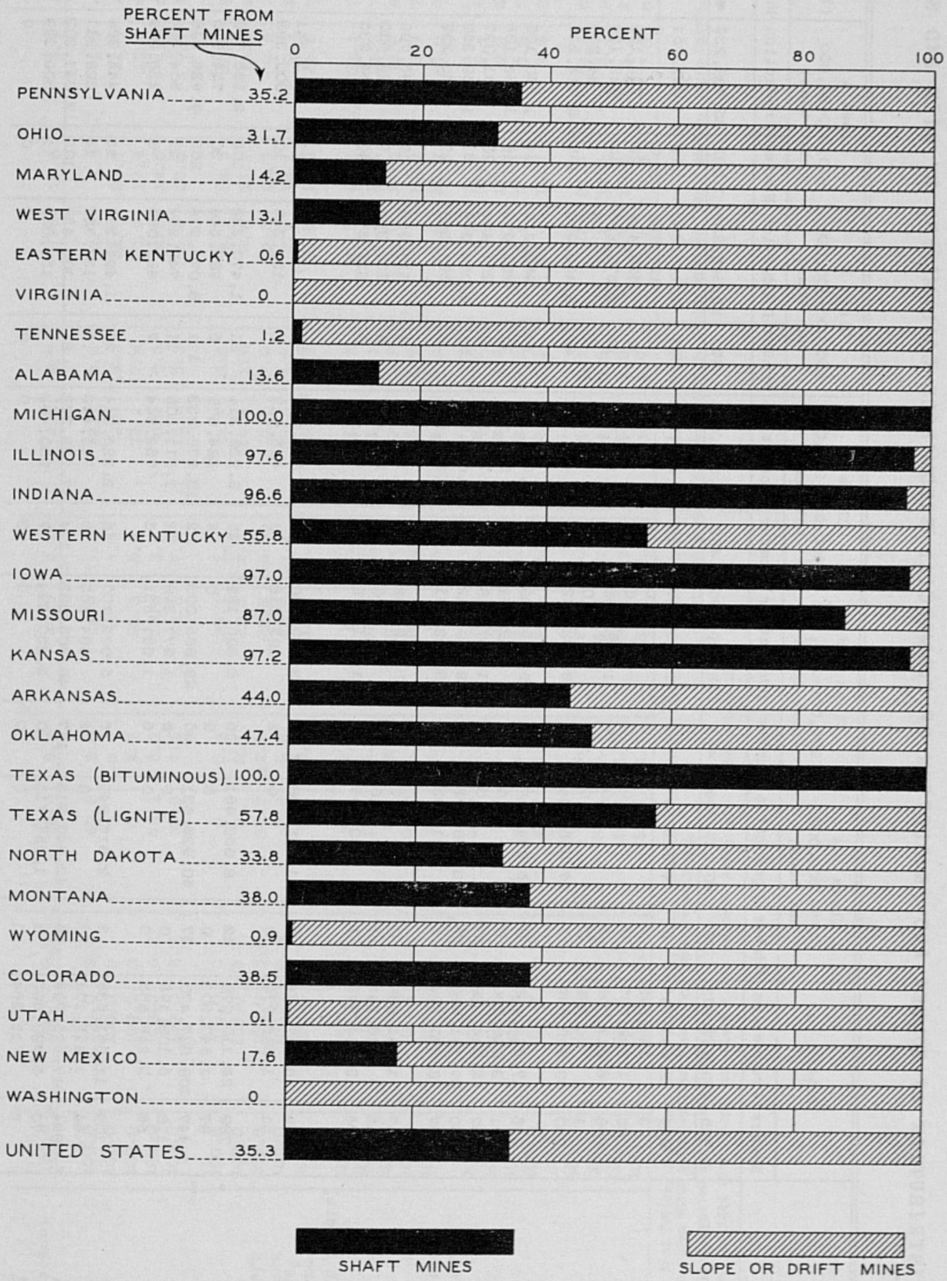
[21] In a shaft mine the haulage crew turns the loaded cars over to the bottom crew at the foot of the shaft. The bottom crew uncouples the loaded cars, runs them onto the cage, and removes and recouples the empties. At the top another crew removes the loaded cars and replaces empties on the cage. In drift mines the mainline-haulage motor hauls a load varying from 10 to 75 cars out of the drift to the mouth of the tipple. There is considerable variation in the organization of haulage in slope mines, depending upon the angle of the slope and the type of hoisting facilities used.

Figure 11.- PERCENTAGE DISTRIBUTION OF BITUMINOUS COAL MINED, BY KIND OF OPENING AND STATE, 1926

(Strip mines excluded)



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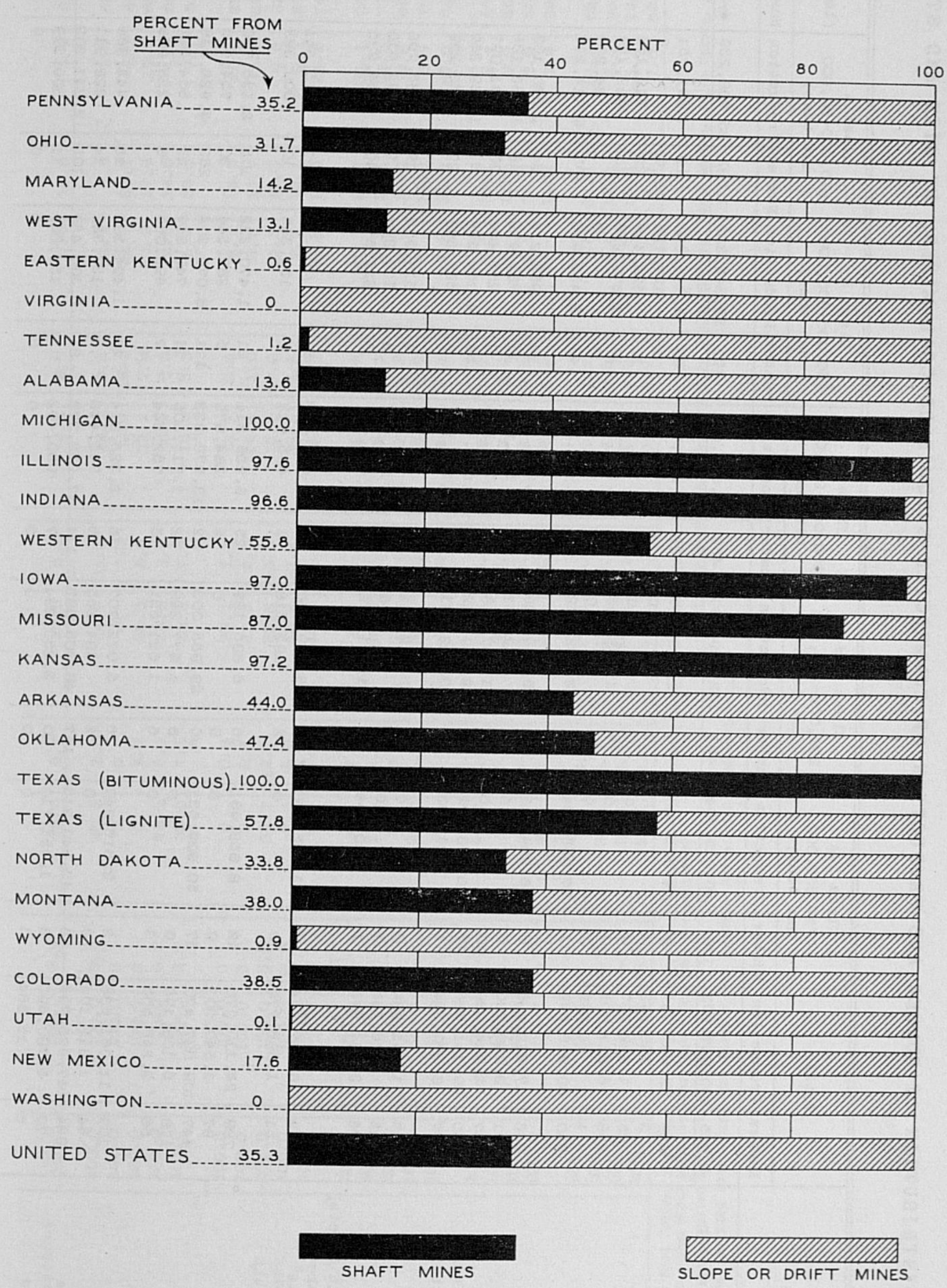

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Table 6.- DISTRIBUTION OF NUMBER AND PRODUCTION OF COMMERCIAL BITUMINOUS-COAL MINES, BY SIZE AND STATE, 1986[a]

State	Total		Class 1-A (over 500,000 net tons)		Class 1-B (200,000-500,000 net tons)		Class 2 (100,000-200,000 net tons)		Class 3 (50,000-100,000 net tons)		Class 4 (10,000-50,000 net tons)		Class 5 (less than 10,000 net tons)	
	Number	Production	Number	Production	Number	Production	Number	Production	Number	Production	Number	Production	Number	Production
United States, number	6,875	439,087,903	198	160,029,294	462	142,889,650	452	65,055,054	460	33,345,382	1,085	25,788,239	4,218	11,980,284
Alabama	229	12,229,287	8	4,928,587	6	1,713,437	26	3,559,152	15	1,144,688	19	451,751	155	431,672
Alaska	3	136,593	0	0	0	0	0	0	2	127,755	0	0	1	8,838
Arkansas	75	1,622,787	0	0	0	0	1	158,628	10	628,447	29	716,168	35	119,544
Colorado	258	6,811,802	0	0	7	1,808,093	15	2,264,007	19	1,379,226	45	923,128	172	437,348
Georgia	1	24,288	0	0	0	0	0	0	0	0	1	24,288	0	0
Illinois	740	50,926,599	31	27,055,204	37	13,132,542	26	3,484,272	48	3,453,903	107	2,414,246	491	1,386,432
Indiana	246	17,822,536	9	6,234,817	18	5,849,229	19	2,909,185	13	956,219	64	1,370,105	123	502,981
Iowa	361	3,960,700	0	0	3	797,751	4	501,939	10	755,978	48	1,063,106	296	841,926
Kansas	187	2,944,028	0	0	5	1,257,948	5	729,673	3	251,406	20	401,097	154	303,904
Kentucky, eastern	330	39,151,586	17	13,958,472	42	12,859,132	43	6,096,453	56	4,052,266	61	1,889,357	111	295,906
Kentucky, western	167	8,370,364	1	621,983	11	3,532,061	17	2,537,954	8	597,368	27	762,239	103	318,759
Maryland	107	1,703,589	0	0	1	222,882	2	319,135	7	518,953	17	436,798	80	205,821
Michigan	15	626,145	0	0	0	0	2	278,447	2	138,394	7	194,610	4	14,694
Missouri	234	3,984,999	1	600,906	4	1,121,972	3	448,454	5	331,577	40	954,935	181	527,155
Montana, North Dakota, South Dakota, and Texas[b]	292	6,087,814	1	1,225,468	11	3,199,008	8[c]	731,831[c]	(c)	(c)	21	415,341	251	516,166
New Mexico	51	1,596,775	0	0	2	583,616	3	485,612	2	138,243	10	300,393	34	88,911
Ohio	788	24,110,078	12	8,858,461	26	6,885,199	25	3,239,214	21	1,470,222	105	2,136,790	599	1,520,192
Oklahoma	97	1,540,303	0	0	0	0	2	284,879	5	289,344	30	754,920	60	211,160
Pennsylvania	1,447	109,887,470	57	50,936,631	90	28,865,003	92	13,278,933	111	8,070,304	262	5,926,918	835	2,809,681
Tennessee	118	5,108,195	0	0	8	1,977,298	12	1,711,305	11	749,267	21	504,532	66	165,793
Utah	56	3,246,565	0	0	6	1,661,551	5	752,544	7	499,095	8	223,039	30	110,336
Virginia	109	11,661,636	3	2,316,840	16	5,072,707	15	2,325,314	20	1,401,307	15	444,965	40	100,503
Washington	64	1,812,104	0	0	2	494,855	6	745,443	2	137,322	14	328,811	40	105,673
West Virginia	824	117,925,706	56	42,240,215	157	48,605,082	114	17,282,278	81	6,100,439	103	2,841,303	313	856,389
Wyoming	70	5,780,590	2	1,051,710	10	3,250,284	7	930,402	2	153,659	11	309,399	38	85,136
Other States[d]	6	15,364	0	0	0	0	0	0	0	0	0	0	6	15,364

United States, percent	100.0	100.0	2.9	36.5	6.7	32.5	6.6	14.8	6.7	7.6	15.8	5.9	61.3	2.7
Alabama	100.0	100.0	3.5	40.3	2.6	14.0	11.4	29.1	6.5	9.4	8.3	3.7	67.7	3.5
Arkansas	100.0	100.0	0	0	0	0	1.3	9.8	13.3	38.7	38.7	44.1	46.7	7.4
Colorado	100.0	100.0	0	0	2.7	26.5	5.8	33.2	7.4	20.3	17.4	13.6	66.7	6.4
Illinois	100.0	100.0	4.2	53.1	5.0	25.8	3.5	6.9	6.5	6.8	14.5	4.7	66.3	2.7
Indiana	100.0	100.0	3.7	35.0	7.3	32.8	7.7	16.3	5.3	5.4	26.0	7.7	50.0	2.8
Iowa	100.0	100.0	0	0	0.8	20.1	1.1	12.7	2.8	19.1	13.3	26.8	82.0	21.3
Kansas	100.0	100.0	0	0	2.7	42.7	2.7	24.8	1.6	8.6	10.7	13.6	82.3	10.3
Kentucky, eastern	100.0	100.0	5.2	35.7	12.7	32.8	13.0	15.6	17.0	10.3	18.5	4.8	33.6	0.8
Kentucky, western	100.0	100.0	0.6	7.4	6.6	42.2	10.2	30.3	4.8	7.2	16.1	9.1	61.7	3.8
Maryland	100.0	100.0	0	0	0.9	13.1	1.9	18.7	6.5	30.5	15.9	25.6	74.8	12.1
Michigan	100.0	100.0	0	0	0	0	13.3	44.5	13.3	22.1	46.7	31.1	26.7	2.3
Missouri	100.0	100.0	0.4	15.1	1.7	28.2	1.3	11.2	2.1	8.3	17.1	24.0	77.4	13.2
New Mexico	100.0	100.0	0	0	3.9	36.5	5.9	30.4	3.9	8.7	19.6	18.8	66.7	5.6
Ohio	100.0	100.0	1.5	36.7	3.3	28.6	3.2	13.4	2.7	6.1	13.3	8.9	76.0	6.3
Oklahoma	100.0	100.0	0	0	0	0	2.1	18.5	5.1	18.8	30.9	49.0	61.9	13.7
Pennsylvania	100.0	100.0	3.9	46.3	6.2	26.3	6.4	12.1	7.7	7.3	18.1	5.4	57.7	2.6
Tennessee	100.0	100.0	0	0	6.8	38.7	10.2	33.5	9.3	14.7	17.8	9.9	55.9	3.2
Utah	100.0	100.0	0	0	10.7	51.2	8.9	23.2	12.5	15.4	14.3	6.8	53.6	3.4
Virginia	100.0	100.0	2.7	19.9	14.7	43.5	13.8	19.9	18.3	12.0	13.8	3.8	36.7	0.9
Washington	100.0	100.0	0	0	3.1	27.3	9.4	41.1	3.1	7.6	21.9	18.2	62.5	5.8
West Virginia	100.0	100.0	6.8	35.8	19.1	41.2	13.8	14.7	9.8	5.2	12.5	2.4	38.0	0.7
Wyoming	100.0	100.0	2.9	18.2	14.2	56.2	10.0	16.1	2.9	2.7	15.7	5.3	54.3	1.5
Other States[e]	100.0	100.0	0.3	19.6	3.6	51.1	2.7	11.7	0.7	2.0	7.3	7.0	85.4	8.6

[a] Based on *Bituminous Coal Tables, 1936-1937* (U. S. Dept. Int., Nat. Bituminous Coal Com., 1938), p. 15. Truck or wagon mines which produced less than 1,000 tons are excluded.

[b] Includes lignite figures compiled by Burèau of Mines.

[c] Data for Class 3 are included with those for Class 2 for Montana, North Dakota, South Dakota, and Texas.

[d] Includes Arizona, Idaho, and Oregon.

[e] Includes Alaska, Arizona, Georgia, Idaho, Montana, North Dakota, South Dakota, Oregon, and Texas.

of the country, 69 percent came from mines that produced over 200,000 tons, but these mines represented only 9.6 percent of the total number. At the other extreme, 77.1 percent of the mines produced annually less than 50,000 tons, but their aggregate output was only 8.6 percent of the total for the country. Over 70 percent of the output in the important mining States of West Virginia, Pennsylvania, and Illinois came from mines producing over 200,000 tons per year. (See table 6.)

Management, by making wise adjustment of the extent of workings to operating and marketing conditions, can go far toward overcoming physical handicaps. In general, the unit cost of roof support in the working places or rooms where the miners load coal does not vary with the daily output of a mine. Such factors as dip, depth of cover, and thickness of the coal seam enter into the problem of operating a mine. But here again, within limits, the problems arising from these factors can be solved in the process of producing a larger output as well as a smaller one. Naturally, areal extent of active working areas and length of haulage vary with daily tonnage. Ventilation and power distribution must also be adjusted to the extent of workings. As daily output increases, these auxiliary services increase, and, unless properly managed, costs may rise at a rate out of proportion to the increase in production.

The areal extent of mine workings is measurable to some degree by the average distance from the mine opening to the working face. In the report by Margaret H. Schoenfeld it was found that for all bituminous mines the average distance to the face was over a mile (6,040 feet). Considerable variation was found between areas and between types of opening. Distances in shaft mines varied from 900 feet in the Texas lignite fields to 1,700 in Arkansas, 7,300 in Ohio and Pennsylvania, and 9,600 feet in Alabama. For drift and slope mines average distances ranged from 700 feet in Texas lignite to 1,500 in Arkansas, 4,600 in Alabama, 6,600 in Ohio, and 7,400 in Pennsylvania. Although considerable changes in distances underground have occurred during the past decade, the figures for 1926 present some indication of the magnitude of the underground operations as related to the size of mines.

As in the case of roof control, maintenance of haulage and other services is not proportionately increased by increase in size of mines. The relationship of different underground operations to size varies according to the conditions surrounding particular mines. Where coal lies at considerable depth beneath the surface, a large mine with a single shaft is more economical than a number of small mines with individual shafts. In areas of shallow cover, multiple shafts with mines of moderate size may be advantageous. Similar principles apply in the case of drift mines.

In general, increasing size of mines is subject to the same laws of increasing and diminishing returns that apply to other large enterprises. During development, before mines have come fully into their stride, increasing size is usually associated with increasing man-day output. As size and capital investment increase, the ratio of added output to new investment tends to diminish, and a point is finally reached beyond which further investment does not result in increased output.

Relatively large mines frequently show better results than smaller mines because they are better managed. Many mining operations in the past have given only limited attention to the benefits that accrue from concentrating operations, an advantage which mechanization of loading greatly emphasizes. The relationship between size of mines and man-day output is determined by the skill with which management coordinates physical conditions and technology.[22]

Age of Mine

In general, old mines have lower man-day output than have new ones. In addition to the disadvantage of increasing distance underground, mines opened 20 or 40 years ago were planned in reference to the technology of that time. Unless management keeps abreast of technical improvements, obsolescence of equipment and increase in areal extent become a cumulative drag on labor output. In changing a mine from hand loading to machine loading the capital needed to improve allied equipment, such as power transmission, haulage motors, mine cars, mine track, and mechanical cleaning equipment, is frequently much greater than the cost of the loading devices themselves. Because of the expense of modernizing allied equipment and

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[22] For statistical study of relation between size of company, sales realization, days worked, and average output per man-day see F. G. Tryon and L. Mann, "Coal," *Mineral Resources of the United States: 1929* (U. S. Dept. Com., Bur. Mines, 1931), Part II, "Nonmetals," pp. 718-33.

because of the short time remaining for the mine to amortize the investment, installation of machine loading in a mine approaching exhaustion is generally ill-advised.[23]

Depletion of Reserves

Current deep-mining practice does not contemplate anything like complete recovery of the coal resources contained in a virgin mine. The highest recovery is secured in strip mines in which, under favorable conditions, coal can be stripped with a recovery of over 90 percent. In underground mining it is common practice in some coal fields to leave a large percentage of the total coal in place permanently to support the roof. In some areas, as in Illinois, producers are compelled to operate their mines in such a way that the surface of the ground above the mines will not subside. Moreover, operators consider it cheaper from the standpoint of immediate cost to leave the pillars in place than to mine them. If the resources in a particular area are so great that depletion is regarded as a problem of the distant future only, the tendency is to sacrifice percentage of recovery in favor of lower current cost. This is a form of skimming the cream similar to that found in the exploitation of forests and other natural resources.

Management's attitude toward depletion of resources is to a considerable extent within the control of the individual concern. On the other hand, the over-all effect of wasteful mining exerts an influence on over-all output in general which, because it is widely dispersed, is scarcely recognized in current operations. When the particular concern controls extensive coal resources, management can extend its operations from more favorable to less favorable seam conditions as the resources from the better seams are depleted. Thus far the shift from better to poorer seams has not greatly affected man-day output for the country; in certain districts, however, the effects of depletion are notable, and in other areas the life expectancy of existing mines is such as to present a serious conservation problem.[24]

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[23] The study by Margaret H. Schoenfeld made in 1926 of the average daily output per man-day in reference to the age of mines indicated that with advancing age there was a general downward trend in output. Many variables enter into such a calculation, and a curve showing the relation between age of mine and man-day output results in trends that are erratic with respect to age but explainable on the basis of other unrelated factors.

Footnote 24 appears on following page.

Estimates made under the auspices of the U. S. Geological Survey indicate that the original resources of coal, including anthracite, were 3,215 billion tons, of which 34 billion had been exhausted by mining and waste at the end of 1936, leaving 3,181 billion tons in reserve.[25] Analysis of these figures shows that 29.5 percent of the existing reserve consists of lignite chiefly in the Dakotas, Montana, and Texas. Bituminous and sub-bituminous coals in the Rocky Mountain States comprise an additional 37.2 percent, and the balance of 33.3 percent consists chiefly of bituminous coals east of the Rocky Mountains. This eastern area, however, consumes roughly 96 percent of the total annual output. It is obvious that total coal resources are ample for centuries, but the highest-quality coals, easily accessible to markets and offering easy mining conditions, are being depleted at a rate such that their life can be measured in decades.

MANAGEMENT

As already apparent, the effect of resource factors upon man-day output cannot be dissociated from management and machines. Unsuitable mining methods and equipment may be a greater drag on output than unfavorable physical conditions. Mine engineers and management have the task of directing development and operation so that organization and technology are advantageously adapted to the conditions encountered as mining proceeds. This responsibility is continuous since experience usually leads to modification of the best of plans, and mine methods as well as equipment become obsolete unless periodically reviewed.

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[24] Rice, Fieldner, and Tryon, *op. cit.*, pp. 679-80. Following is the substance of observations from this work concerning depletion in several fields.

In Pennsylvania the Blossburg seam and the Moshannon seam are in an advanced state of depletion. The life of the famous Connellsville coking coal is placed at from 20 to 30 years at the 1929 rate of production and that of the Pittsburgh bed at 100 years. Pennsylvania anthracite reserves are 29 percent exhausted.

The Sharon bed in northern Ohio, the Brazil block seam in Indiana, and the Big Vein in the Georges Creek field of Maryland, like the Blossburg and Moshannon seams in Pennsylvania, are nearly depleted.

The reserves of the "smokeless" coals of southern West Virginia located in beds of present workable thickness and quality would last but 85 years at the 1929 rate of production. Thinner beds in this area, as mapped by the State Geological Survey, contain enough coal for some 60 additional years.

Even the relatively more abundant high-volatile coal of the southern Appalachian region is definitely exhaustible and conservation of reserves is becoming a matter of increasing importance. The highest grade gas and metallurgical coals in commercially workable beds in southern West Virginia are 22 percent exhausted and in Kentucky 11 percent exhausted.

The low sulphur coals of Southern Illinois have a distinctly limited life.

[25] Hendricks, *op. cit.*

Management exerts its influence by adopting sound principles of mine development with reference to roof control, by scheduling operations so that temporary openings (rooms) are worked out rapidly before the roof deteriorates, by providing permanent roof support for openings of long life (main haulage roads), and by furnishing an adequate supply of timber well adapted to the needs of the mines at the working face.

With the rapid tempo of operations in a highly mechanized mine today, roof conditions must be controlled; hence roof does not affect productivity so much as certain other physical factors, notably thickness of seam. In mines in which roof control is ineffective, however, productive operations are delayed, and this in turn may lead to serious trouble. The differentiation between good and bad roof control is more important to the machine-loading mine than to the hand-loading mine. Since the inherent strength of roof limits the width of openings and the spacing of working places, it is apparent that some appraisal of these factors and the adoption of effective methods for dealing with them are indispensable conditions to satisfactory man-day output.

Provision for roof control forms an important item of managerial skill, but it is only one of many items in which physical conditions affect the manner of laying out a mine. Engineering practice in mine lay-out has advanced notably during the past 50 years but it has not yet reached a stage of perfection that precludes substantial progress in the future.

Changes in organization and technology in mines that are going concerns call for even greater exercise of managerial skill than is required in laying out new mines. Success or failure of a major change such as transition from hand loading to mechanized loading frequently depends upon the skill and wisdom with which management directs the process. An important change of this kind is sure to evoke a feeling of uncertainty on the part of operating personnel. Mental attitudes among the supervisory force and among miners can largely make or break the effectiveness of an installation. Recognition of these principles on the part of key men is a prerequisite for successful mechanization. Labor cooperation and crews able and willing to change former methods within the limits of welfare and safety are likewise indispensable. In seeking such cooperation, factors that may be detrimental to labor.

as well as favorable factors, need to be recognized frankly in connection with each installation.

Satisfactory coordination of men, machines, and working conditions, when new technologies are adopted, involves careful timing and grouping of functions in order to avoid lost motion. From a different angle, a proper system of allocating costs is indispensable since, without a sound basis of measuring results and detecting mistakes, it is impossible to assure that ultimate practice under the new mechanisms will reach an essential level of efficiency.

Long-time versus short-time results need to be weighed carefully in any appraisal of performance. Spurious economies that may seem to improve performance today are dearly bought if they shorten the life of a mechanical installation or of a mine. Needless waste of coal reserves represents deferred charges; unless such charges are reflected in current costs, the profit showing is distorted. The physical life of a machine can be partly controlled by proper maintenance, but for operating purposes its life dates from installation to the time it gives way to a new machine that will do its work more economically. In a period of rapid technical change, obsolescence becomes a heavy burden if investments are made in equipment only partly adapted to the condition in which it functions. Cautious operators who can judge this factor and are able to postpone installations pending perfection of suitable machines are likely to profit by their delay.[26]

Even when fully suitable equipment has been installed and an attitude of cooperation has been built up within an operating personnel, there still remains need for careful correlation of machines to each other and to physical conditions of the mine. For example, advantages of a thick seam are partly lost if loaders with a capacity of 50 tons per hour are operated with cutting or hauling facilities with capacity of only 40 tons per hour. Exact balance between the capacities of mechanical units in relation to physical conditions is seldom attained but it is a goal toward which managerial effort and talent need constantly to be directed.

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[26] See articles by Walter M. Dake, "Analyzing Variables Which Can Make or Break Program of Underground Mechanization," *Coal Age*, Vol. 42, No. 10 (Oct. 1937), pp. 59-63; "Lost Dollars Found by Time-Study Analysis in Completely Mechanized Operations," *Coal Age*, Vol. 43, No. 4 (Apr. 1938), pp. 55-8.

Faulty coordination of mine processes with the varying factor of roof control all too frequently reduces the performance of loading equipment substantially below its normal capacity. Effective handling of roof is one of the most important means of preventing maladjustment between mine processes. For a high level of labor output every detail of mine operation, including cutting, drilling, blasting, loading, timbering, hauling, hoisting, and the preparing of coal for market, needs to be closely adapted to physical conditions. Not only must operating cycles of all machines be synchronized and incorporated into definite production schedules, but an adequate system of power distribution must be maintained.

MAN-DAY OUTPUT - A RESULTANT OF NUMEROUS FACTORS

Under some resource conditions man-day output is exceptionally high, under others exceptionally low, and there are numberless gradations between the extremes. By picking areas of great dissimilarity striking differences are unearthed; but as labor productivity approaches similarity, it becomes increasingly difficult to place the responsibility on the particular factor which is most important in its effect upon output. From an analysis of figures on man-day output for 1936,[27] nevertheless, it is possible to point out effects upon labor productivity of various combinations of physical conditions as well as of technology and management.

The most striking example of phenomenally favorable resource conditions is an output of 76 tons per man-day realized in a Montana strip mine with a 25-foot seam under a cover of 20 to 50 feet. The thick coal seam under relatively shallow cover and the use of the most effective types of stripping equipment are paramount in making possible this high output. It is clear, however, that potential results from advantageous methods could not be realized unless other factors of financing, management, and marketing conditions were also favorable. The mine in question is operated by highly skillful management with strong financial backing, and, being a captive mine, the parent interest, the Northern Pacific Railroad, assures an outlet for its product.

At the other extreme are found areas in which adverse physical factors, such as thin seams, bad roof, adverse dip, poor

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[27] *Bituminous Coal Tables, 1936-1937* (U. S. Dept. Int., Nat. Bituminous Coal Com., 1938).

quality, rolls, large volumes of water, etc., are interlocked with such factors as small mines, seasonal production, lack of mechanization, lax management, and restricted output because of competition with other fuels. The resulting man-day output averages for these areas are exceedingly low. Texas bituminous mines, for instance, averaged only 0.81 tons per man-day; Bureau County, Illinois, 1.11; Osage County, Kansas, 1.45; Ray County, Missouri, 1.77; Montgomery and Pulaski Counties, Virginia, and Lafayette County, Missouri, 1.94. Both Michigan and Iowa, averaging 2.73 and 2.78 tons, respectively, are also examples of the effect of difficult conditions upon productivity.

Average productivity for Pennsylvania was 4.22 tons per man-day, the more important producing counties averaging from 4.28 to 4.92 in the western part of the State and from 3.08 to 4.65 in the central part. Physical conditions, particularly seam thickness, are more favorable in the former than in the latter. A greater part of the mechanized loading in western Pennsylvania is by mobile loaders, whereas in central Pennsylvania conveyors predominate.

Illinois has a combination of exceptionally high man-day output in some areas and exceptionally low output in others, resulting in an average of 6.55 tons. Will County, where all the tonnage is produced by strip mining, has the highest average, 13.58 tons per man-day, and certain other counties where seam and roof conditions are ideal for mechanized loading averaged from 6.21 to 9.57 tons. Markets are accessible, mechanization has been extensively applied, and managerial skill has been notably progressive.[28]

The above figures reflect the close interlocking and inseparability of resources, technology, management, and markets. These factors provide definite restrictions or unlimited possibilities for potential labor output. With the advance of mechanization man-day output becomes somewhat less dependent on resource conditions than it was when mining was largely done by hand. Physical factors nevertheless have an important influence in determining which areas become mechanized and the degree to which mechanization may profitably be carried.[29]

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[28] *Ibid.*

[29] Further discussion of resource conditions in particular areas as they affect development of mechanized loading will be found in chapter VI.

To summarize, it may be expected that in time decline of reserves will result in coal being mined under physical conditions more adverse than those in seams now in operation, and this will naturally put limits upon increases in man-day output. Considered locally, there are many areas in which the relatively poor quality of coal and the difficulties encountered in mining preclude current development of the industry beyond the capacity required to supply local needs. Savings in transportation make it feasible to mine for local markets coal that could not be profitably produced and sold in distant markets. Taking the country as a whole, however, resource conditions are not at present the prime limiting factor either upon expansion of the industry or upon man-day output.

Technology and management have come a long way in combatting physical handicaps, even to the extent of enabling coal from unfavorable areas to compete with coal from seams in which physical conditions are relatively favorable. The most effective means of overcoming physical obstacles is technology. By using the most suitable devices for meeting conditions found in a particular seam and by keeping operations properly balanced, management may frequently anticipate physical difficulties and minimize their potential drag upon output.

The initial step in good management is acquisition of a good property to manage. A concern that takes this first step successfully will secure better results than a concern, otherwise equally well managed, that acquires a poor property for development. In the typical case, better-managed concerns are likely to hold better properties and to be better equipped technically, with the result that effects of resources, technology, and management tend to cumulate instead of neutralizing each other.

So many separate factors enter into the sum total of resource conditions, of management, and of technology and into the whole competitive situation of individual concerns that in actual practice factors controlling labor output appear in infinite combinations. This does not prevent qualitative recognition of the influence of resource factors, but it renders difficult any quantitative measurement of their effects in relation to other conditions that likewise influence output.

CHAPTER IV

STRIP MINING: A RESULT OF SPECIAL RESOURCE CONDITIONS*

Resource conditions associated with some seams make it advantageous to mine the coal from the surface. The type of mining by which this is done is called stripping. The process involves first removing the soil and rock on top of the coal (called overburden) and then loading the coal from the surface (see figure 12). Except at small mines with insignificant tonnage, the equipment used in removing overburden and in loading coal consists of power shovels, the capacity of which has progressively increased as the stripping industry has developed.

Coal lying near the surface in relatively thin seams that are unsuited to deep-mine processes can frequently be recovered by stripping. In some areas coal that could not be profitably deep-mined is being successfully stripped. The efficiency of stripping, like that of deep mining, depends upon management, technology, and resource factors. Depth of cover or overburden is the controlling factor. With the advance in technology it has become increasingly feasible to remove thicker and thicker overburden, and today stripping is carried on in some areas in which the coal lies at an average depth of 55 feet below the surface. Some of the large shovels in operation in 1936 were able to handle as much as 85 feet of overburden in passing through an especially thick area.

The materials for this chapter have been drawn primarily from four publications issued by the Bureau of Mines.[1] These publications have been supplemented by materials made available by the National Bituminous Coal Commission and certain State mining departments and divisions of forestry. Trade literature published by the industry and by manufacturers of equipment

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*By Willard E. Hotchkiss and Robert L. Anderson, Engineer-Economist, National Bituminous Coal Commission.

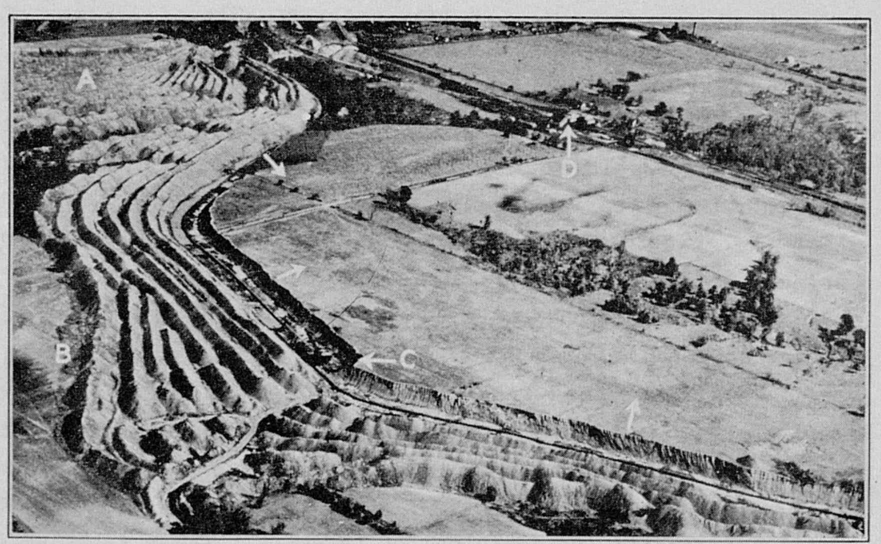
[1] F. E. Cash and M. W. von Bernewitz, *Methods, Costs, and Safety in Stripping and Mining Coal, Copper Ore, Iron Ore, Bauxite, and Pebble Phosphate* (U. S. Dept. Com., Bur. Mines Bull. No. 298, 1929); Scott Turner and Bureau of Mines Staff, *Mining Bituminous Coal by Stripping Methods* (U. S. Dept. Com., Bur. Mines I. C. 6383, mimeo., Nov. 1930); O. E. Kiessling, F. G. Tryon, and L. Mann, *The Economics of Strip Coal Mining* (U. S. Dept. Com., Bur. Mines Econ. Paper No. 11, 1931); Albert L. Toenges and Robert L. Anderson, *Some Aspects of Strip Mining of Bituminous Coal in Central and South Central States* (U. S. Dept. Int., Bur. Mines I. C. 6959, mimeo., Oct. 1937).

has also been utilized. A number of strip operations were inspected and conferences were held with operators and others familiar with this branch of the coal industry.

PHASES OF STRIP-MINING TECHNOLOGY

Technical advance in strip mining has been directed toward improving each of the processes involved in recovering the coal and preparing it for market. These include, preeminently, the handling of overburden and the loading of coal, but the control of conditions such as coal cleaning and drainage has also undergone radical improvement within the last few years. Extensive cleaning and preparation plants have been built at the more important strip mines in order to overcome the handicap of poor quality which in earlier years restricted the markets for strip-mined coal.

Successful power strip mining was undertaken as early as 1885, the equipment being constructed primarily of wood and



United Electric Coal Companies

FIGURE 12.– AIRPLANE VIEW OF A STRIP MINE

In the upper left corner at A is a worked–out area. The first or "box" cut, for getting down to the coal in the lower area, was made along the line B, where the overburden can be seen piled on the surface of the ground. The face of the present cut is shown at C, the overburden from this being piled to the left in the space left vacant by the removal of the coal and previous overburden. The unlettered arrows show the direction in which the stripping operation is advancing, the overburden being taken off slice by slice to get at the coal 30 to 50 feet below the surface. The mine track for transporting the coal follows the face of the stripping operation around to the tipple at D, where the product is screened and prepared for shipment.

operated by steam. Figure 13 shows an early mechanical stripping shovel of about 1885. At first, $\frac{3}{4}$-cubic-yard dippers were used, but later the size was doubled and wooden equipment was replaced by steel. During the period from 1910 to 1918 steam shovels of relatively crude design and weighing 150 tons were used. Operation prior to the time of the World War was intermittent, for though the practicability of recovering coal by surface methods had been demonstrated, expansion was limited until machines reached a stage of development which would permit an increase of the economic stripping ratio between the depth of overburden and the thickness of the coal.

Probably the most significant advance in stripping equipment was the full-revolving, electric-powered shovel, weighing 300 tons, truck-mounted for operation on a railroad track and carrying a 6-cubic-yard dipper. Today electric shovels with caterpillar or crawler traction are common with working weights of 1,000 to 1,750 tons. Dippers with capacities as high as 33 cubic yards are operating on electric revolving shovels.[2] Figure 13 shows a modern strip shovel in operation.

From the standpoint of power and mobility, the greatest advances were made during the period 1918-28. Notable among more recent improvements is the utilization of high-tensile, light-weight steel so as to increase the yardage handled by machines without increasing the over-all load. Efficiency has sometimes been raised as much as 25 or even 40 percent. Among other improvements are the location of driving mechanisms on each corner of the shovel and automatic hydraulic devices for leveling the machine as it moves over the uneven surface of the coal.

Considerable advances have also been made in drilling the overburden when cuts have to be made through heavy rock. The introduction of liquid-oxygen explosives has contributed greatly to efficiency, as has the change from vertical to horizontal blast-hole drilling where the nature of the overburden permits such a practice. Horizontal drilling can generally be used when hard rock is not more than 16 feet thick. Some of the newer drilling equipment bores holes as

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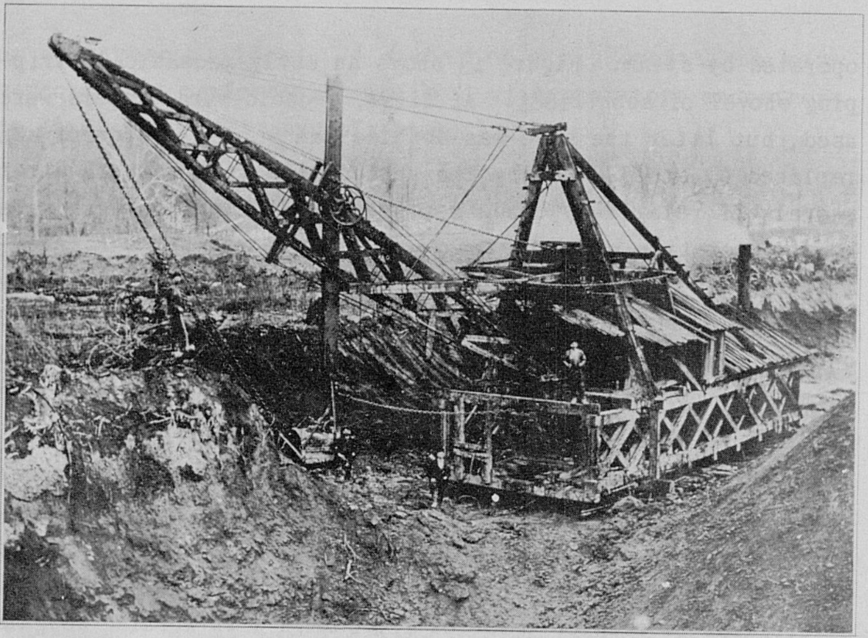
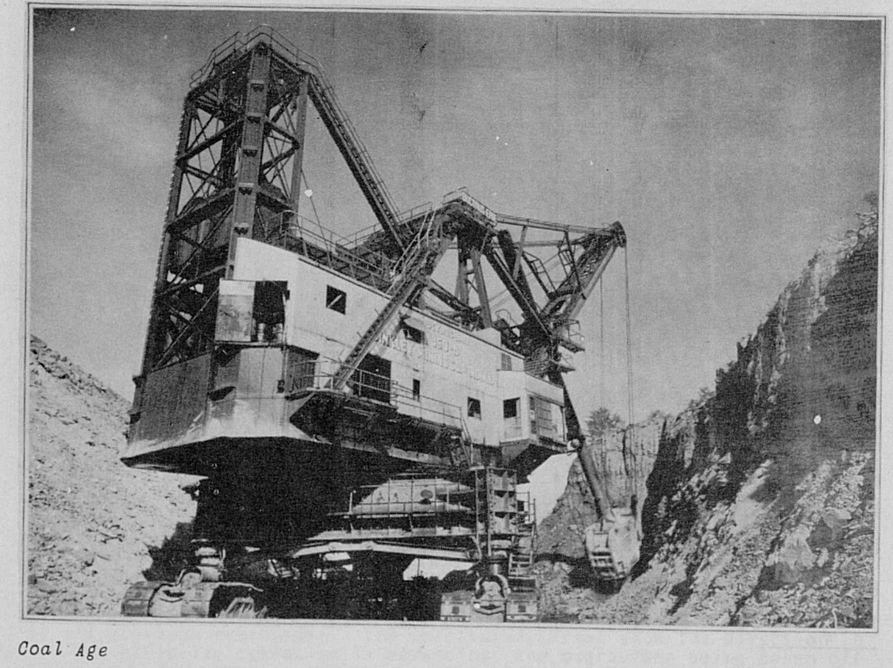
[2] Cf. article by M. M. Moser, 1937 Annual Issue of the *Chicago Journal of Commerce*. Mr. Moser, Vice President in charge of operations of the United Electric Coal Companies, has kindly supplemented this article by several other items in respect to improved technology.



Coal Age

1885 – Mechanical Stripping Starts With Dry-Land Dredge Having ¾-Cubic-Yard Dipper



Coal Age

1938 – Electric Power Shovel Equipped With 30-Cubic-Yard Dipper

FIGURE 13.– EARLY AND MODERN STRIP SHOVELS

large as 12 inches in diameter, permitting a high concentration of explosive and increasing the efficiency of the blast.

Great improvement has also been made in handling the coal after the overburden has been removed. Where the nature of the seam necessitates blasting, the use of a channeling machine, similar to the undercutting machine employed in deep mining, not only makes the explosive more effective but produces a larger percentage of lump coal. Power shovels, smaller than stripping shovels but equally effective, load the coal into railroad cars, motortrucks, or trailers. Coal-loading shovels have advanced in size; the present-day shovel has the capacity of the average stripping shovel used 15 years ago.

Haulage has been greatly facilitated through better-planned tipple sites, specially designed locomotives, and improved dispatching systems. The tendency has been to replace locomotive haulage by motortrucks, which have been found cheaper to operate. In instances where rail haulage is still used, manual labor in shifting tracks has been practically abolished. When rapidity of operation requires frequent moves, regular track-shifters or caterpillar tractors are used to shift the tracks as the coal is loaded. These improvements in strip-mining processes have been accompanied by increased attention to preparation of coal for market, and most of the important strip mines are equipped to screen and size their product and often to clean it mechanically.

Advances after 1914 revolutionized the technology of strip mining, and those added within the past decade not only have greatly reduced cost but have made possible the removal of thicker overburden and a consequent extension of the coal areas that can be profitably stripped. The sum total of these advances has brought the equipment used to a state of refinement and power which reflects a notable embodiment of American engineering genius.

Following is an abridged description of a large strip operation in the Middle West.[3] The coal seam averages 6 feet in thickness. Overburden varies, but one of the sections observed consists of 36 feet of surface soil and clay, 16 feet of limestone, and 2 feet of hard shale. Vertical holes for blasting rock are drilled 10 inches in diameter with electric drills and

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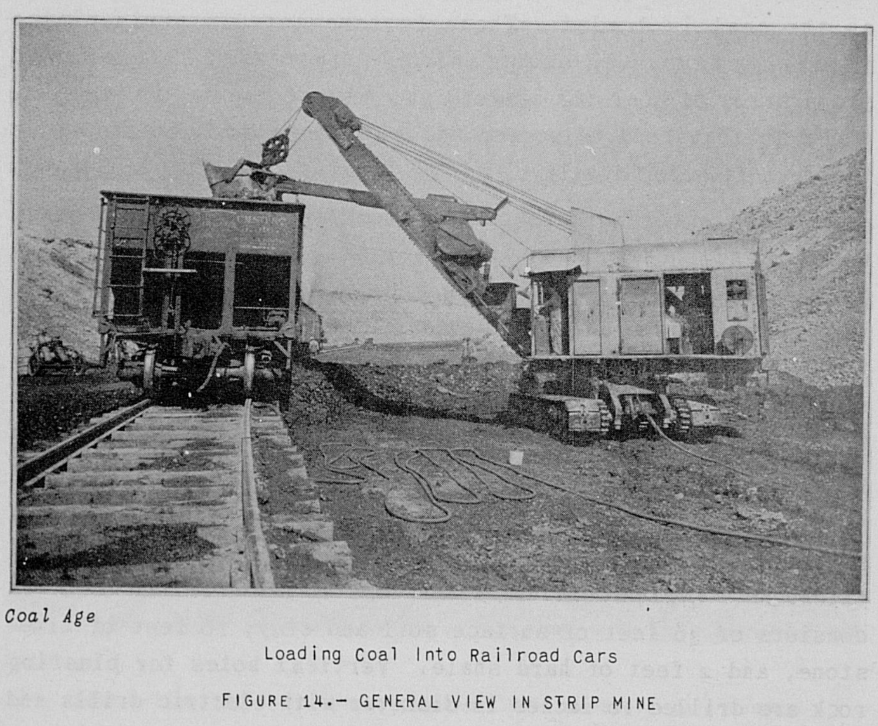
[3] Toenges and Anderson, *op. cit.*, pp. 42-6.

Coal Age

Dragline Excavator and Strip Shovel in Background, Tractor in Foreground



Coal Age

Loading Coal Into Railroad Cars

FIGURE 14.— GENERAL VIEW IN STRIP MINE

spaced on 30-foot centers. They are usually drilled through the limestone into the shale. From 10 to 14 holes are shot electrically at one time.

The mine consists of three sections, two of which operate continuously and the third in rush seasons. Each of the two sections which operate continuously uses an electric stripping shovel and a dragline in tandem for removing overburden. In these two sections the top 25 feet of overburden is excavated with the dragline and the lower 30 feet with the shovel. The stripping shovels are equipped with 90-foot booms, 64-foot sticks, and 15-cubic-yard dippers, and the draglines are equipped with 170-foot booms and 12- and 14-cubic-yard dippers, respectively. The section of the mine that operates only in rush seasons removes the overburden with a large stripping shovel without the assistance of a dragline. This stripping shovel is equipped with a 120-foot boom, an 84-foot stick, and a 15-cubic-yard dipper. The average depth of stripping is about 55 feet, but overburdens with a depth of 85 feet can be handled with tandem units if they are kept on an outside curve.

Coal at this mine is loaded with electrically operated shovels carrying 4¼-cubic-yard dippers. One dipper is made of aluminum, the others of steel alloy. The character of the seam makes it necessary to blast the coal. Drill holes in the coal are staggered on 10-foot centers and the charge is electrically fired. Each of the coal-loading shovels handles about 3,400 tons of raw coal per shift.

This particular mine uses track haulage. Three locomotives handle the output of each section until the length of haulage exceeds 2 miles in one direction, when a fourth locomotive is added. Five trackmen shift and maintain the track for each loading unit. The track is extended approximately 300 feet per shift. Drainage for the mine is handled by surface ditches supplemented by sumps from which the accumulated water is removed from time to time by electric pumps. The mine has a modern preparation plant. Table 7 shows the labor requirements of the two sections of this mine that operate continuously on the basis of an output of 6,000 tons per working day.

Technological advances in stripping have greatly widened the initial cost differential between strip and underground mining. The output per man-day achieved in particular fields in which

Table 7.- LABOR REQUIREMENTS OF A LARGE STRIP MINE WITH AN AVERAGE DAILY PRODUCTION OF 6,000 TONS[a]

Occupation	Number of men	Hours worked per day	Days worked per week	Total man-hours per week
Total	213	-	-	8,079
Drillers, helpers, and shooters	30	7	5	1,050
Stripping-shovel crew[b]	18	8	6	864
Dragline crew[b]	18	8	6	864
Loading-shovel crew[c]	6	7	5	210
Coal drillers and shooters	6	7	5	210
Locomotive engineers	7	7	5	245
Locomotive brakemen	3	7	5	105
Trackmen	16	7	5	560
Tipple men	48	7	5	1,680
Mechanics and helpers	7	7	5	245
Electricians and helpers	9	7	5	315
Shopmen	12	7	5	420
Miscellaneous:				
Teamsters	4	7	5	140
Locomotive hostlers	3	7	5	105
Truck drivers	2	7	5	70
Wash-house men	1	7	5	35
Watchmen	1	7	5	35
Carpenters and helpers	2	7	5	70
Repairmen	2	7	5	70
Pumpers	6	7	5	210
Monthly men	12	8	6	576

[a] Albert L. Toenges and Robert L. Anderson, *Some Aspects of Strip Mining of Bituminous Coal in Central and South Central States* (U. S. Dept. Int., Bur. Mines I. C. 6959, mimeo., Oct. 1937), p. 46.

[b] Two machines, each requiring an operator, an oiler, and a groundman for each of three shifts.

[c] Two shovels, each requiring an operator for one shift and a groundman for two shifts.

resource conditions are highly favorable has been phenomenal. This has been notably true in the Rosebud field in Montana, where resource conditions are ideal for stripping. Such conditions are not, of course, typical of the industry generally, but labor output has increased greatly in all the principal strip-mining areas.

One of the serious handicaps of strip mining in its early stages was the poor quality of the product. Shipment of weathered, outcrop coal, or coal containing rust and mud, created great prejudice against strip coal. Even before 1914 this handicap had been recognized and some mines were installing cleaning plants. With the falling off of abnormal war demand in 1918, it became clear that the demand would be for cleaned coal.

Except in captive mines which furnish railway fuel to parent companies and commercial mines which sell their entire output to railroads and other concerns that can use run-of-mine coal, the trend for a number of years has been toward marketing prepared coal. In 1936 strip mines having cleaning plants produced 38.9 precent of the total tonnage of strip-mine coal, whereas only 25.4 percent of deep-mine coal was from mines with cleaning plants. For several years, as shown in the accompanying tabulation, the percentage of strip coal produced at mines equipped with cleaning plants has exceeded that for deep mines:[4]

Year	All mines	Strip mines	Deep mines
1934	21.2	34.3	20.4
1935	23.4	39.4	22.3
1936	26.3	38.9	25.4

When strip operators began to install cleaning and sizing devices they had the advantage, characteristic of a new industry, of being able to put in the most modern machinery without the expense of scrapping obsolete equipment.

Efforts to improve the quality of coal have not been confined to handling after it is taken from the mines. Cleaning the coal surface ahead of the loading shovel has also made substantial contribution to quality. The most common method is to use a bulldozer (a tractor-propelled blade) for scraping loose rock and dirt, and this is usually followed by hand shoveling and sweeping with wire brooms. Other methods of cleaning the coal surface involve the use of horse-drawn scrapers, sweepers with

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[4] Total production of all mines with cleaning plants and total production of strip mines with cleaning plants taken from *Bituminous Coal Tables, 1936-1937* (U. S. Dept. Int., Nat. Bituminous Coal Com., 1938), p. 44. For total production of all mines and strip mines see F. G. Tryon, L. Mann, and W. H. Young, "Bituminous Coal," *Minerals Yearbook, 1937* (U. S. Dept. Int., Bur. Mines, 1937), pp. 787-867; M. F. McMillan, R. L. Anderson, and Others, "Bituminous Coal," *Minerals Yearbook, 1938* (1938), pp. 687-745. The deep-mine figures were computed by subtracting strip tonnage from total tonnage.

revolving steel brushes somewhat like street sweepers, and compressed air to blow away the dirt.

In addition to the applications of technology for the specific purpose of improving quality, there is a natural tendency for the quality to improve with increased depth of overburden. In shallow seams weathering has, in many locations, a deleterious effect upon the product. Much of the coal now being stripped, especially in such heavy-tonnage areas as Illinois and Indiana, lies under a protective bed of limestone, sandstone, or hard shale that can be handled only by the most powerful shovels, frequently preceded by blasting. Under these conditions the inherent quality of strip coal varies little from that of shaft-mine coal in the same field.

All ranks of coal are produced by stripping. In 1936, 4.3 percent of strip coal mined was lignite, 77.6 percent was bituminous, and 18.1 percent was Pennsylvania anthracite. Bituminous coal in that year was stripped in 15 States and lignite in 4 States.[5]

WAR STIMULUS TO STRIP MINING

In 1914, 35 strip mines employed 1,355 men for 187 days and produced 1,281,000 tons of coal, or an average of 5.1 tons per man-day.[6] In the latter part of 1915 the Allies' war orders began coming in, and for the next 5 years coal mining was highly profitable. The ease with which strip mines could be opened, the rising cost of timber and other deep-mine supplies, high wage rates that enhanced the advantage of the greater labor output in strip mining, and scarcity of common labor made stripping a natural means of getting into this profitable war business.

The limiting factor in coal output soon came to be car supply rather than consumer demand. There was no discrimination in the allotment of cars between deep mines and strip mines; strip mines shared the available cars on the basis of mine capacity. For the time being, poor quality had little effect on sales. Industrial plants came to be glutted with war orders and were generally glad to get any kind of coal as an alternative

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[5] Computed from data published in *Bituminous Coal Tables, 1936-1937*, p. 21; anthracite data are from M. van Siclen, H. L. Bennit, and Others, "Pennsylvania Anthracite," *Minerals Yearbook, 1938*, p. 776.

[6] Kiessling, Tryon, and Mann, *op. cit.*, p. 27.

to closing down. Many underground operators were tied by long-time contracts that prevented them from taking advantage of high open-market prices. The result was that poor-quality strip coal often brought a higher average price than superior deep-mine coal. Production from strip mines mounted to 8,288,000 tons in 1918.

POST-WAR PROGRESS

War conditions were, of course, temporary, but the armistice found strip-mine operators strongly entrenched, with initial development costs behind them and in a position to realize their natural advantages. The great strikes of 1919 and 1922 doubtless tempered considerably the adjustment to peacetime conditions. Stripping made notable advances throughout the period 1914-28, except during the post-armistice year 1919 and the depression year 1921. A leveling off in the bituminous industry as a whole from 1918 to 1929 did not interrupt the progress of strip mining, although strip production declined a bit in the depression years following 1929.

COMPETITIVE ADVANTAGES OF STRIP MINING

Having come out of the war with several definite advantages over underground mines, stripping continued to forge ahead in regions in which resource conditions permitted the use of stripping methods. In addition, improvements in technology have made it possible progressively to extend this type of mining over areas from which the coal formerly could have been recovered only through deep-mining methods.

The inherent advantage of strip mining over deep mining is in its high man-day output. Notwithstanding great advances in deep-mining technology, the favorable labor-output differential of strip mines is much greater today than it was before the war. This, together with the success of strip-mine operators in improving the quality of their product, places them in a peculiarly strategic position.

Hearings held by the National Bituminous Coal Commission in Washington, D. C., in July 1938 revealed some striking differences in strip-mine and deep-mine total costs per ton. The accompanying tabulation shows these cost differences in important stripping areas as reported to NRA for the 10 months from April 1934 to January 1935 and to the National Bituminous Coal Commission for the last 9 months of 1937:[7]

State	Strip mines		Deep mines	
	Apr. 1934 to Jan. 1935[8]	Apr. 1937 to Dec. 1937[9]	Apr. 1934 to Jan. 1935[8]	Apr. 1937 to Dec. 1937[9]
Illinois	$1.26	$1.43	$1.62	$1.87
Indiana	1.38	1.46	1.61	1.80
Ohio	(10)	1.41	(10)	2.00
Southwestern[11]	(10)	1.82	(10)	2.62

In comparing these data it should be remembered that stripping involves a much higher capital investment per ton and that the figures do not include interest.

Strip mining has also overcome several initial disadvantages. Formerly strip-mine operations were seriously affected by weather conditions. Engineering progress in planning mines, with adequate provision for handling drainage, has gone far toward eliminating weather stoppages, and today wet weather does not seriously retard activity. Neither are operations greatly affected by low temperatures; shovel operators are protected and there is very little manual labor required at a modern stripping operation.

The ease with which large shovels can be operated in multiple shifts is an important advantage of strip mining. One shift a day is still customary in underground mines, although there is considerable indication that the highly mechanized mobile loader is encouraging double-shift operations. The stripping shovel requires only a small part of the total working force of

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[7] Weighted average costs, including total producing, administrative, and selling costs per ton. Increased costs between 1934-35 and 1937 were due to higher wage rates.

[8] Cost figures under the Bituminous Coal Code of NRA for 1934-35. See F. E. Berquist and Associates, *Economic Survey of the Bituminous Coal Industry Under Free Competition and Code Regulation* (National Recovery Administration, Div. of Review, Industry Studies Sect., Work Materials No. 69, mimeo., Mar. 1936) vol. II, pp. 699, 701.

[9] Cost data as compiled by National Bituminous Coal Commission from hearings held July 6 to 23, 1938. See Docket No. 15, Exhibits Nos. 186, 209, 91, and 283 for Ill., Ind., Ohio, and southwestern strip costs; Exhibits Nos. 189, 212, 90, and 284 for deep-mine costs. These exhibits are available in printed form at the offices of the National Bituminous Coal Commission in Washington.

[10] Data not available.

[11] Includes Kansas, Missouri, Texas, and the following Counties in Oklahoma: Coal, Craig, Latimer, Muskogee, Okmulgee, Pittsburg, Rogers, Tulsa, and Wagoner.

the mine, and multiple-shift operation of the stripping shovel has met little opposition from employees.[12]

Modern high-power shovels represent a heavy investment. The total cost of an installation, exclusive of tipple and cleaning plant, at a recently opened strip mine was approximately three-quarters of a million dollars. The effect of multiple-shift operation, when enough coal can be marketed to make this possible, is the spreading of the fixed charges over larger operations, thus reducing overhead. The continuity with which strip mines operate is dependent almost entirely upon the demand for coal and not on any physical obstacles to continuous operation. If demand is light, a strip mine may shut down in bad weather, but if demand is brisk, the same mine may operate in multiple shifts irrespective of weather conditions. Ten years ago a number of strip mines in the southeastern Kansas field were operating stripping shovels three shifts for approximately 4 months in the year, two shifts for 6 months, and one shift for 2 months. This practice was fairly representative except in areas where the mines had a continuous market, in which event they operated three shifts the year round.[13]

It was notable that in many districts strip mines worked more time during the strike years 1922, 1927, and 1928 than did their deep-mine competitors. In some cases, as in Ohio and Montana in 1927 and 1928, this was due to the fact that strip mines were running open-shop, but in other fields it was found possible to operate on temporary wage agreements pending settlement of deep-mine strikes.[14] On the whole, strip mines have hitherto been less subject to strikes than have deep mines.

Strip mining probably had some advantage over deep mining at the start by virtue of the fact that it shares, to a greater extent than does deep mining, a technology common with other industries. Surface excavation is the first mechanical problem with which strip mining is concerned. The technology of excavation already developed in the construction and other industries was at once available for use in the removal of overburden and the excavation of coal. In recent years the

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[12] The customary practice is for the strip shovels to work multiple shifts, but the coal-loading shovels, haulage equipment, and tipple are only operated one shift per day.

[13] Kiessling, Tryon, and Mann, *op. cit.*, p. 18.

[14] *Ibid.*

technology of excavation in coal mining has embodied much higher concentration of power than is found in other industries in which it is necessary to move large quantities of earth.

The comparative youth of the stripping industry, suggested in discussing cleaning and sizing equipment, has heretofore given the industry an advantage over underground mining in the utilization of the most up-to-date appliances. At the time strip mining was getting its initial start during and after the war, operators were in a position to concentrate attention on selecting the most efficient equipment available. Deep mines that had been operating for a period of years frequently had large investments in existing equipment, some of which had to be scrapped when new installations were made.

The physical and economic advantages which a new industry possesses by reason of its ability to install modern equipment are augmented by important psychological and organizational advantages. An operating mine is a going concern. As soon as the mine comes into normal production, operating with a particular type of equipment, the habits of both managers and men tend to crystallize around the existing situation, and as time goes on a certain resistance to change develops. This is particularly true in an industry like bituminous coal in which men habitually come up through the ranks. Although such industries usually take pride in being "practical", tradition rather than the most efficient current practice is frequently the basis of their policies and procedures.

The underground branch of the bituminous-coal industry is gradually breaking away from some of its established traditions. Although deep-mining technology has not stood still, the fact remains that until a few years ago the rapid strides in the technology of coal loading had been confined to mines producing only a minor part of the country's total deep-mine tonnage.

Present indications are that highly mechanized mining will soon become the rule rather than the exception in deep mining. In strip mining this has always been the case because of the very nature of the process. Dependence on up-to-date machinery seems to have called forth, in this branch of the industry, an exceptional aggressiveness, with the result that strip operators as a rule go in for the newest devices once these devices have been shown to be more efficient than those they are designed to replace.

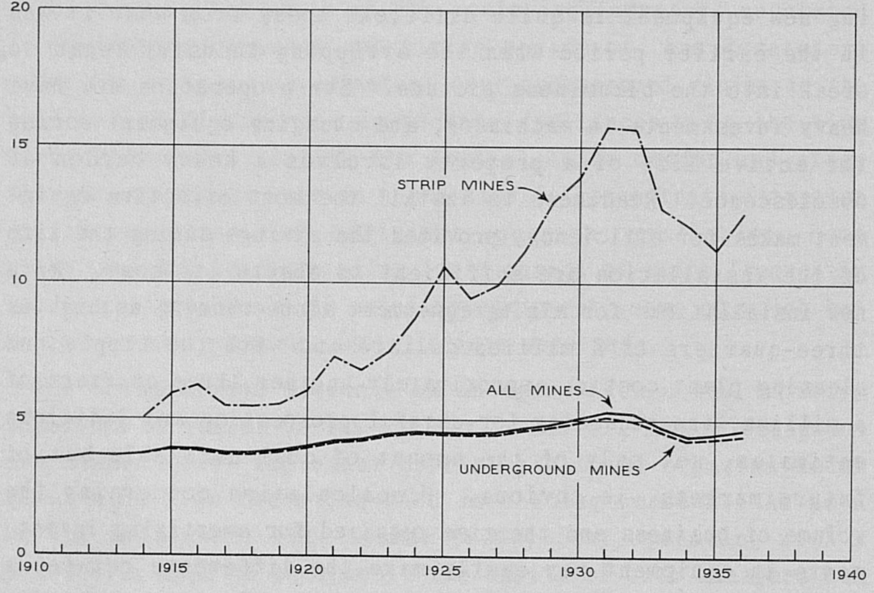
It should be noted that the situation in respect to installing new equipment is quite different today from what it was in the earlier period when the stripping industry began to break into the bituminous picture. Strip operators now have heavy investments in machinery, and changing equipment during the active life of a property involves a heavy burden of obsolescence. Readiness to install the most effective equipment makes for efficiency, provided the savings during the life of the installation are sufficient to absorb its cost. With new installations for mining equipment alone running as high as three-quarters of a million dollars and with the tipple and cleaning plant costing approximately another three-quarters of a million, the necessity for careful prospecting and judicious estimates, not only of the amount of coal available but of future markets, is obvious. Miscalculation concerning the volume of business and the time required for amortizing investments in equipment may easily make the difference between a successful enterprise and a dismal failure. It is the practice in all well-managed stripping ventures in which heavy investments are made in equipment to plan amortization of initial cost during the active life of the mine. Sometimes the owners dismantle equipment and set it up at a new mine, the new investment in such cases being merely the cost of moving.

To recapitulate, strip mining to date has its greatest advantage over underground mining in its superior man-day output. This has come primarily from the extraordinary advance in power, size, and flexibility of stripping equipment. Not only has advancing technology enabled the industry to make an impressive showing in terms of tonnage, but it has also made it possible to minimize many of the handicaps under which strip mining formerly labored - notably poor quality of much of its product, original dependence on weather conditions, and the comparatively limited range of coal deposits in which stripping technique could be used.

MAN-DAY OUTPUT IN STRIP MINING

Data contained in annual reports by bituminous operators to the Bureau of Mines and the National Bituminous Coal Commission

Figure 15.- NET TONS PER MAN PER DAY AT ALL BITUMINOUS-COAL MINES, UNDERGROUND MINES, AND STRIP MINES, 1910-36



BASED ON TABLE B-9

MINERAL TECHNOLOGY AND OUTPUT PER MAN STUDIES
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have been compiled and charted to show output per man per day separately in all mines, in deep mines, and in strip mines for the United States as a whole and for important strip-mining States for 1910-36, except that measurement of man-day output for strip mines began in 1914, the first year in which such data were requested. The amount of stripping prior to that date was very small.

Man-day output in strip mines, as presented in figure 15 for the United States, has always been higher than in deep mines (see also table B-9). In 1914 output per man-day was 5.06 tons in strip mines and 3.71 tons in deep mines; at the high point in 1931 the difference in favor of strip mines was 10.66 tons. Prior to 1925 the effect of high labor output in strip mines was infinitesimal in influencing output per man-day of all bituminous mines. In 1914, 0.3 percent of the country's production came from strip mines and in 1925 only 3.2 percent. By 1936 the percentage was 6.4 and in 1937 it was 7.1 (see also table B-10). As a result of the increasing proportion of strip tonnage to total production and the higher output per man-day at strip mines it is estimated that strip mining has added from 0.1 to 0.2 ton to the average daily output per man employed in the bituminous industry.

With labor output in strip mines increasing rapidly after 1927, a peak of 15.78 tons per man-day was reached in 1931. Bureau of Mines data show a sharp decline in output per man-day after 1932, but this record obviously reflects changes in the method of reporting and in the shortening of the working day in 1934.[15]

The relative importance of strip and deep mining appears much more significant when areas are compared in which both types of mining are carried on extensively.[16] Illinois and Indiana are heavy-tonnage areas for deep mining and likewise for strip mining. In Illinois production from strip mines increased rapidly after 1924, in which year it was only 3.4 percent of its total bituminous output. By 1937 it was 22 percent of total output. Strip mining in Indiana has played an even greater role, and its advance has been more impressive than in Illinois. In 1922, 7.1 percent of total Indiana production was from strip mines; in 1937, the percentage was 47 (see table B-10 for intervening years).

Curves of output per man-day for both States are shown in figure 16. It is apparent that strip mines have had considerable influence in raising the man-day output for all mines, especially in Indiana. After 1932 the recorded decline in man-day output in strip mines is more a reflection of differences in methods of reporting and of the shorter working day than of actual increase in labor requirements.[17] Advancing

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[15] In general, changes in the method of reporting man-days have distorted labor-output figures in strip mines more than they have those in deep mines. Man-days prior to 1932 were figured on the basis of the average number of men times the number of days of tipple operation.

In strip mining it has been common practice for the group of employees known as the stripping-shovel crew to work a full week, either 6 or 7 days, even though the rest of the mine was operating on, perhaps, a 4- or 5-day basis. In some cases the operation of a strip mine is such that the strip shovels may uncover the coal seam considerably in advance of the time it is to be loaded.

When these strip-shovel employees, who average about 25 percent of the mine personnel, work regularly more days than the tipple operates, average man-day output figured on tipple time is too high. Beginning in 1932 mines were asked to report actual man-shifts where such records were kept. This practice would of course bring about at least a partial correction of the previous error and result in showing a considerably smaller output per man-day than had formerly been shown on the basis of tipple time.

For the distribution of a typical strip-mine labor force see table 7.

[16] See table B-10 for percentages of total production mined by stripping in the important coal-stripping States and in the United States (1914-38) and table B-11 for tonnage stripped by States (1936).

[17] See ftn. 15.

Figure 16.- OUTPUT PER MAN PER DAY IN MAJOR COAL-STRIPPING STATES, BY KIND OF MINE, 1910-36

(Ratio scale)

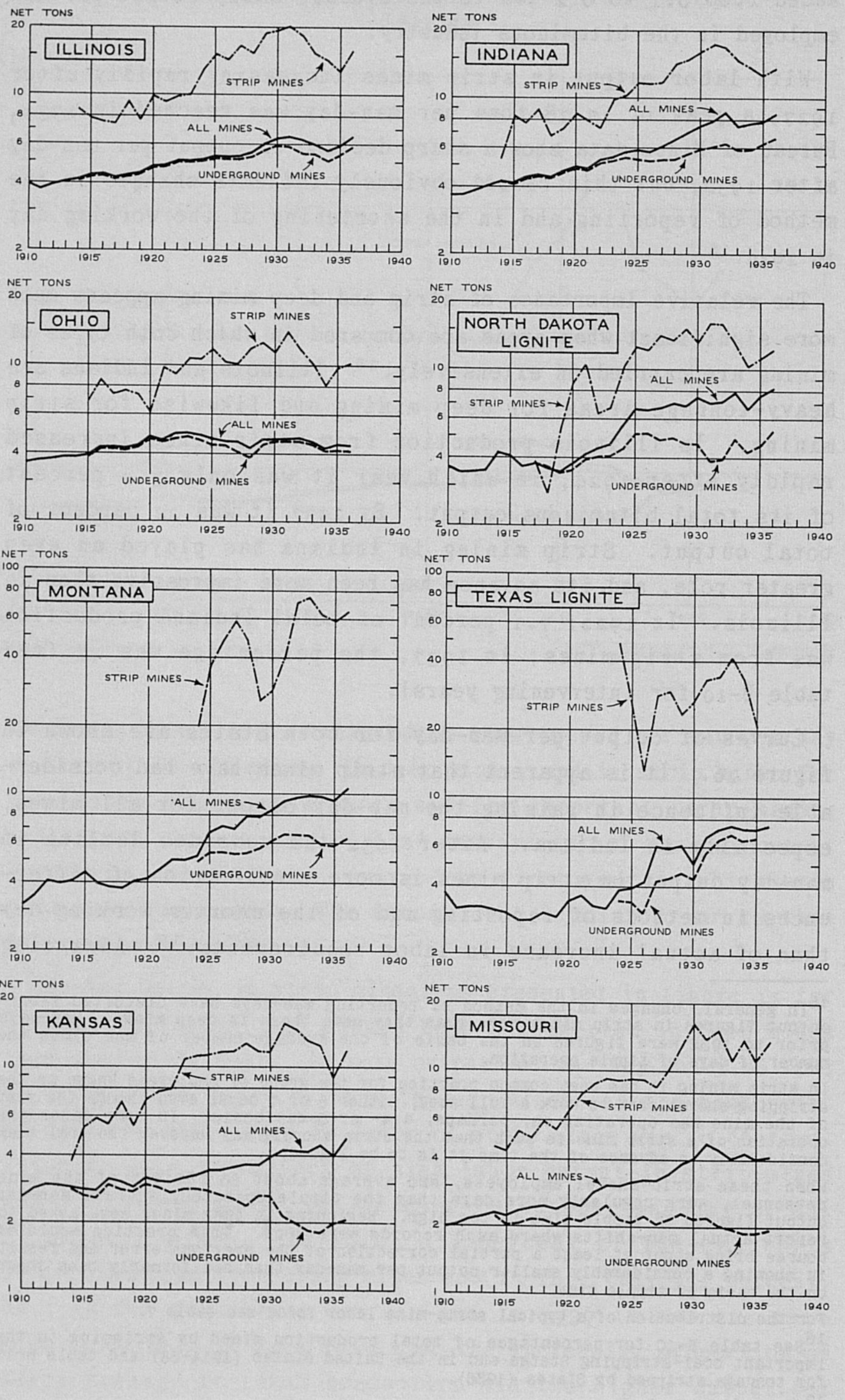
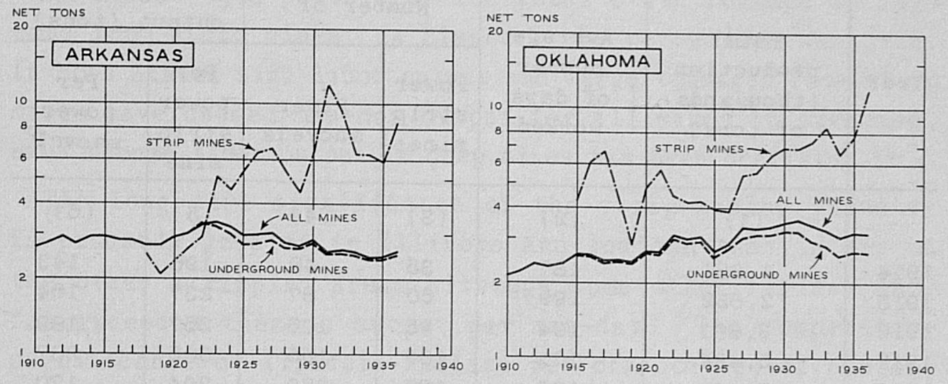


Figure 16.- OUTPUT PER MAN PER DAY IN MAJOR COAL-STRIPPING STATES, BY KIND OF MINE, 1910-36 - *Continued*

(Ratio scale)



BASED ON TABLE B-9

MINERAL TECHNOLOGY AND OUTPUT PER MAN STUDIES
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technology in this area has probably more than offset thus far the extension of strip mining into thinner coal under deeper cover.

Ohio is the only important Appalachian State in which a significant amount of stripping has been done. In terms of the percentage of strip coal to total tonnage the growth of strip mining in Ohio has been erratic. As early as 1922, 11.3 percent of the tonnage was reported stripped; there was then a decline, after which a peak of 17.1 percent was reached in 1927. After 1927 strip tonnage fell off again, but there are recent indications of revival. In 1937 the strip production was 10 percent of the total for the State.

The lignite fields of North Dakota and Texas have for some years been large centers of strip mining, partly because these districts contain level beds lying close to the surface and partly because the value of lignite is so small in comparison with that of bituminous coal that it can only be mined profitably by the cheapest methods.

The man-day output curve for Montana reflects almost entirely the performance of the operation in Rosebud County, in which a 25-foot seam of coal lies under a cover of from 20 to 50 feet. With such ideal resource conditions the output per man-day has surpassed that of any other area, a high of 75.5 tons per man per day being reached in 1933. This Montana coal has a heating

Table 8.– SUMMARY OF BITUMINOUS STRIPPING OPERATIONS AT MINES USING POWER SHOVELS, 1914–36[a]

Year	Total production (thousands of tons)	Average number of days worked	Number of		Average daily output (tons)	
			Power strip mines	Power shovels	Per power strip mine[b]	Per power shovel[c]
	(1)	(2)	(3)	(4)	(5)	(6)
1914	1,281	187	35	48	196	143
1915	2,832	199	60	87	237	164
1916	3,881	194	75	106	267	189
1917	5,484	171	105	155	305	207
1918	7,949	196	138	239	294	170
1919	5,386	154	145	256	241	137
1920	8.176	184	141	268	315	166
1921	4,606	112	125	240	329	171
1922	9,298	143	189	340	344	191
1923	11,087	140	197	380	402	208
1924	13,184	154	189	389	453	220
1925	16,497	175	179	363	527	260
1926	16,083	171	183	375	514	251
1927	17,867	177	207	424	488	238
1928	19,131	180	176	385	604	276
1929	19,767	170	170	397	684	293
1930	18,938	176	156	322	690	334
1931	18,524	165	148	303	759	371
1932	19,459	167	180	329	647	354
1933	18,065	165	214	381	512	287
1934	20,469	172	243	443	490	269
1935	23,267	203	262	489	437	234
1936	27,479	184	271	543	551	275

[a] Data for small horse- or hand-stripping pits and for mines combining stripping and underground methods in the same operation are excluded.

Data for 1914-31 from F. G. Tryon, L. Mann, and H. O. Rogers, "Coal," *Mineral Resources of the United States: 1930* (U. S. Dept. Com., Bur. Mines, 1932), Part II, "Nonmetals," pp. 599-773 and W. H. Young, L. Mann, and F. G. Tryon, "Bituminous Coal," from same for 1931 (1933), pp. 416-88; data for 1932 from unpublished data of the Bureau of Mines; data for 1933 from W. H. Young, L. Mann, and F. G. Tryon, "Bituminous Coal," *Statistical Appendix to Minerals Yearbook, 1932-33* (U. S. Dept. Int., Bur. Mines, 1934), pp. 373-438; data for 1934 from L. Mann and F. G. Tryon, "Bituminous Coal," from same for 1934 (1935), pp. 281-341; data for 1935 from F. G. Tryon, L. Mann, and W. H. Young, "Bituminous Coal," *Minerals Yearbook, 1937* (U. S. Dept. Int., Bur. Mines, 1937), pp. 787-867; and data for 1936 from *Bituminous Coal Tables, 1936-1937* (U. S. Dept. Int., Nat. Bituminous Coal Com., 1938).

[b] Col. (1) divided by the product of cols. (2) and (3).

[c] Col. (1) divided by the product of cols. (2) and (4).

value of 9,000 B. t. u. per pound, which makes it probably the cheapest energy, measured in terms of human labor, produced at any coal mine in America.

In Kansas 73.4 percent of the total State tonnage in 1937 came from strip mines; in Missouri the percentage was 57.8. In both States high labor output and large tonnages from strip mines have caused man-day output for all mines to increase, even though labor output in deep mines has been declining.[18]

The long-time significance of the strip-mining industry is probably greater in Illinois and Indiana than in any of the other stripping areas although some other regions have far exceeded them in output per man-day. The comparative significance of Illinois-Indiana performance is, of course, enhanced by the fact that these are heavy-tonnage areas both for strip mining and for deep mining and also by the fact that mechanization of loading, as well as of other deep-mine processes - cutting, hauling, drilling - in these States, is highly developed and still advancing.

Increase in the size of shovels at strip mines has been a large factor in increasing man-day output. Table 8 shows that at power strip mines in the United States the average daily output of coal per power shovel increased from 143 tons in 1914 to 276 tons in 1928 and to a maximum of 371 tons in 1931. Power shovels include those used for stripping overburden and loading coal. The daily output per mine increased from 196 tons in 1914 to 604 tons in 1928 and to a maximum of 759 tons in 1931. Although these averages show enormous increases, they are weighed down by the inclusion of a number of small operations. Exclusion of these would of course raise the averages.

GENERAL CHARACTERISTICS OF STRIP MINING

The fact that each site which can be feasibly mined by stripping presents a separate problem has resulted in machinery

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[18] Strip mining has also been done in Pennsylvania - in 1 or 2 years the output amounted to nearly 2 million tons. In Alabama, Colorado, Iowa, Kentucky, Maryland, Michigan, Tennessee, Washington, West Virginia, and Wyoming strip mining has been inconsequential compared with underground mining, and no stripping has ever been reported in Virginia, New Mexico, and Utah.

Figure B-1 shows output per man-day curves for all mines and strip mines (where data were important enough to show) for the above States. Table B-9 shows output per man-day for all mines, deep mines, and strip mines in the United States and the following States: Alabama, Arkansas, Illinois, Indiana, Kansas, Kentucky, Missouri, Montana, North Dakota (lignite), Ohio, Oklahoma, Pennsylvania, Texas (lignite), and Wyoming.

being designed to order for the particular property on which it is to operate. The size of the unit is determined not only in reference to the amount of overburden to be removed but likewise in reference to the scheduled annual tonnage and the seasonal or other peak demands.

Production in strip mining is limited by the amount of coal that can be uncovered in a given time. Because of the large investment in equipment, it is essential to organize stripping operations so that a maximum yardage of overburden can be moved with as little loss of effective working time as possible. More yardage can be stripped when the material is broken into easily manageable sizes, and it therefore becomes necessary to study the character of the overlying strata and to use the kinds and amounts of explosive that will break up the rock for easy handling by the shovel.

In thin seams tonnage per acre is of course less than in thick seams, and it accordingly requires more acres to produce a given annual tonnage. The amount of material moved per ton of coal produced is, with the same thickness of cover, greater in thin seams than in thick ones, and the distance from loading operations to the tipple increases more rapidly, with a corresponding increase in the cost of haulage. The character of the overburden is also an important consideration in determining the cost of recovery. If there is a large percentage of hard strata, drilling and blasting costs rise correspondingly.

A number of different factors appearing in varying combinations in different coal seams determine the areas from which coal can be profitably recovered by stripping. The most important of these, as already indicated, are the thickness of the seam, the quality of the coal, and the depth and character of the overburden, but the selling price of coal and its location in reference to potential markets are also important considerations.

PROBABLE FUTURE SIGNIFICANCE OF STRIP MINING

The factors that seem destined to determine the future position of strip mining in the bituminous industry are resource conditions, technology, and markets, with the possibility that other factors such as attitude of labor and public policy in respect to conservation may ultimately impose checks to expansion. None of these factors is absolute, but the interrelation between them will necessarily determine the progress of strip mining and the limits to its advance, both absolutely and in relation to underground mining. As long as strip operators can put large quantities of coal on the market at costs that cannot be matched by deep-mine operators, the urge to expand the stripping industry will continue to be strong.

It is doubtful whether efforts to maintain prices can greatly restrict the pressure for expansion exerted by low costs. However, as the expansion of the industry makes it necessary to exploit fields in which the coal resources lie farther and farther below the surface, with corresponding increases in cost of equipment, the cost of stripping and of deep mining may tend toward equilibrium.

Advancing technology has tended to offset any increasing costs which might be occasioned by the extension of strip mining into deeper seams. Not only is strip-mine coal being recovered from depths that would have been considered prohibitive a few years ago but productivity and cost differentials in its favor remain impressive.

If advancing technology should so enlarge the field of strip mining that this branch of the industry would come to furnish a highly significant part of the total tonnage, the attitude of labor might impose a restraining influence on expansion. In general, the United Mine Workers of America have thus far shown a cooperative attitude toward the introduction of mining machinery. The union has not seriously opposed stripping except when efforts have been made to employ nonunion workers. The influence of the union has been exerted to insure that union miners employed in stripping operations were fairly compensated.

As long as the total output of strip mines remained insignificant in proportion to the total tonnage of the country, its small volume of employment in proportion to tonnage was not a matter of great concern. It is clear, however, that relative labor output of strip mines and deep mines in recent years has been of an entirely different order of magnitude from the labor output of mechanical-loading compared with hand-loading deep mines. The extent to which strip mines can increase their relative tonnage without a greater sharing of gains with labor is not yet known.

Government taxation and regulation may have some restraining effect on the development of strip mining. The question of how properties containing natural resources should be taxed is highly controversial and applies to both strip mines and deep mines. Discussion with operators in the two branches of the industry has brought out opposing points of view on the subject. Strip-mine operators contend that the relatively heavy taxes on their properties serve as an offset against obvious damage to the surface of the ground and point out that many of the strippable seams are under lands which are not otherwise highly productive. They also think that they render a public service by securing a higher recovery of the coal deposit and thus avoid the waste incident to deep mining, especially that which occurs in areas where only 50 percent of the coal is recovered.

Deep-mine operators, on the other hand, emphasize the rapidity with which resources in strip mines are exhausted, and some of them argue that present taxes on strip mines are in general not high enough to compensate for the early disappearance of taxable values in these mines when the coal has been removed.

Whatever the merits of the opposing views, the maintenance of mining communities, whether in strip-mine or deep-mine areas, is a problem in human conservation rather than in taxation, although taxation might be used in approaching it.

The social cost of stripping includes damage to the surface. Stripped areas become for the time being barren waste; they are withdrawn from use and are capable of reclamation only at great expense. Dissipation of the top soil precludes agricultural use, and all vegetation develops slowly in the exposed subsoil which is often mixed with broken rock. The original productivity of stripped-over lands varies greatly between areas but, as noted at the Washington World Power Conference in 1936, an estimated 2,500 acres in the Central and Eastern States are devastated annually by bituminous and lignite stripping.[19]

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[19] See G. S. Rice, A. C. Fieldner, and F. G. Tryon, "Conservation of Coal Resources," *Transactions, Third World Power Conference* (Washington, D. C.: 1938), vol. VI, sect. IV, paper no. 11, p. 692. The following quotation from the same paper indicates how the problem is handled in Germany: ". . . . America may learn from the experience of Germany, where 140,000,000 tons of lignite or brown coal are mined annually by stripping. Much attention has been paid by the German Government and the mining companies to regrading the surface and restoring it to usefullness. Systematic afforestation is practiced, and in some localities the tillable surface soil is scraped off and later spread over the completed fill, so as to make the surface available for agricultural use."

But strip mining entails aesthetic as well as economic considerations. Miles of spoil bank in stripped-over areas not only reflect destruction of plant and soil resources but mar the landscape. As strip mining expands, mutilation of the countryside makes the industry increasingly vulnerable from a public angle, and this has been recognized by operators in some areas in the form of cooperative reclamation projects. Considerable areas of stripped-over land have been planted to forests and occasionally to orchards, and several exhausted mines have been used to form artificial lakes.

The spectacular development of stripping in Indiana and Illinois in recent years makes the need for reclamation especially great in those States. A cooperative venture, undertaken in 1920 by the Indiana Coal Producers' Association and the Forestry Division of the State Conservation Department, resulted in the planting of some 4,500 fruit trees on Indiana coal lands. It was reported later that they were flourishing and producing large quantities of fruit.[20] The scope of this program has been considerably expanded in recent years. A memorandum from the Forestry Division several years ago put the Coal Association on notice concerning public interest in reclamation. The association was reminded that a definite reforestation program carried out by every member would be a convincing argument against legislative interference. Annual reports of the Conservation Department show that more than $2\frac{1}{2}$ million trees were planted on coal lands in 1935, and over 7 million in 1936 and 1937. The 1937 report notes the establishment of several lakes to be opened to the public for fishing.[21]

Early in 1938 a similar program was inaugurated in Illinois. Under this program the operator purchases the necessary stock from the Division of Forestry at nominal prices and the planting is done by his own men under supervision of a trained State Forester. When a producer manifests a willingness to cooperate, the Division of Forestry makes a survey of the area and recommends species to be planted. The program is considered good business for the State, both for the future

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[20] Cash and von Bernewitz, *op. cit.*, pp. 118-20.

[21] The authors are indebted to Mr. H. A. Woods, Indiana State Forester, for the information upon which the above outline was based and for a circular concerning the Greene-Sullivan State Forest, which has been developed out of stripped-over lands.

value of the timber and for the recreational possibilities. Eight Illinois operators cooperated in planting 350,000 trees in 1938.[22] Although total acreage reclaimed is small in comparison with the total area of stripped-over land, current trade literature indicates that the subject is receiving increasingly serious attention.

A second conservation aspect of the stripping industry is its effect upon coal reserves. Initially the effect is favorable. Strip mining stands much higher, from the standpoint of coal conservation, than does underground mining. In deep mines of the principal strip-mining States one-third to one-half of the coal is ordinarily left in the ground. Although the stripping process excavates coal rapidly and on a large scale, the amount of coal wasted in well-conducted strip mines is low.

The only angle from which strip mining might have an adverse effect upon coal reserves would be through the influence it exerts upon the direction taken by underground mining. In such areas as Illinois and Indiana, where the ratio of strip tonnage to deep-mine tonnage is high and increasing, the pressure of strip-mine cost differentials naturally makes it more and more difficult for high-cost underground operators to meet the competition of strip mines. This influence has a tendency to concentrate more and more of the deep-mine production in coal seams having the best resource conditions and in which a high degree of mechanization can be utilized to reduce operating costs. As will be developed at greater length in succeeding chapters, the ratio of mechanical-loading to total deep-mine output in Illinois and Indiana has increased rapidly in recent years; by 1937 mechanical loading covered over 70 percent of the total deep-mine tonnage in Illinois and over 80 percent of that in Indiana.

The low-sulphur coals of southern Illinois have a distinctly limited life.[23] If the best deep-mine resources of the State as well as the seams available for stripping should become exhausted, reliance would have to be placed on the poorer seams or the industry would migrate to other areas.

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[22] The authors are indebted to Mr. Anton J. Tomasek, Illinois State Forester, for the above information.

[23] Rice, Fieldner, and Tryon, *op. cit.*, p. 679.

To recapitulate, it is impossible to predict that any one of the forces that might have a restraining influence on the development of stripping will retard the expansion of the industry in the near future. If, however, the increasing costs of equipment for removing deeper and deeper overburdens should be augmented by higher labor costs or new burdens in the form of taxes or conservation requirements, other things being equal, the time when an equilibrium between the costs of strip mining and deep mining is reached will be considerably advanced.

Resource and other limitations in the way of indefinite extension of strip mining, together with the fact that technology in this branch of the industry is further advanced and more widely extended than it is in deep mining, make it highly improbable that stripping will ever become a dominant part of the industry from the standpoint of total tonnage. Whatever the future may hold, the present fact is that, in spite of its great advances during and since the World War, only 7 percent of the total bituminous tonnage of the country in 1937 came from strip mines. This being the case, study of mechanization in relation to employment opportunity must focus primarily upon developments in underground mines.

CHAPTER V

HISTORY, DESCRIPTION, AND PRESENT DISTRIBUTION OF MECHANICAL-LOADING DEVICES*

The hand miner's most arduous task is shoveling coal into mine cars. Coal tonnage loaded each year equals the total weight moved in excavating the Panama Canal and until recently all this work was done by human muscle. At a wage of $5.50 per day, the mechanical work involved in loading the Nation's coal costs the equivalent of about $7.50 a kilowatt hour.[1] Loading by hand requires from 50 to 60 percent of the total working force in a bituminous mine. This last stronghold of heavy hand labor has resisted the trend toward mechanization until quite recently.

Numerous loading devices were developed and installed before the types that operated successfully under different mining conditions were perfected. The first loading machine used in the United States, the so-called Stanley Header brought over from England in 1888,[2] was designed to break down the coal as well as to load it. The record of operation indicates that the loading device was not successful and that the coal was loaded by hand. Experimentation on a machine designed exclusively as a loading unit was started between 1893 and 1898, and the machine known as the Jones loader or Coloder was patented in 1902. It was not put into service in the mines of the Pocahontas Fuel Company, however, until 1918. Another early combination cutting and loading machine was the O'Toole, developed in 1896. Conveyors were introduced by C. R. Claghorn in his mine at Vintondale, Pennsylvania, as early as 1902, but further installations lagged. The first mobile loader was the Hamilton, installed in Illinois in 1903, and it was reported to have averaged 150 tons per day. The first shovel-type loading machine was developed by the Myers-Whaley Company and

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*By Leo N. Plein; Walter M. Dake; Willard E. Hotchkiss; Charlotte K. Warner; and Joseph J. Gallagher, Assistant Statistical Analyst of the National Research Project.

[1] F. G. Tryon and Others, *Technology and the Mineral Industries* (WPA National Research Project in cooperation with U. S. Dept. Int., Bur. Mines, Report No. E-1, Apr. 1937), p. 15.

[2] See *Coal Mine Mechanization Yearbook, 1929* (American Mining Congress), pp. 364-70; also "Milestones in Mechanical Loading," *Coal Age*, Vol. 41, No. 10 (Oct. 1936), pp. 405-8.

a complete working unit was installed in a Tennessee mine in 1908, but its success was impaired by inability to regulate car supply to its operation. The Jeffrey Company acquired the Morgan and Hamilton patents and by 1913 had started to manufacture loading equipment. In 1916 a Thew electric shovel was installed in a mine of the Union Pacific Coal Company. In the same year there was introduced in the anthracite field a pit-car loader, and Joseph F. Joy began his experiments with the mobile loader. In the following year scrapers were introduced in the bituminous mines of central Pennsylvania, having been used in the anthracite field as early as 1914. In this period progress with mechanical loading was slow; most of the installations were purely experimental. Another new idea in 1926 was the duckbill self-loading head for conveyors developed in the mines of the Union Pacific Coal Company; this was later taken over by the Goodman Company for manufacture.[2]

For practical purposes the commercial application of mechanical loading in the bituminous coal mines of the United States may be dated from 1922, the year when the first Joy loader, invented by Joseph F. Joy, appeared on the market.

In 1923, the year in which the U. S. Geological Survey began to gather data on mechanical loading, 1,900,000 tons of bituminous coal, or 0.3 percent of underground production, were mechanically loaded. This rose from 4.5 percent in 1928 to 13.1 percent in 1931 and remained at approximately this level through 1935. In 1936 and 1937 the percentage increased to 16.3 and 20.3, respectively; in 1938 the trade journal *Coal Age* estimated that one-fourth of the country's deep-mine output was mechanically loaded. The progress of mechanical loading in the different mining areas of the country and its effects are discussed in the following chapters.

Mechanical loading equipment is divided into two groups: machines which virtually eliminate hand shoveling except for incidental clean-up and machines which, without eliminating shoveling, greatly reduce the labor involved. In the first category fall mobile loaders, scrapers, and duckbills; in the second, pit-car loaders and face conveyors. A description of the manner in which these different types of equipment operate will indicate their function.

Among loading devices now in use, scrapers embody under ideal conditions the most intensive application of power, but they are low in adaptability to varying conditions and their use is consequently restricted. Pit-car loaders represent limited application of power, and though still operating in considerable numbers, they are beginning to have little but historical significance. Duckbill loaders occupy an intermediate position in regard to power, but their range is limited by the fact that in some conditions in which they operate well the high-powered mobile loaders are even more advantageous, whereas under other conditions the less-powerful conveyors are preferred. The degree to which the different devices substitute mechanical power for man-power is indicated by the following tabulation:

Type of machine	Horsepower	Daily capacity[3]	Factory price
Pit-car loader	1- 5	15- 25	\$ 700-\$ 1,500
Conveyor	5-30[4]	50-300	1,100- 2,000
Duckbill	15-30	50-300	1,500- 2,500
Scraper	$7\frac{1}{2}$-25[5]	50-250[5]	1,500- 2,500
Mobile loader	$22\frac{1}{2}$-50	100-800	6,500- 13,500

SCRAPERS

The scraper is a scoop device pulled by a rope operated from a hoist. The coal is dragged along the mine floor to an elevated loading point. Some scraper units have greater power than mobile loaders and so rank as the most complete form of mechanized loading. The use of scrapers has been very limited since they are best applied to long-face mining, though applications of the scraper principle have been made to room-and-pillar loading.

The scraper requires a freedom of motion which bars it from places where close timbering is necessary, with the result that it can be used only in mines that have good roof. Bottom must be fairly hard or the scraper will cut into it and pick up impurities with the coal. This can be alleviated by leaving a thin band of bottom coal in place, but since scrapers usually operate in thin seams, reduction of the recovery ratio may

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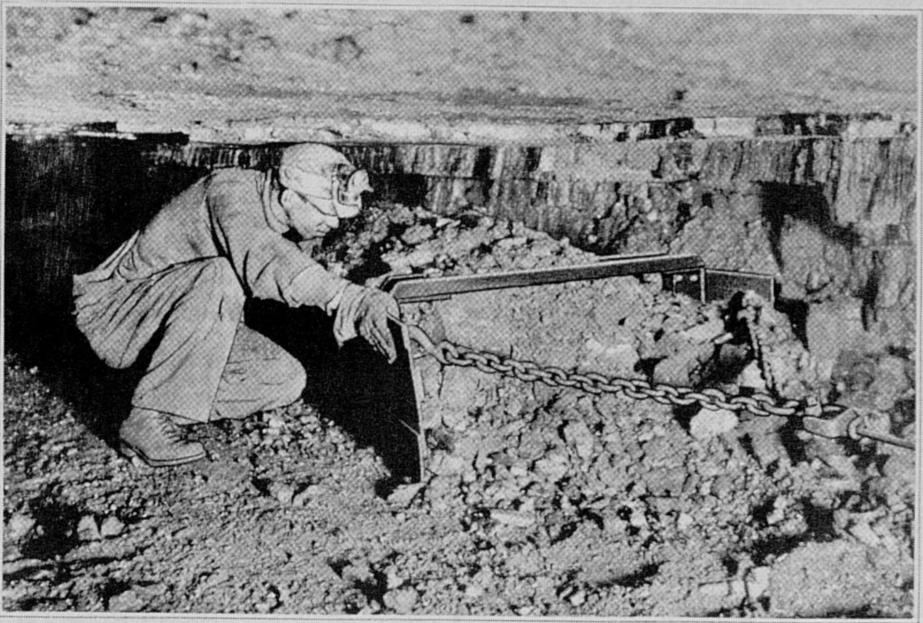
[3] In terms of tons of coal. Capacity here is viewed as actual output in service rather than the manufacturer's rating.

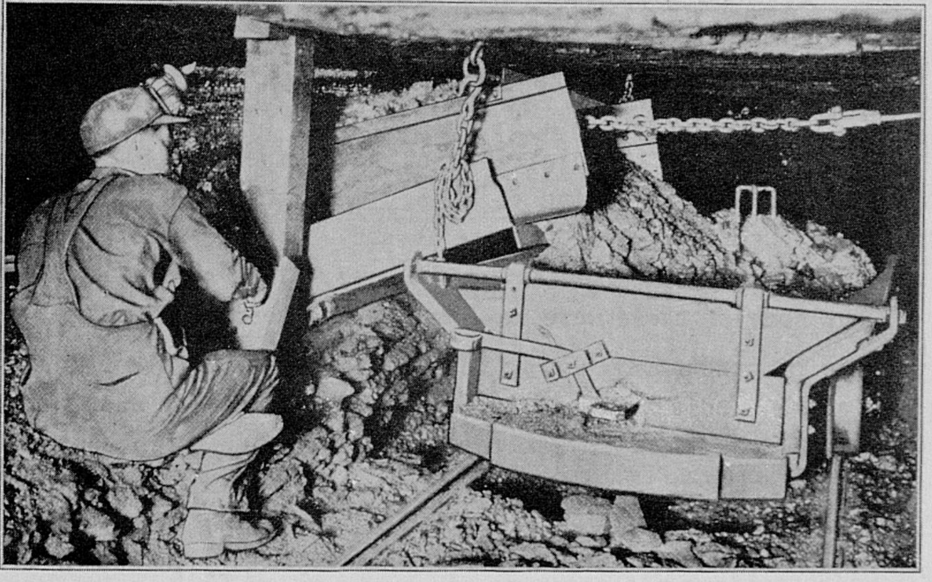
[4] Chain-type units run 5 to 20 and shaker drives 15 to 30 horsepower; room belts run about 5 to 20 and mother belts 20 to 30 horsepower.

[5] Usual units in service; some large scrapers may run up to 100 horsepower or more, with a correspondingly higher output.



Goodman Manufacturing Co.

Scraper Picking Up Its Load at the Face in Longwall Mining



Goodman Manufacturing Co.

Scraper Unloading Over Steel Apron or Chute Into Mine Car

FIGURE 17.- SCRAPER LOADERS

render operation unprofitable. As with all loading devices, impurities loaded with the coal complicate the preparation problem. If the coal is soft, scrapers may also cause undue breakage; however, for some uses, such as coking, value is not impaired by degradation.

In the bituminous fields scrapers have hitherto been employed chiefly with the longwall system of mining or with some related system affording long working faces. This was because the expense of moving the equipment from place to place made it essential to have large tonnage available for each set-up of the scraper. A notable illustration of this requirement occurred in the large-scale Union Pacific operations at Rock Springs, Wyoming. Mines were equipped with scraper installations in the early period of mechanization. High-powered hoists with large scraper scoops were used and large tonnages per machine shift were secured. The time consumed in dismantling units and reassembling them in new locations so reduced net output per man-day that experiments with other equipment were undertaken and scrapers were largely replaced by duckbills. The only way in which scrapers can operate successfully with room-and-pillar mining is to provide exceedingly wide rooms or else to work the face at an angle so as to make it substantially longer than the width of the room.

Figure 18 shows the distribution of scrapers by States and counties at the beginning of 1938.[6] All told, 119 scrapers, distributed over 10 States, were in use. Annual sales reported by manufacturers in the last 3 or 4 years have averaged about 15, but some of these were no doubt replacements.

Areas of concentration for scraper loading are Walker County in Alabama, Indiana County in Central Pennsylvania, and Colfax County in New Mexico. Scattered installations also occurred in Jefferson and Marion Counties in Alabama; in Clearfield, Cambria, Tioga, and Armstrong Counties in central Pennsylvania; in Sweetwater and Lincoln Counties in Wyoming; and in a few counties in West Virginia, Virginia, Kentucky, and Tennessee. In Logan County, Arkansas, and Le Flore County, Oklahoma, a device built on the scraper principle and called a scow is used. Coal in these counties is thin but firm and overlain

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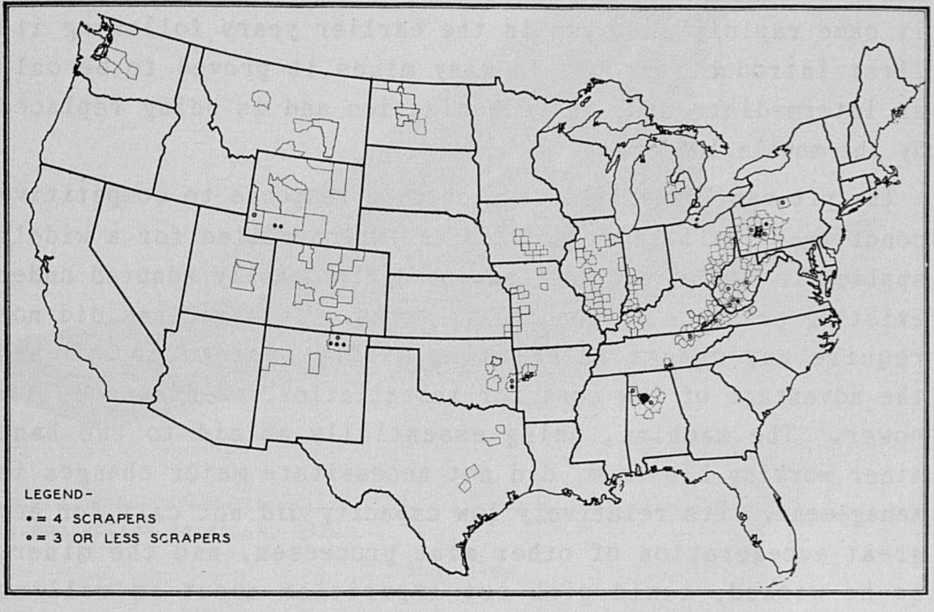
[6] These figures are based on machines in use in 1936 plus sales of new equipment and State report data for 1937. Sales of loading equipment during 1938 are discussed at the end of this chapter.

Figure 18.- DISTRIBUTION OF SCRAPERS INSTALLED IN UNDERGROUND BITUMINOUS-COAL MINES AT THE BEGINNING OF 1938



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by a soft mud band which permits recovery in large chunks. In general, present distribution of scrapers is confined to areas in which roof and floor are good but seams are thin and pitching.[7] Probable fields of expansion for scraper loading appear to be confined largely to areas already penetrated. On the other hand, advances in the theory and practice of roof control, which would result in concentrated mining on long faces, might greatly widen the field of scraper operations.

PIT-CAR LOADERS

Pit-car loaders are the simplest of the mechanical-loading devices. They consist of elevating conveyors with the upper end high enough to load the coal into the mine car while the lower end rests near enough to the floor to make shoveling easy. A crew of two to four men operates the machine, shoveling the coal onto the conveyor. This device is relatively

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[7] In 1937, 539 scrapers loaded about 2,900,000 tons of anthracite, or nearly 27 percent of the machine-loaded output, compared with less than 2 percent of that in bituminous mining. Hard coal, hard bottom, thin beds, and pitching seams, added to the fact that impurities are removed in elaborate preparation plants, account for the extensive use of scrapers in anthracite mining.

Scrapers or "slushers" are also used extensively in metal mining, particularly in Lake Superior iron ranges and in Alabama.

light and can be moved from place to place either on the track or on the floor of the mine. Because the pit-car loader does not require any substantial change in existing mine practice, it came rapidly into use in the earlier years following its first introduction, but in many mines it proved to be only an intermediate step in mechanization and is being replaced by the mobile loader.

The pit-car loader was developed in response to competitive conditions in Illinois and Indiana which called for a widely applicable labor- and cost-saving device easily adapted under existing practice to loading in rooms. This machine did not require any change in existing mining systems and it had the advantage of low cost for installation, maintenance, and power. The machine, being essentially an aid to the hand miner working his room, did not necessitate major changes in management. Its relatively low capacity did not call for any great acceleration of other mine processes, and the miner, as he worked, could pick out impurities about as well as under hand loading. The 16-percent decrease in unit labor requirements for Illinois and Indiana, realized under favorable circumstances, approached a net gain more closely than is usual with machine installations.

Conditions which stimulated the introduction of pit-car loaders were largely confined to the Illinois-Indiana area. By the time a changed labor situation inspired growing interest in mechanization in other heavy-tonnage areas, higher-powered machines were being perfected and management had become more skilled in their application. These circumstances go far toward explaining both the rapid advance and the subsequent decline of pit-car loaders. This type of loader cannot be used to advantage in thin seams and is awkward to manipulate in places where close timbering is required. Improvements in design might have remedied some of these defects, but before this happened pit-car loaders began to be replaced by the higher-powered mobile loader.

Figure 20 indicates by States and counties the present location of pit-car loaders in use in the early part of 1938.[8] Over three-fifths of the number in use are concentrated in Illinois, about one-fifth are in western Pennsylvania, and the balance are widely scattered.

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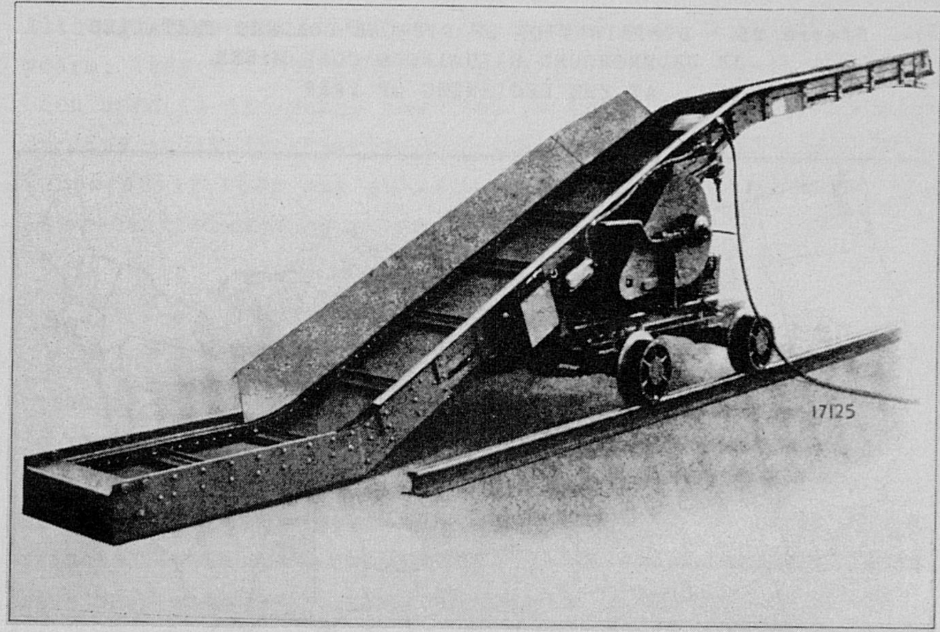
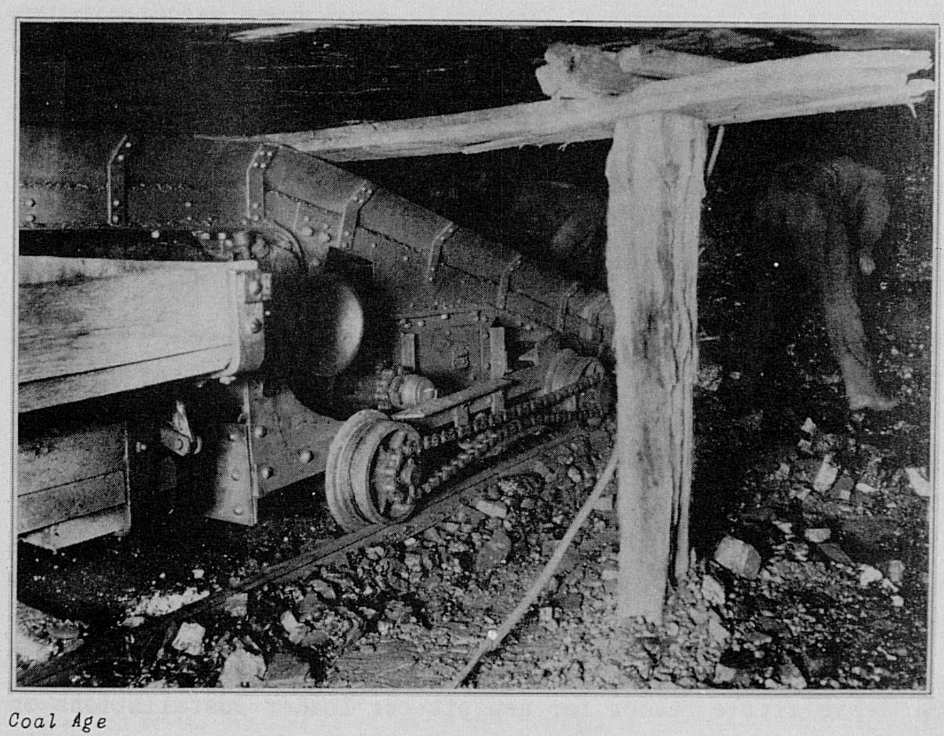
[8] Figures shown are in most cases the same as in 1936 since very little new equipment was reported sold in 1937. Sales increased in 1938.



Mechanization Yearbook, 1929

Shop View

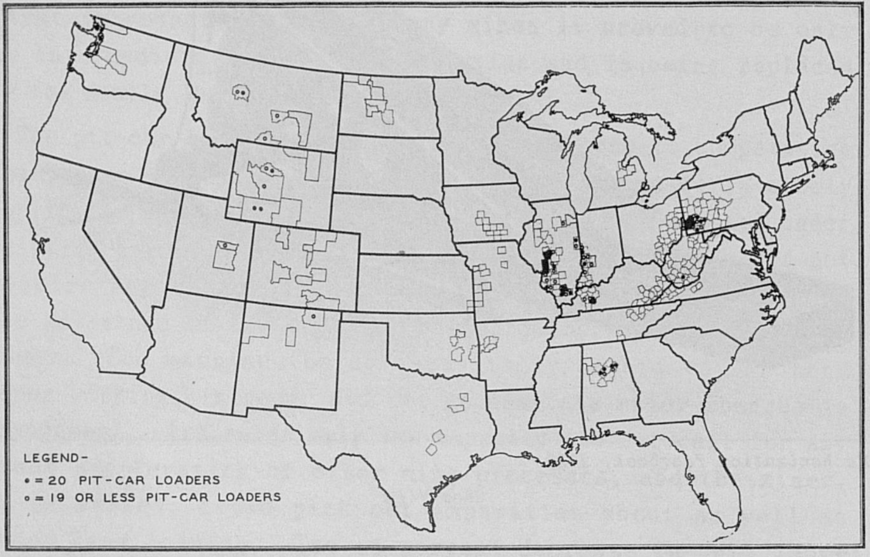


Coal Age

Hand Shoveling Onto Pit-Car Loader

FIGURE 19.- PIT-CAR LOADERS

Figure 20.- DISTRIBUTION OF PIT-CAR LOADERS INSTALLED IN UNDERGROUND BITUMINOUS-COAL MINES AT THE BEGINNING OF 1938



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Although the number of pit-car loaders in Illinois has declined greatly - from 2,162 in 1931 to 1,159 in 1937 - they are still used in 13 counties of the State, mainly in Macoupin and Franklin and in lesser numbers in Sangamon, Madison, and Williamson. In Indiana there were only 74 pit-car loaders in 1936 as against 233 in the peak year 1930, and no new equipment was reported sold in 1937. The Pittsburgh seam of western Pennsylvania and St. Clair and Jefferson Counties of Alabama are other centers where pit cars are still used in substantial numbers. Thirty-one new pit-car loaders were sold in 1937, two-thirds of which went to part of the West Virginia low-volatile field where this device has not previously been used. In 1938 sales increased to 139, most of which also went to West Virginia.

Advances in machine design and underground management appear to leave little reason for new pit-car loader installations on a large scale. As a general rule seam conditions that permit their use also permit use of mobile loaders; under adverse physical conditions such as poor roof and close timbering, conveyors or duckbills can usually be applied more effectively.

Although pit-car loaders will continue to be used for many years, they will be confined mainly to areas where they have been used in the past, and even in these areas a progressive decline in their relative significance is plainly indicated. Temporarily they may go into new fields as the first step in mechanized-loading programs.

DUCKBILLS (SELF-LOADING CONVEYORS)

The duckbill is a shovel device with a flared mouth which is attached to the end of a shaking conveyor. The duckbill itself is pushed under the pile of broken coal and the differential movement of the conveyor carries the coal backward from the loading head onto the conveyor proper. The duckbill is used principally in southern Wyoming. Other self-loading conveyors have been used in the past but none is on the market today.[9]

The duckbill represents an intermediate step between the conveyor and the mobile loader in the application of power to loading. Theoretically it is usable wherever hand-loaded conveyors are applicable, provided it is installed to work in level places or on pitches favoring the load. In actual practice it has proved particularly valuable in pitching seams. Although it is, of course, usable in flat seams, the mobile loader is normally preferred if timbering is not too close. Scaly or bumpy bottom is a hindrance to the duckbill unless a floor of coal can be left in place, since the duckbill head can not be raised or lowered like the mobile loader. Unless the floor is smooth and hard and the coal exceptionally clean or the market undiscriminating, duckbill loading necessitates mechanical cleaning or at least improved hand picking in the tipple.

The distribution of duckbill loaders at the beginning of 1938 is shown in figure 22. Three-fourths of all the duckbills in the United States are in Sweetwater County, Wyoming, where the mechanism was originally developed in the mines of the

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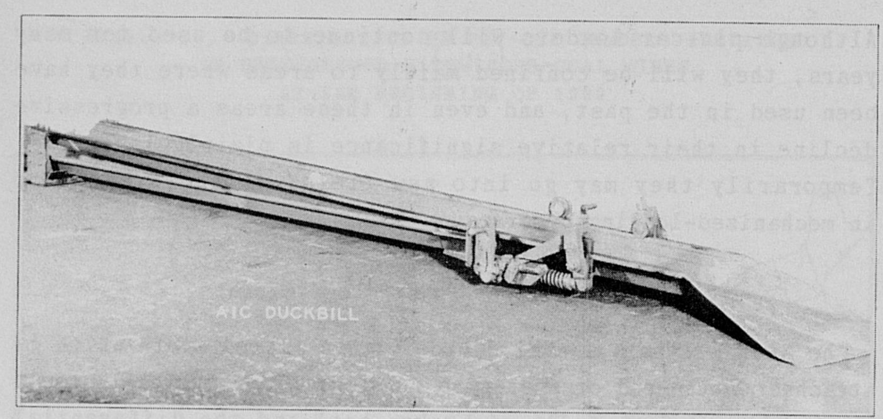
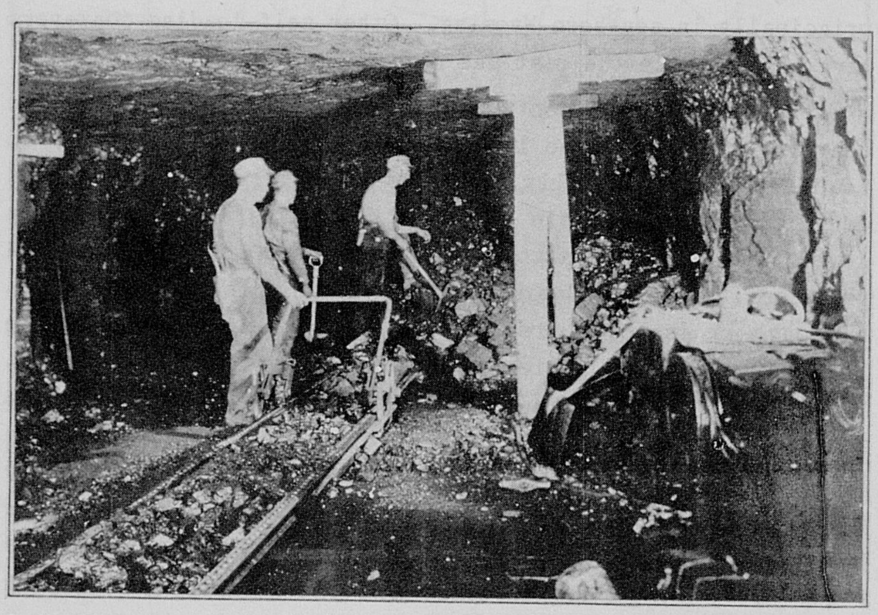
[9] A modification of the duckbill loader is reported in use in Washington. "The main pan line is carried up on the . . . . rib, ... the face is diagonal and the upper end of the pan line is an improvised 'duck bill' flattened on the upper side with the full height of the pan on the lower side. The flat duck bill extends along the full length of the face. The coal reaches the pan by gravity and then flows along the pan line to the loading point on the gangway." (George Watkin Evans, "Mechanization in the Roslyn Coal Field," *Transactions of the American Institute of Mining and Metallurgical Engineers*, Vol. 130 [1938], p. 309.)



Goodman Manufacturing Co.

Shop View



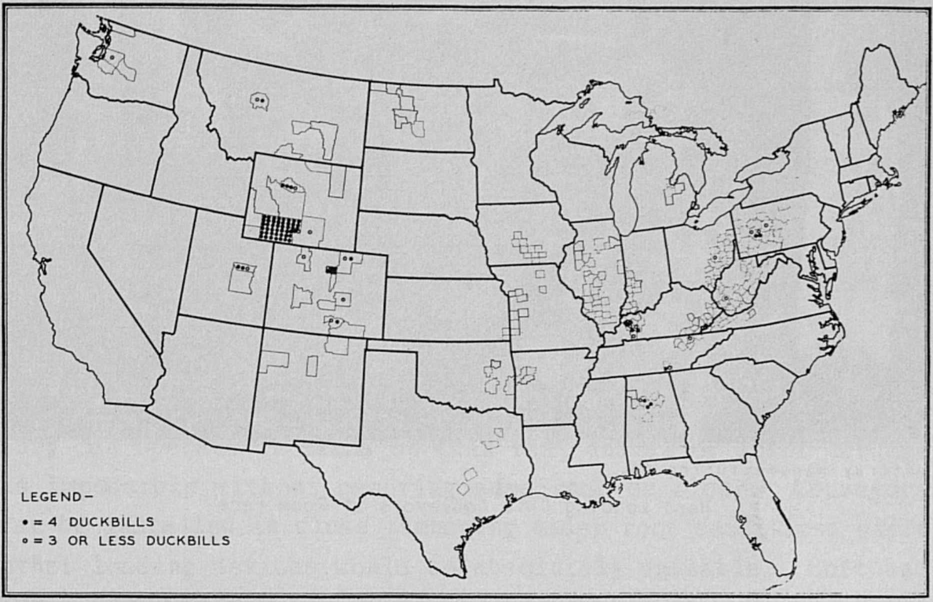
Coal Age

Duckbill Loading in Entry

FIGURE 21.- DUCKBILL LOADERS

Union Pacific Coal Company. It proved to be well adapted to the pitching seams of this area and management became highly skillful in its use. A considerable number of duckbills have been used in Colorado, and scattered installations have occurred in central Pennsylvania, Alabama, Tennessee, Montana, Washington, West Virginia, and Ohio. Kentucky purchased a substantial amount of this equipment in 1937 and 1938, most of

Figure 22.- DISTRIBUTION OF DUCKBILL LOADERS INSTALLED IN UNDERGROUND BITUMINOUS-COAL MINES AT THE BEGINNING OF 1938



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which went into western Kentucky. Utah also bought duckbill equipment in 1937 and in 1938.

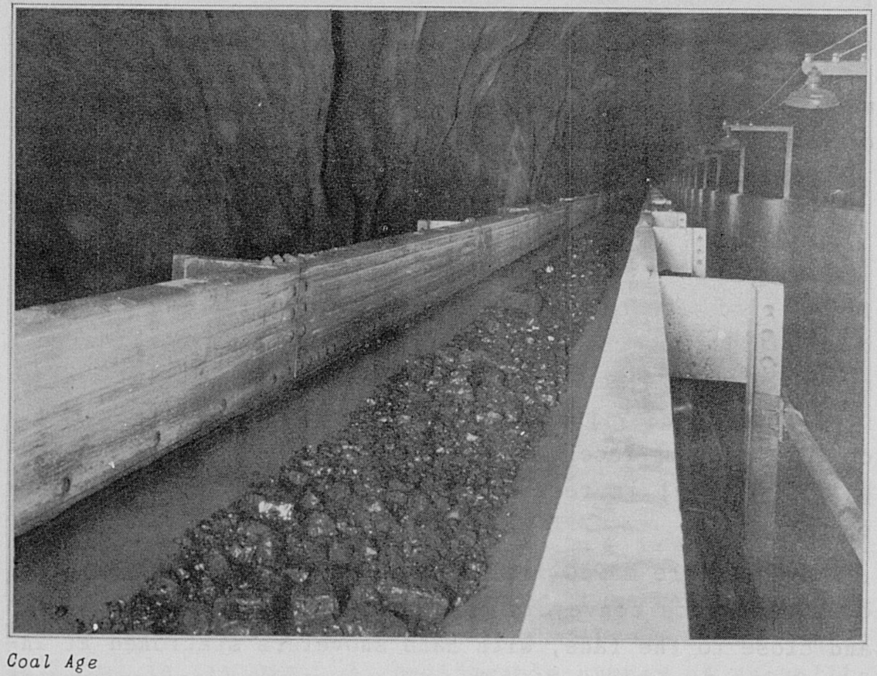
HAND-LOADED CONVEYORS

Conveyors are of three main types - shaking, chain-and-flight, and rubber-belt. They consist of a compressed-air or electrically operated power drive to which are attached a number of standardized conveyor sections. These units are all designed for easy portability. Conveyors were originally confined to long-face work but were later adapted to room-and-pillar mining; in recent years the latter has been their primary field.

Conveyors are moved into position after the coal has been cut. The face conveyors are usually placed parallel with and close to the face, with hand shovelers stationed at intervals to load the coal. The face conveyors are arranged to discharge into room conveyors which in turn carry the coal out of the room to mine cars on the entry or, in some cases, to a mainline conveyor belt. One of the chief advantages of the conveyor is that it eliminates the necessity for bringing

Jeffrey Manufacturing Co.

Hand Loading Onto Conveyors at Room Face



Coal Age

Belt Conveyor Leading From Slope Bottom to Surface

FIGURE 23.— CONVEYORS

mine cars into rooms, which is especially useful in thin seams. The transport function of conveyors is also being used increasingly in connection with mobile loaders to transfer the coal to mine-car loading points or to the mine outlet.

The hand-loaded conveyor, like the pit-car loader, is one of the slower-speed and lower-capacity forms of mechanical loading. At first it was considered merely as an auxiliary tool for the hand loader, and although this continues to be its prime function, it is now used to perform a number of other services such as aiding mobile loaders and gathering haulage. In a few cases conveyors have absorbed the entire function of mine haulage.

The flexibility of conveyors is further enhanced by the fact that they can be used under almost any mining conditions. They can operate in seams so thin that animal or motor haulage is impossible without removing some roof or floor. Conveyors can be installed in close timbering under roof conditions where other loading devices would be absolutely unusable. Soft and friable coals can be handled by the slow-speed conveyors with little degradation, and since they permit hand picking, their use is not limited by impurities.

Figure 24 shows the distribution of conveyor units at the beginning of 1938.[10]

The two areas of high conveyor concentration are West Virginia and central Pennsylvania. The greatest increase in the distribution of conveyors in recent years has been in the southern West Virginia coal fields. For the State as a whole, 275 new units were sold in 1937. In 1936, in the high-volatile field centering in Logan, Kanawha, and Boone Counties, there were 27 conveyor mines which produced 1,242,000 tons; in 1937 there were 38 such mines which produced 2,370,000 tons. In the low-volatile field there were 21 mines that produced 922,000 tons in 1936; this had increased to 25 mines and 1,250,000 tons in 1937. Particular significance attaches to the development of conveyor loading in the low-volatile field. This coal is sold in a quality market and, if seams contain impurities beyond the limit of tolerance, hand picking becomes necessary

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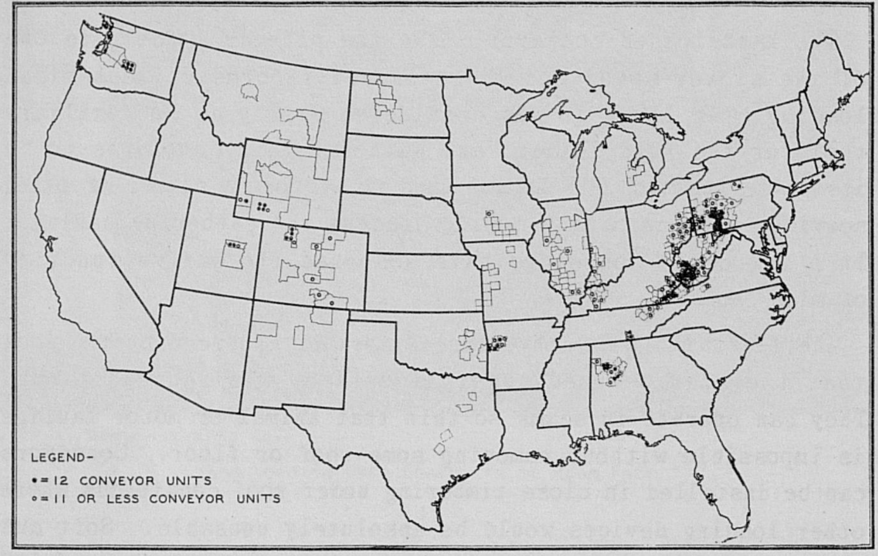
[10] The chart is based on units in use in 1936 plus 1937 sales. The latter, because of duplication in manufacturers' reports, tends to exaggerate actual number of units in use; nevertheless, the chart is indicative of field distribution in 1938. Some conveyors were probably sold for use in conjunction with duckbills, but detailed information on this point is not available.

Figure 24.- DISTRIBUTION OF HAND-LOADED CONVEYORS INSTALLED IN UNDERGROUND BITUMINOUS-COAL MINES AT THE BEGINNING OF 1938



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for mines that lack cleaning plants. Moreover, the coal is soft and friable and suffers excessive degradation unless carefully handled.

In the Panhandle of northern West Virginia conveyors have been introduced but, as conditions are similar to those in eastern Ohio and western Pennsylvania where mobile loading is successful, a shift to mobile loaders is already taking place. In the Upper Potomac field and adjacent Georges Creek field in Maryland conveyors are in use. They have been introduced in other southern Appalachian fields - Virginia, eastern Kentucky, Tennessee, and Alabama. Sale of new units continued sharply upward in 1937.

In northern Appalachian fields the greatest use of conveyors has been in central Pennsylvania, particularly in Cambria, Somerset, and Indiana Counties. Friable coals, thin seams, and competitive market conditions which demanded clean coal were the main reasons for the large installations in this area. Data for 1937 showed no new central Pennsylvania areas using conveyors; sales were in areas already penetrated.

Conveyors are still experimental in some cases in western Pennsylvania, but in one or two mines in the Pittsburgh seam they have proved to be a technical success. Practically all the important mining districts in Ohio are experimenting with conveyors; 18 units were in use in 1936 and sales records indicate that the number was doubled in 1937. Mobile loaders were the only machines that had been notably successful in Ohio prior to 1936.

In the far West conveyor loading is expanding in the pitching seams of Colorado and Utah. Success has been attained in the Roslyn field in Washington with a device which combines conveyors with a modified duckbill principle.

Until recently the hand-loaded conveyor has not been used extensively in the Midwest. Macon County is the only place in Illinois where conveyors were used in the past, but in 1936 conveyor equipment was sold for use in Fulton, Macon, Macoupin, Williamson, and Saline Counties. Not all this was for hand loading; part was for transportation. Conveyors were shipped to Knox and Vermillion Counties in Indiana in 1937. However, many parts of the Illinois-Indiana area are better suited to conveyor loading than are other areas in which it has been successful. As transition from pit-car to mobile loading in this area runs its course and further increases the pressure upon surviving hand-loading mines, some of the mines in which conditions are not suited to mobile loading are likely to put the experience of other areas to use by installing conveyors or duckbills.

The use of conveyors is recent in western Kentucky and is still in the experimental stage. In Missouri conveyors have been used in the past but none was in use in 1936. Iowa showed a revived interest in conveyors in 1937 following unsuccessful trials in earlier years. Arkansas is the only area in the Mississippi Valley using conveyors extensively.[11]

Table 9 shows the recent spread of conveyor installations in the South. Mines using conveyors in the southern Appalachian field more than doubled between 1930 and 1936. The West

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[11] As in the case of scrapers, the greatest center of conveyor loading is the Pennsylvania anthracite region. Conveyors are used in thin and moderately pitching anthracite seams and have facilitated a second and sometimes a third mining in badly broken ground where necessity for close timbering would make it impossible to use scrapers or mobile loaders. In this area conveyors combine loading with the initial hauling function and in some cases represent a transition from mule to motor haulage.

Table 9.- NUMBER OF MINES USING HAND-LOADED FACE CONVEYORS, BY STATE, 1930 AND 1936[a]

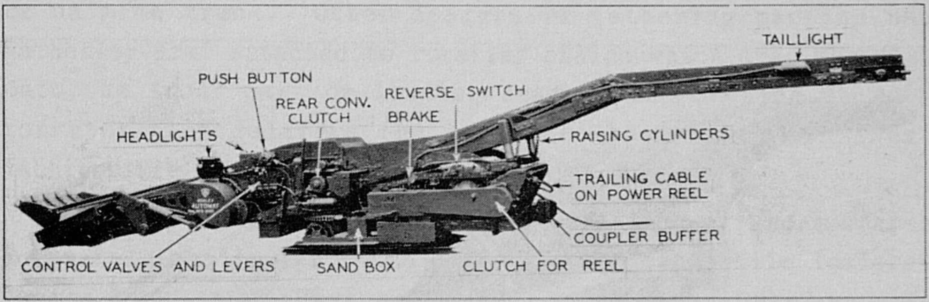
States	Number of mines	
	1930	1936
Total	142	185
Appalachian, Northern	67	52
Maryland	2	3
Ohio	3	6
Pennsylvania, central	60	38
Pennsylvania, western	2	5
Appalachian, Southern	40	91
Alabama	14	15
Kentucky, eastern	7	10
Tennessee	1	3
Virginia	5	6
West Virginia	13	57
Far West	18	22
Colorado	6	8
Montana	3	0
Utah	2	4
Washington	4	4
Wyoming	3	6
Mississippi Valley	17	20
Arkansas	10	15
Illinois	0	1
Indiana	0	2
Iowa	1	2
Missouri	4	0
Oklahoma	2	0

[a] Data for 1930 from F. G. Tryon, L. Mann, and H. O. Rogers, "Coal," *Mineral Resources of the United States: 1930* (U. S. Dept. Com., Bur. Mines, 1932), Part II, "Nonmetals," pp. 599-773; data for 1936 from *Bituminous Coal Tables, 1936-1937* (U. S. Dept. Int., Nat. Bituminous Coal Com., 1938).

Virginia State Department of Mines reported 57 conveyor mines in 1936 and 75 in 1937. In the northern Appalachian field conveyor mines dropped from 67 to 52, chiefly because of the decline in central Pennsylvania where experimentation in conveyors was active in 1930.

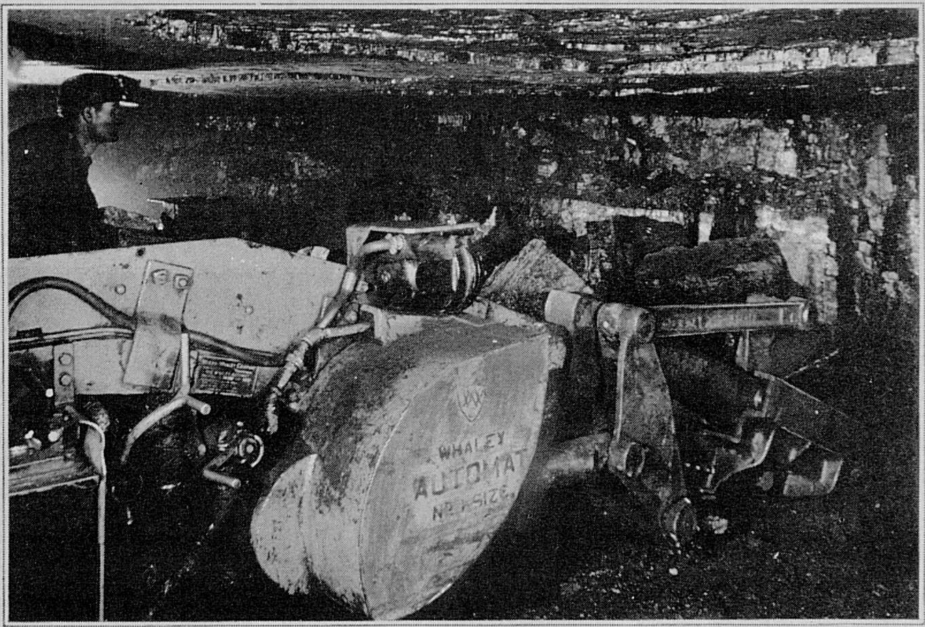
MOBILE LOADERS

Mobile loaders are of two general types, those employing the shovel principle and those using the gathering principle.



Myers-Whaley Co.

Shop View

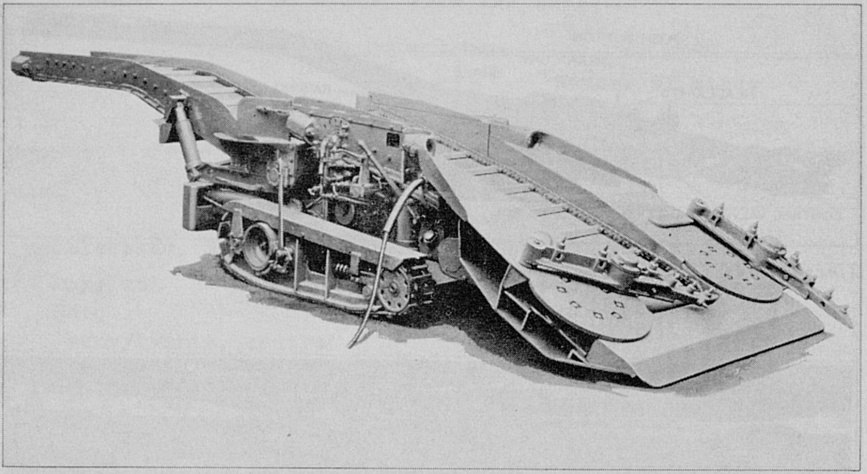


Myers-Whaley Co.

Loading Coal at Face

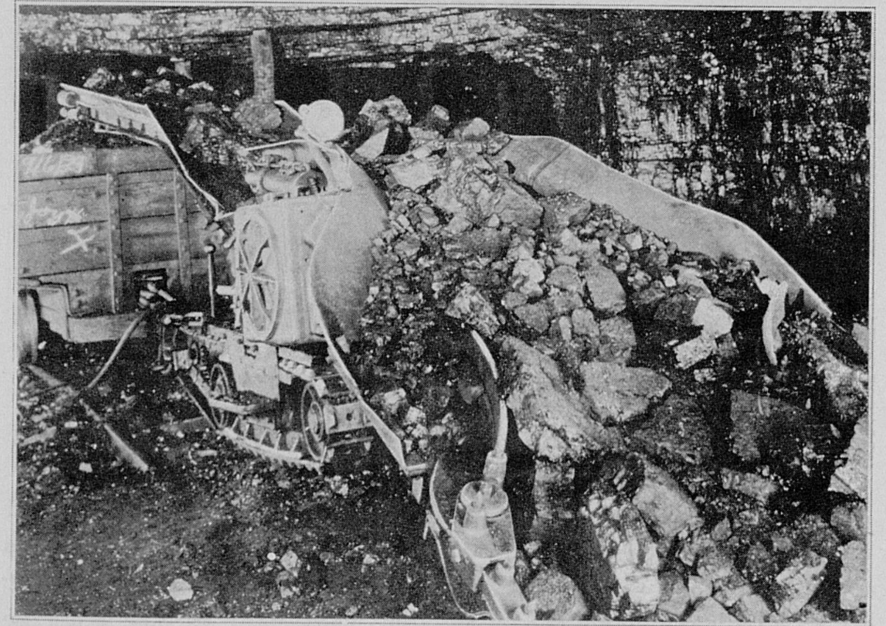
FIGURE 25.- SHOVEL-TYPE MOBILE LOADER

The shovel type forces the shovel forward under the coal parallel to the mine floor, and at the same time lifting rods tilt the front end of the device so that the coal slides or is thrown back onto the conveyor, that part of the machine which delivers the coal to the mine car (see figure 25). In other types the shovel is mounted on a boom which is swung around and discharged directly into the mine car. One design of gathering loader is equipped with two claw-like gathering arms attached to rotating disks which pull the coal onto the conveyor part of the machine (see figure 26). This machine is caterpillar-mounted and can be moved either without rails



Joy Manufacturing Co.

Shop View



Joy Manufacturing Co.

Loading Coal at Face

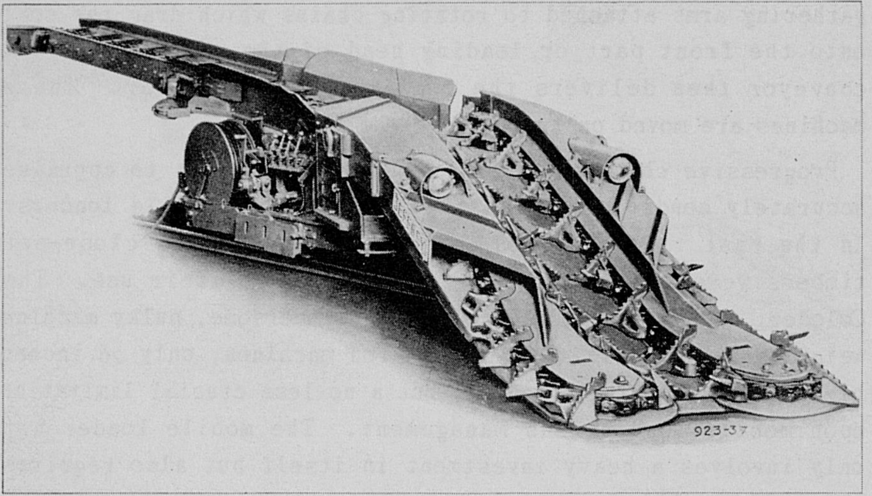
FIGURE 26.- TRACTOR-MOUNTED GATHERING-TYPE MOBILE LOADER

or on mine track. Other designs of gathering machine use gathering arms attached to rotating chains which drag the coal onto the front part or loading head of the machine where a conveyor then delivers the coal into the mine car. These machines are moved on tracks. (See figure 27.)

Progressive changes in design make it difficult to appraise accurately conditions which favor or handicap mobile loaders. In the past thin seams and poor roofs requiring close-set timbers were a most important limitation to their use. The Coloder, an early mobile type, was a cumbersome, bulky machine weighing 18 tons; in contrast, $4\frac{1}{2}$-ton machines, only 26 inches high, are in operation today. But a no less crucial limitation upon mobile loading was management. The mobile loader not only involves a heavy investment in itself but also requires that all auxiliary equipment be in tempo. Such handicaps as low-capacity mine cars, cutting machines, and haulage motors, track in poor condition, inadequate power, and limitations on blasting were all obstacles to a continuous cycle of operations. Unless management in cooperation with labor can achieve parallel and uninterrupted operation of all mine processes, idle time and futile effort make results disappointing. These were real limitations to the use of mobile loaders in thick seams where it was relatively easy to get large tonnages per machine; in thinner seams, with less concentrated tonnage, they practically prohibited their use.

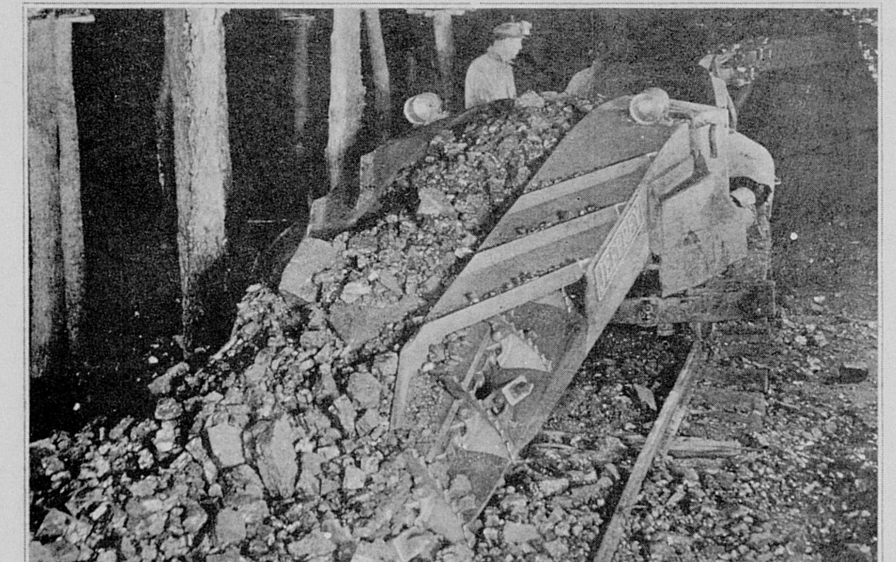
Physical handicaps, aside from thin seams which have restricted the use of mobile loaders, have been poor roof and floor, friability, and excessive impurities. Technology is gradually minimizing these obstacles. Smaller and more flexible machines and improved roof control are reducing the hampering effects of close timbering. Floors must still be relatively hard and free from excessive pitch. Both track and caterpillar operation are possible on grades up to 9 or 10 percent, but less is preferable. Coal should not be so soft and friable as to suffer degradation unless produced for an industrial market in which lump sizes are unessential. As the machine precludes hand picking, it must operate in connection with a mechanical cleaning plant unless the coal is clean enough to satisfy the market in which it is sold.

Present distribution of mobile loaders is shown in figure 28. Their first successful application was in those high-wage areas



Jeffrey Manufacturing Co.

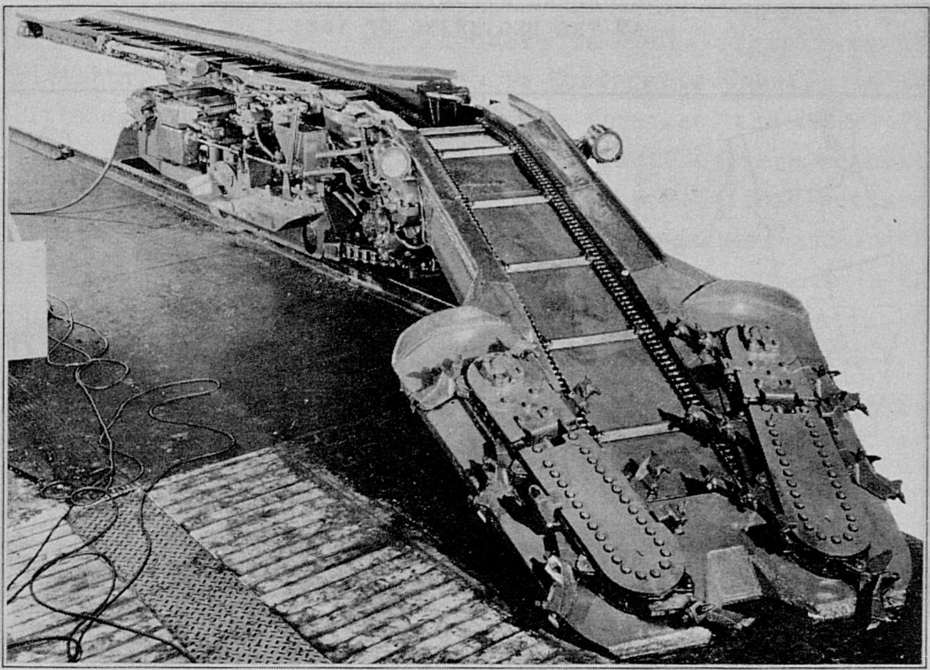
Shop View



Jeffrey Manufacturing Co.

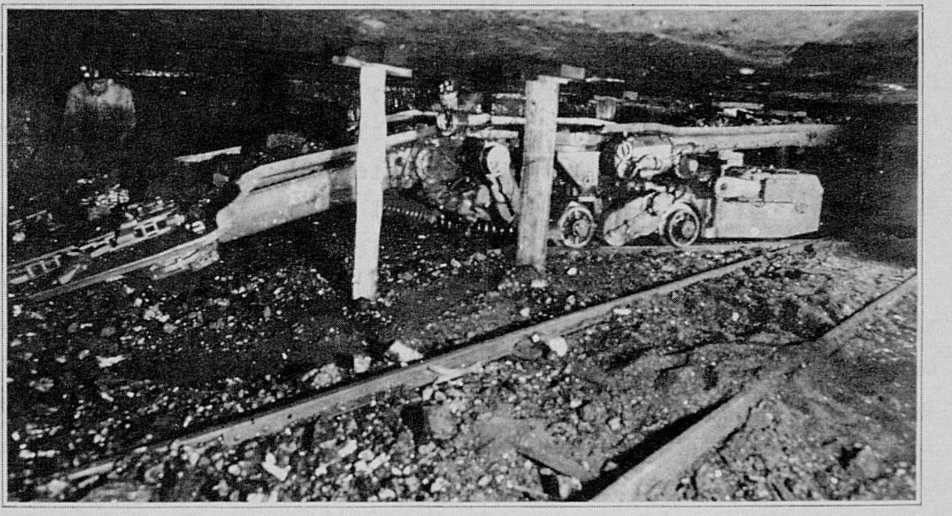
Loading Coal at Face

FIGURE 27a.— TRACK—MOUNTED GATHERING—TYPE MOBILE LOADER



Goodman Manufacturing Co.

Shop View

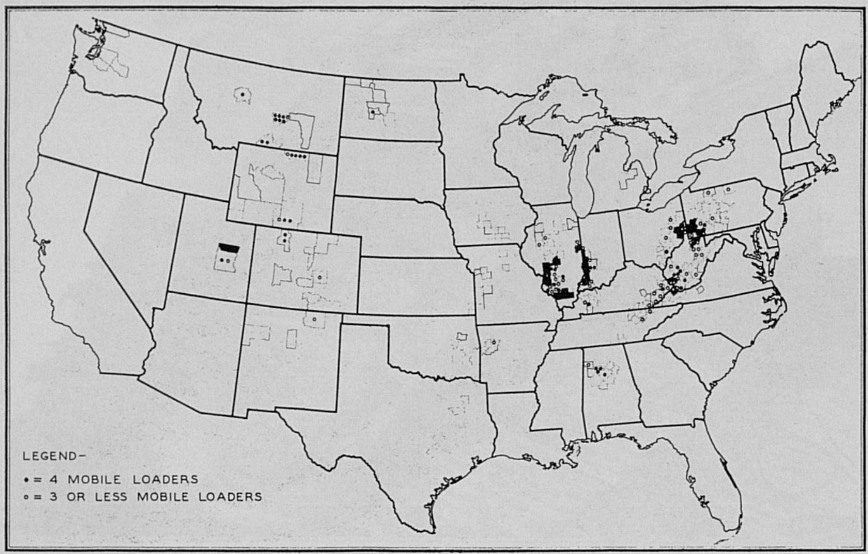


Goodman Manufacturing Co.

Loading Coal at Room Face

FIGURE 27b.— TRACK—MOUNTED GATHERING—TYPE MOBILE LOADER

Figure 28.- DISTRIBUTION OF MOBILE LOADERS INSTALLED IN UNDERGROUND BITUMINOUS-COAL MINES AT THE BEGINNING OF 1938



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where seams were thick and relatively level and clean, with timbering open enough to allow adequate movement. Southern Illinois, Indiana, Carbon and Sheridan Counties in Wyoming, parts of Montana, and Carbon County in Utah met these conditions. These were the areas in which mobile loading first spread. The Pittsburgh seam in western Pennsylvania was the scene of persistent and determined effort to adapt mobile loaders under difficult roof conditions. Despite draw slate and consequent close timbering, considerable success was at length attained. In the southern portion of the Pittsburgh seam in Monongalia, Marion, and Harrison Counties, West Virginia, draw slate was not a limiting factor,[12] but here, as in the Island Creek seam of southern West Virginia, low wage scales prevented an early interest in mechanization.

With the rise in wage rates after 1933-34 interest in the mobile loader suddenly spread to the thick-seam areas of the South. The sweep of the mobile loader through Scotts Run district of Monongalia County and through parts of Logan

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[12] The Pittsburgh seam is exceptionally thick in this area and part of the top coal is left unmined in order to control the roof.

County, West Virginia, accomplished overnight what had been technically possible for a decade. By 1938 the mobile loaders had appeared in large numbers in West Virginia in the Pittsburgh and Sewickley seams in Monongalia County, in the Pittsburgh seam of Marion and Harrison Counties, and in several seams of Logan County; scattered installations were reported in the Kanawha and New River fields. Installations occurred also in eastern and western Kentucky, in Tennessee, and in the Warrior field in Alabama. Along with this rapid advance in the South was shown a revival of interest in mobile loading in the Pittsburgh seam of western Pennsylvania and eastern Ohio.

Table 10 is presented to indicate the rapid spread which has occurred in recent years in the use of mobile loaders. Although the Mississippi Valley States continue to lead in the number in use, the chief interest in new installations has definitely shifted to the Appalachian States.

The limits to which mobile loading will go in thin seams will depend upon a balance of advantages and disadvantages of mobile loaders and conveyors. Improved designs and concentrated experience with mobile loading in the Illinois-Indiana area during the period of wide wage differentials from 1924 to 1933 prepared the ground for the striking response to changed labor conditions which resulted from NRA codes and extensions of collective bargaining in 1933 and 1934. In the same connection experiments by strong companies in western Pennsylvania and Ohio under the difficult conditions of the Pittsburgh seam were making substantial contributions to the management factors involved in mechanical loading, although tonnages loaded were much less impressive than those in the Illinois-Indiana area.

The sudden advance of mobile loading in West Virginia after 1935 reflected in some measure the momentum which it had acquired through the successful experience in the Midwest and in other fields. West Virginia operators had a choice of designs from which they could select those most suitable to particular seam conditions; they were able to go directly to the equipment best suited to their conditions. Limitation of design and absence of experience in the middle twenties made it impossible for concerns, except those that had favorable deposits and a high level of management, to succeed with mobile loading.

Table 10.- NUMBER OF MOBILE LOADERS IN USE, BY STATE, 1930, 1936, AND 1937[a]

States	Number of loaders		
	1930	1936	1937
Total	545	980	1,272
Appalachian, Northern	74	139	190
Ohio	22	47	75
Pennsylvania, central	3	2	4
Pennsylvania, western	49	90	111
Appalachian, Southern	48	149	250
Alabama	2	10	17
Kentucky, eastern	6	2	17
Tennessee	0	2	3
Virginia	8	9	17
West Virginia	32	126	196
Far West	94	110	129
Colorado	3	9	9
Montana	27	31	38
New Mexico	0	3	3
Utah	31	43	51
Wyoming	33	24	28
Mississippi Valley	329	582	703
Arkansas	0	0	3
Illinois	255	431	512
Indiana	65	146	177
Kentucky, western	9	1	7
North Dakota	0	4	4

[a] For sources of data for 1930 and 1936 see table 9, ftn. a; data for 1937 are preliminary estimates of the Nat. Bituminous Coal Com. based on reports of State Depts. of Mines, operators, and sales of new equipment.

Although mechanization of mine processes other than loading were well advanced in the twenties, refinements in the application of machine processes were nevertheless stimulated by the advent of mobile loading. Improvements were made in cutting, hauling, drilling, blasting, generating and distributing power, and above all in the preparing of coal at the tipple.[13]

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[13] A notable instance of a combination of technical and managerial advance is found in blasting. For reasons of safety some State laws prohibit blasting during a shift while any men except shot-firers are in the mine. Such a restriction means that mobile loading can operate only intermittently unless all the coal which can be loaded during a shift is blasted in advance. Thus part of the advantage of concentrated working places is lost. Intermittent loading neutralizes much of the cost advantage that flows from mechanization. To meet these difficulties, mechanical devices for breaking down the coal were developed and used instead of chemical explosives, and they constituted an important link in the chain of mechanization in some areas.

Spurts such as those that took place in Illinois and Indiana after 1928 and in West Virginia after 1935 are not likely to be repeated. With the sudden penetration of the thick-seam, good-roof areas of the Pittsburgh, Sewickley, and Island Creek beds, many of the most favorable opportunities in West Virginia have been utilized. Few areas with ideal seam conditions remain unexplored, but there are still a number of areas that can utilize the flexibility which improvements in design have given to mobile loaders in recent years.

SALES OF LOADING EQUIPMENT IN 1938

As this report approached completion, information became available on the sales of loading equipment in 1938. It

Table 11.- NUMBER OF MOBILE LOADERS, SCRAPERS, AND CONVEYORS IN ACTUAL USE IN 1936, AND SALES REPORTED IN 1937 AND 1938, IN THE BITUMINOUS-COAL INDUSTRY, BY STATE[a]

States	Mobile loaders			Scrapers			Conveyors[b]		
	In use in 1936	Sales in 1937	Sales in 1938	In use in 1936	Sales in 1937	Sales in 1938	In use in 1936	Sales in 1937	Sales in 1938
Total	980	292	241	106	13	6	1,170	835	749
Appalachian, Northern									
Pennsylvania	92	23	47	31	–	–	366	105	52
Maryland	–	–	–	–	–	–			
Ohio	47	28	15	–	–	–	18	37	23
Appalachian, Southern									
Alabama	10	7	39[c]	27	5	2	64	64	64
Kentucky	5	18		11	–	–	35	106	98
Tennessee		1			1	–	21	38	20
West Virginia	126	73	80		5	3	196	275	332
Virginia	9	8	9	–	1	–	70	16	5
Middle Western									
Illinois	431	81	38[d]	–	–	–	7	19	20
Indiana	146	31							
Trans-Mississippi	114[e]	22[f]	13[g]	37[h]	1[i]	1	393[j]	175[k]	135[l]

[a] L. N. Plein and Others, "Sales of Mechanical Loading Equipment for Use in Coal Mines in 1938," *Weekly Coal Report No. W. C. R. 1127* (U. S. Dept. Int., Nat. Bituminous Coal Com., mimeo., Feb. 18, 1939), pp. 3-8.

[b] Includes hand-loaded conveyors and conveyors equipped with duckbills or other self-loading heads. The figures for number in use in 1936 are not exactly comparable with those for number sold in 1937 and 1938 because of uncertainties in defining what constitutes a conveyor. The comparison, however, will serve to indicate which regions have made the largest proportionate increases.

[c] Mostly in Kentucky.

[d] Mostly in Illinois.

[e] Includes Colorado, Montana, New Mexico, North Dakota, Utah, and Wyoming.

[f] Includes Arkansas, Montana, Utah, and Wyoming.

[g] Includes Colorado, Montana, Oklahoma, Utah, and Wyoming.

[h] Includes Arkansas, New Mexico, Oklahoma, and Wyoming.

[i] Wyoming.

[j] Includes Arkansas, Colorado, Iowa, Montana, Utah, Washington, and Wyoming.

[k] Includes Arkansas, Colorado, Iowa, Utah, and Wyoming.

[l] Includes Arkansas, Colorado, Iowa, Oklahoma, Utah, and Wyoming.

was not considered advisable to add this information to the preceding charts showing the distribution of units in use at the beginning of 1938 because it is not known how many of the sales represent replacements and how many represent new installations. Table 11 shows the number of units in use in 1936 and the sales in 1937 and 1938 by geographical regions.

INTENSIVE AND EXTENSIVE ADVANCE IN MECHANICAL LOADING

From the foregoing analysis it will be seen that mechanization of loading is advancing along an intensive and an extensive front. The extensive advance is typified largely by the introduction of machines into areas and seams formerly regarded as offering no incentive to mechanize. The intensive advance is found in the substitution of mobile loading both for hand loading and for pit-car loader installations. West Virginia, where suitable forms of mechanization are being installed without a long period of trial and error, is a striking example of parallel advance on both an intensive and an extensive front. The best example of a purely intensive advance is the substitution of mobile for pit-car loaders in Illinois and Indiana.

The effect of mechanization on employment depends as much upon the type of mechanism as upon the extent of installations, and of course it depends also upon the percentage of total output in a mine or area which is handled by machine. In central Pennsylvania, where the low-powered conveyor predominates and where mechanized mines still load a substantial tonnage by hand, mechanization has not had the same employment repercussions that it has when mobile loaders are used for substantially all the tonnage from the mines in which they operate. Figures 29 and 30 show distributions of tonnage mechanically loaded, by county.

Because savings from mobile loading are greatest with a continuous and balanced operation of all mine processes, there is a strong inducement to load as much of the mine's output by machine as possible. This results in a cumulative intensity of mechanization with mobile loaders in a way which does not apply to the lower-powered mechanisms. The machine itself embodies a more intensive application of power, it requires a collateral mechanization of other mine processes, it stimulates refinements in management to permit balanced and

Figure 29.- UNDERGROUND BITUMINOUS-COAL PRODUCTION MECHANICALLY LOADED BY ALL TYPES OF MACHINES, BY COUNTY, 1937

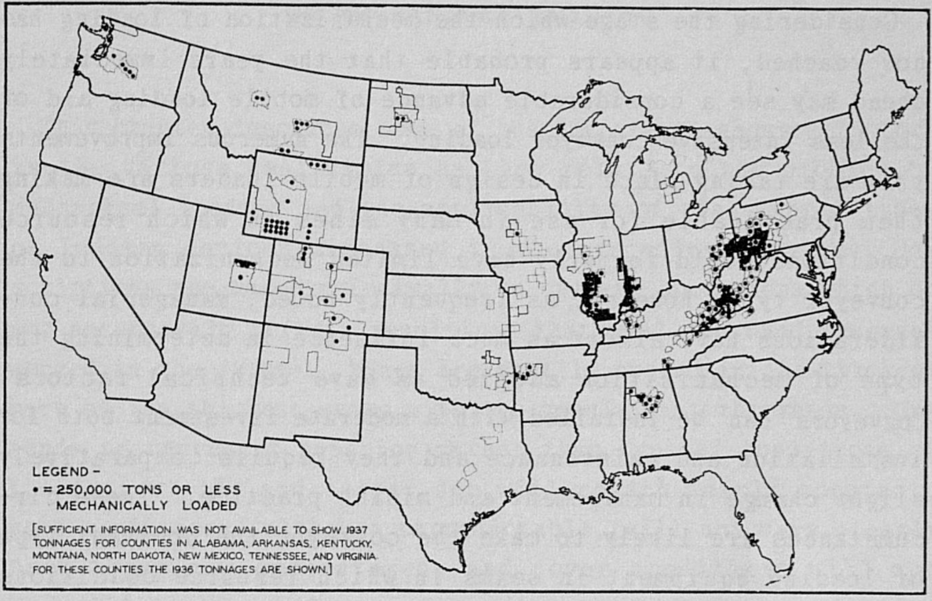

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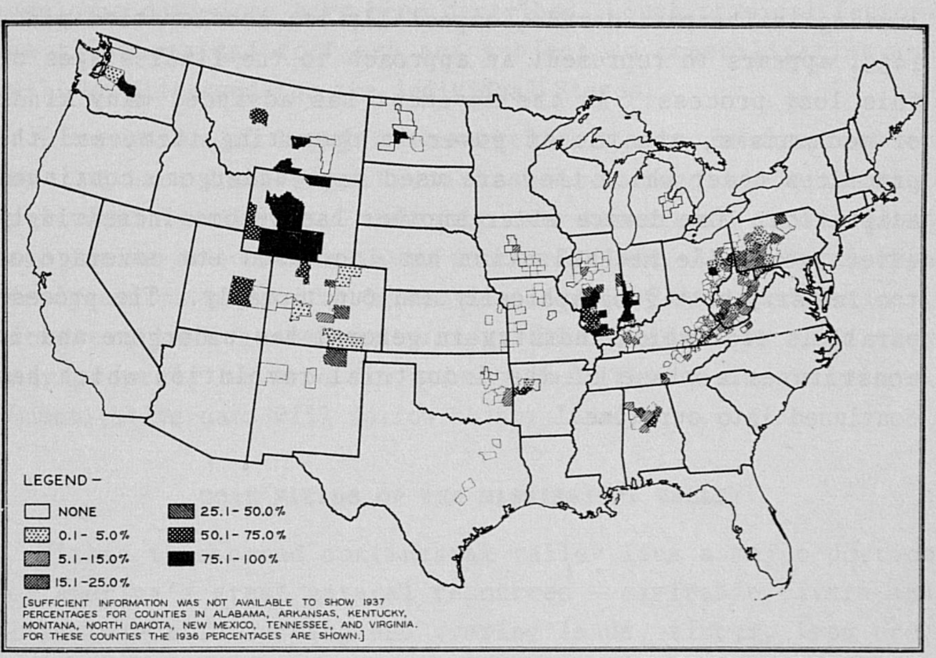
Figure 30.- PERCENTAGE DISTRIBUTION OF UNDERGROUND BITUMINOUS-COAL PRODUCTION MECHANICALLY LOADED BY ALL TYPES OF MACHINES, BY COUNTY, 1937



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continuous operation, and it encourages complete rather than partial mechanization.

Considering the stage which the mechanization of loading has now reached, it appears probable that the years immediately ahead may see a considerable advance of mobile loading and of the less intensive conveyor loading. The numerous improvements that are taking place in design of mobile loaders are making them practicable for use in many mines in which resource conditions would formerly have limited mechanization to the conveyor type; however, as frequently noted, managerial considerations have almost as much influence in determining the type of mechanization adopted as have technical factors. Conveyors can be installed with a moderate investment both for installation and maintenance and they require comparatively slight change in management and mining practice. These circumstances are likely to make the conveyor the dominant type of loading equipment in seams in which resource conditions are relatively unfavorable.

Both intensive and extensive advance of mechanization result from constant adjustment between technical and resource conditions. It is the same process which has characterized mining technology for more than a half-century. Mechanization of loading in the past decade, especially its acceleration since 1935, appears to represent an approach to the final stages of this long process. As the movement has advanced many kinds of mechanisms, the use of power in operating them, and the practices under which they are used have undergone continued adaptation. One device after another has become increasingly effective, while mechanization has increased its coverage of the industry both geographically and functionally. The process parallels that which industry in general has undergone and it constitutes a phase of the industrial revolution which has continued into our time.

CHAPTER VI

INFLUENCE OF RESOURCE CONDITIONS ON MECHANICAL LOADING*

This chapter describes some of the important resource factors in the various coal fields as they relate to the problem of mechanical loading and the applicability of the several types of loading devices discussed in the preceding chapter. Descriptions are based principally on current operations which do not necessarily reflect conditions that will surround reserves worked in the future. Mines are usually opened in the thickest part of the thickest seams with the result that thickness today tends to represent superior rather than typical conditions of the future. By and large, dip will remain fairly constant, roof conditions, although unpredictable, will not vary greatly from those now encountered, and cover conditions will not be modified to any large extent. Looking to a more distant future, mining will encounter increasing difficulties in respect to all the resource conditions as the better seams are depleted.

Resource conditions common to groups of States within broad geologic divisions have been described. Such physical factors as thickness and roof are not subject to generalization and will be discussed for the individual States.

Discussion of local areas within States in complicated by the fact that significant resource conditions overlap political boundaries. Commonly used terms such as districts and fields are in many cases poorly defined, and several such designations may apply to the same area. These designations, however, have become so current in the industry that they may properly be used for purely qualitative descriptions. Quantitative data will follow county lines.

COAL FIELDS OF THE MISSISSIPPI VALLEY

Within this broad continental valley lies a major portion of America's great natural resources - navigable rivers and lakes, fertile farming and grazing lands, timber, iron ore,

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*By Leo N. Plein and Willard E. Hotchkiss.

lead and zinc, bauxite, petroleum, natural gas, and one-sixth of the Nation's coal reserves. The area in 1936 produced nearly one-fifth of the national output of bituminous coal and anthracite.

Despite the fact that by and large the geology of this area is rather uniform, there is considerable variety in the resource conditions associated with the coal seams. Coal-loading methods show great variation in the degree of mechanization ranging from the power strip areas of Illinois, Indiana, Missouri, and Kansas and the highly mechanized deep mines of Illinois, Indiana, and Arkansas to the hand-loading underground mines of Michigan, Iowa, Kansas, Missouri, and Texas.

Although combinations of circumstances explain the differences in loading methods, up to the present most of the underground mechanization has developed in Illinois and Indiana in those coal seams generally conceded to have the best physical conditions. Relatively high wage scales and competitive factors have gone hand in hand in the growth of mechanical loading in these two States.

In Arkansas competition with other fuels and long freight hauls to market have forced mechanization into seams having difficult physical conditions in an attempt to reduce mining costs. Resource conditions in this State are distinctly different from those of the others of the Mississippi Valley. Thin, dipping seams are worked by longwall methods with conveyor loading. Seams are mined under physical conditions which are considered impossible in Illinois and Indiana. Economic conditions and high-quality coal explain why such seams are worked in Arkansas and not in Illinois and Indiana. The variety of Arkansas experience and its relatively high percentage of mechanized loading give it a place in the mechanization picture considerably more significant than would be indicated from its small output. Changes in the competitive position of western Kentucky in recent years have required the development of mechanical loading in physical conditions which are probably inferior to those of southern Illinois but decidedly superior to those of Arkansas. In the underground mines of Michigan, Iowa, Kansas, Missouri, and Texas physical conditions are difficult and economic forces have seldom been sufficiently strong to induce management to use mechanical loading.

Seams are opened principally by shafts or by stripping. The combination of flat surface and level seams makes stripping highly desirable where cover is not too great in proportion to seam thickness. These combinations occur frequently and stripping has therefore become highly important in the Mississippi Valley, whereas the combination of flat surface, level beds, and shallow cover seldom appears in a manner offering stripping possibilities in the Rocky Mountains or in the Appalachians.

In the Illinois-Indiana area the possibilities of mechanical loading under favorable physical conditions have by no means been exhausted in spite of the high concentration of mechanization in this area in the past. However, conditions in the mines not thus far mechanized are considerably different and in general less favorable than in the mines that have hitherto been mechanized. Resource conditions surrounding further extension of mechanization in Illinois and Indiana deep mines will conform more closely to those encountered in Appalachian areas.

Illinois

For many years Illinois has been the leader in tonnage produced by mechanical-loading methods from deep mines, and since 1930 it has led in the production of coal by strip mining. Management and high wage rates have combined to bring about this leadership, but to a large extent the development of machine loading in Illinois also hinged on the almost ideal physical conditions associated with the No. 6 seam.[1] Future growth of mechanical loading will depend more and more upon skill in overcoming less favorable conditions associated with other seams.

Illinois has more than a half-dozen coal seams, but only three of them are important. In 1937 the No. 6 seam contributed 72 percent of the State's output; No. 5, 20 percent; and No. 2, 5 percent. The No. 6 seam, which is located in that part of the State south of Springfield, has particulary good physical conditions, and in 1937, 92 percent of the State's

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[1] The coal seams in this State are designated by number rather than by name. This is somewhat similar to the nomenclature used in Indiana where Roman numerals are used. In nearly all other States seams have names based usually upon localities where they were first discovered, such as Pittsburgh (in Pennsylvania, Ohio, and West Virginia), Pocahontas (in West Virginia and Virginia), and Paris (in Arkansas).

output of mechanically loaded coal came from this seam. The balance, 8 percent, came from the No. 5 seam, in which physical conditions are not comparable to those of the No. 6 seam. Mechanical loading was not reported in any of the other seams. Stripping was distributed among four of the seams, in contrast to mechanical loading in only two. Table 12 shows the percentage relationship between production, mining methods, and seams.

Table 12.- PERCENTAGE DISTRIBUTION OF BITUMINOUS-COAL PRODUCTION IN ILLINOIS, BY SEAM AND BY MINING AND LOADING METHOD, 1937[a]

Item	Seam[b]						
	Total	1	2	3	5	6	7
Total production[c]	100.0	1.3	5.1	0.1	20.3	72.0	1.2
Shipping-mine production, total	100.0	0.7	5.0	0.1	18.2	75.6	0.4
By stripping[d]	100.0	0	18.4	0	21.8	58.5	1.3
By deep mining	100.0	0.9	0.9	0.1	17.1	80.8	0.2
By mechanical loading	100.0	0	0	0	8.1	91.9	0
By mobile loaders	100.0	0	0	0	6.1	93.9	0
By pit-car loaders	100.0	0	0	0	17.3	82.7	0
Ratio mechanically loaded tonnage to underground tonnage	69.7[e]	0	0	0	36.6	87.4	0
Ratio strip-mined tonnage to total tonnage	22.4[e]	0	86.0	0	27.9	18.0	69.7

[a] Computed from *Fifty-sixth Coal Report of Illinois, 1937* (Illinois Dept. Mines and Minerals, 1938).

[b] No production from the No. 4 seam at shipping mines. Local production from No. 4 seam was less than 0.01 percent of State output.

[c] Shipping mines accounted for 92 percent and local mines for 8 percent.

[d] Shipping mines produced 95.3 percent of the 11,725,870 tons mined by stripping.

[e] Includes local mines.

The No. 6 seam is a typically thick coal deposit ideally adapted to mechanical loading, with roof and floor conditions which are generally considered good, although there are some variations from county to county.[2] The seam ranges in average thickness from 40 inches in Fulton County to 113 inches in Franklin County. Although this represents a wide range, most

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[2] See table B-12 for counties in which No. 6 and other seams are mined and table B-13 for tonnages mechanically loaded in No. 5 and No. 6 seams by county.

of the production comes from seam thicknesses between 6½ and 7 feet. The bed is characterized by a 1- to 4-inch parting, known as the Blue Band, located from 21 to 42 inches above the bottom. This impurity is easily eliminated either by hand or by mechanical cleaning, and few other impurities occur.

Roof conditions vary considerably over different parts of the No. 6 seam. In Franklin and Williamson Counties roof consists of shale from 75 to 110 feet thick, overlain by limestone cap rock. The shale does not stand well when the full thickness is mined, so advantage is taken of the unusually thick coal by leaving from 18 to 60 inches in place to support the roof.[3] In the eastern part of Williamson County, where the coal is only 5 or 6 feet thick, roof is good and the seam is mined to its full height. In the Belleville district, which lies east of St. Louis, and in the central Illinois district roof conditions are not so good as they are in Franklin and Williamson Counties, but they are somewhat better than in the Danville district on the eastern boundary of the State. The floor or bottom is usually a hard shale or clay, 4 to 8 inches thick, underlain by limestone.

The No. 5 seam is mined in the northern and central portions of the State (principal producing counties being Fulton, Macon, Peoria, Sangamon, and Tazewell) and in the southern field (Perry, Saline, and Williamson Counties). This seam is adapted to mechanical loading although physical conditions are not so nearly ideal as in the No. 6. The range in thickness is from 50 inches in Williamson and Peoria Counties to 84 inches in Perry County. Most of the production, however, comes from an average thickness of 5 feet. The seam is hard, massive, and uniform from top to bottom. Clay veins, however, which extend through the coal and into the roof, occur and are obstacles to mechanical loading in that they interrupt operation schedules and increase costs.

Roof conditions are fairly good where the No. 5 seam is mined in the Springfield area, but in some places shale and limestone are intermingled in the cap rock and, when the immediate roof of shale or pyrite is absent or falls, the main roof

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[3] Attempts were occasionally made to recover the top coal after mining operations, but recovery has been difficult and expensive. Studies by the United States Coal Commission in 1922 indicated only 47 percent recovery in southern Illinois. Seven percent of the coal lost consisted of top and bottom coal left in place. (*Report of the U. S. Coal Commission* [S. Doc. 195, 68th Cong., 2d sess., 1925], pt. III, pp. 1854, 1856.)

is treacherous and may cave to a height of 35 feet. Where the No. 5 seam is mined in southern Illinois the roof in general is satisfactory. In the north-central area the bottom consists of dark fire clay which heaves badly when wet. The same is true of some areas in the southern portion of this seam.

The No. 2 is a thin seam ranging from 27 to 36 inches and is mined principally by stripping methods (86 percent in 1937). In the LaSalle district, however, longwall mining is practiced, which indicates a controllable roof.

Coal deposits in Illinois lie nearly horizontal and, except for those lying near enough to the surface to permit stripping,

Table 18.- BITUMINOUS-COAL PRODUCTION, SEAM THICKNESS, METHOD OF MINING, AND DISTRIBUTION OF LOADING EQUIPMENT IN ILLINOIS, BY COUNTY, 1937[a]

County producing over 100,000 tons	Production (net tons)	Number of seam mined	Average seam thick-ness[b] (inches)	Percent of total production		Percent of deep production		Percent of mechanically loaded tonnage mined by -	
				Strip mined	Deep mined	Hand loaded	Mechan-ically loaded	Mobile loaders	Pit-car loaders
Total	52,432,255	-	-	22.4	77.6	30.3	69.7	81.4	18.6
Christian	4,759,298	6	83	0	100.0	3 6	96.4	99.1	0.9
Clinton	264,413	6	84	0	100.0	100.0	0	0	0
Franklin	10,108,267	6	113	0	100.0	1.5	98.5	87.4	12.6
Fulton	3,334,320	5, 6	54, 40	80.5	19.5	100.0	0	-	-
Grundy	169,528	2	27	59.9	40.1	100.0	0	-	-
Henry	728,938	1, 2	56, 31	73.6	26.4	100.0	0	-	-
Jackson	1,720,094	6	87	36.3	63.7	5.6	94.4	100.0	0
Knox	863,175	1, 6	52, 42	56.5	43.5	100.0	0	-	-
LaSalle	476,729	2	31	48.6	51.4	100.0	0	-	-
Macon	145,289	5	52	0	100.0	51.1	48.9	0	100.0[c]
Macoupin	3,520,886	6	83	0	100.0	6.8	93.2	51.0	49.0
Madison	1,658,632	6	78	0	100.0	37.6	62.4	66.4	33.6
Marion	317,542	6	77	0	100.0	20.3	79.7	100.0	0
Menard	143,649	n.a.	n.a.	0	100.0	100.0	0	-	-
Montgomery	928,598	6	94	0	100.0	0	100.0	84.2	15.8
Peoria	1,485,717	5	50	0	100.0	91.5	8.5	100.0	0
Perry	3,873,355	5, 6	84, 76	73.4	26.6	56.1	43.9	96.3	3.7
Randolph	1,390,113	6	71	54.5	45.5	28.7	71.3	90.1	9.9
St. Clair	2,697.626	6	79	16.8	83.2	46.9	53.1	96.9	3.1
Saline	3,497,557	5, 6	62, 60	22.8	77.2	50.9	49.1	93.0	7.0
Sangamon	2,594,104	5, 6	68, 66	0	100.0	53.6	46.4	5.1	94.9
Tazewell	282,621	5	52	0	100.0	100.0	0	-	-
Vermilion	2,274,403	6, 7	69, 66	6.9	93.1	62.6	37.4	78.1	21.9
Washington	335,717	6	70	0	100.0	30.5	69.5	94.2	5.8
Will	1,393,077	2	36	100.0	0	0	0	-	-
Williamson	2,818,989	5, 6	50, 91	21.5	78.5	34.4	65.6	80.5	19.5
Undistributed[d]	649,618	-	-	7.5	92.5	99.1	0.9	100.0	0

[a] Computed from *Fifty-sixth Coal Report of Illinois, 1937* (Illinois Dept. Mines and Minerals, 1938).

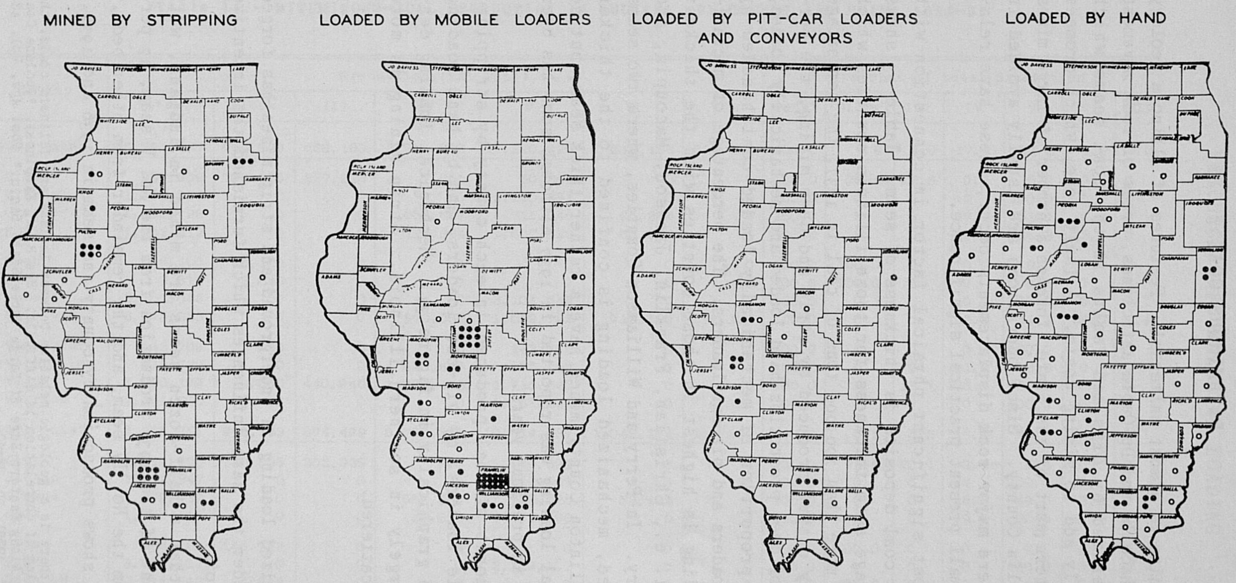
[b] Unweighted average. Includes both strip and underground mines.

[c] Conveyor-loaded tonnage.

[d] Includes counties with less than 100,000 tons annual production.

n.a. Data not available.

Figure 31.- ILLINOIS COUNTY DISTRIBUTION OF TONNAGE MINED BY STRIPPING AND UNDERGROUND TONNAGE LOADED BY MOBILE LOADERS, BY PIT-CAR LOADERS, AND BY HAND, 1937



MINED BY STRIPPING

LOADED BY MOBILE LOADERS

LOADED BY PIT-CAR LOADERS AND CONVEYORS

LOADED BY HAND

LEGEND-

EACH SOLID CIRCLE (●) REPRESENTS 500,000 TONS OR MAJOR FRACTION THEREOF EACH OPEN CIRCLE (○) REPRESENTS 250,000 TONS OR LESS

BASED ON DATA OF THE ILLINOIS DEPARTMENT OF MINES AND MINERALS

MINERAL TECHNOLOGY AND OUTPUT PER MAN STUDIES
WPA-NATIONAL RESEARCH PROJECT E-157

shaft mining is almost universal. Features of Illinois geology are the LaSalle and Du Quoin anticlines, areas of rock movement characterized by dips and faults in the coal seams which materially add to mining costs. A fault zone, which crosses the southern part of the State, touches a number of large mines in Franklin County. Since operations are usually avoided in areas where major rock displacements occur, these have relatively small present practical significance.

The most significant physical factor in connection with Illinois coal deposits is thickness of seam. Table 13 shows the average seam thickness for those Illinois counties which produced more than 100,000 tons of coal in 1937, the percentage of county output produced by strip and deep mining, the percentage of deep production hand loaded and mechanically loaded, and the proportion of mechanically loaded coal handled by mobile loaders and pit-car loaders. The percentage of mechanical loading is highest in those counties with the thickest seams, i. e., Christian, Franklin, Jackson, Macoupin, and Montgomery. In Perry and Williamson Counties, where two seams are mined, mechanized loading is confined to the thicker seam. Clinton County mines have a rather thick seam, but no mechanical loading was reported in 1937 although some has been reported in previous years.

The amount of coal produced in each county by stripping, by mobile loaders, by pit-car loaders, and by hand loading is shown graphically in figure 31. Mechanical loading centers largely in southern Illinois. Strip mining is more widely scattered.

Indiana

Mechanized loading in underground and strip mines has forged ahead under the same influences which furnished the incentive in Illinois.

More than a half-dozen seams are mined in Indiana, with 65 percent of the 1937 production from the No. V seam, 17 percent from the No. IV seam, and the remainder from other beds.[4] Table 14 shows production by county and seam in 1936 and 1937.

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[4] Although there is a geologic relation between Indiana and Illinois coals, the whole problem of correlation is difficult. See R. W. Karpinski, "Indiana Coal Fields Lie Along Eastern Edge of Large Three-State Basin," *Coal Age*, Vol. 43, No. 12 (Dec. 1938), pp. 36-40.

Table 14.- BITUMINOUS-COAL PRODUCTION IN INDIANA, BY COUNTY AND SEAM, 1936-37[a]

County	Production (net tons)							Percent of total production						
	Total	Block	III	IV	V	VI	VII	Total	Block	III	IV	V	VI	VII
1936, total	16,594,367	764,020	668,160	2,911,806	11,220,029	813,196	217,156	100.0	4.6	4.0	17.6	67.6	4.9	1.3
Clay	997,909	702.560	227,214	7,850	60,285	0	0	100.0	70.4	22.8	0.8	6.0	0	0
Gibson	1,100,291	0	0	0	1,100,291	0	0	100.0	0	0	0	100.0	0	0
Greene	1,398,728	0	0	658,297	715,046	25,385	0	100.0	0	0	47.1	51.1	1.8	0
Knox	1,862,819	0	0	186,324	1,607,823	68,672	0	100.0	0	0	10.0	86.3	3.7	0
Owen	56,100	56,100	0	0	0	0	0	100.0	100.0	0	0	0	0	0
Parke	3,810	3,810	0	0	0	0	0	100.0	100.0	0	0	0	0	0
Pike	3,101,645	0	0	0	3,101,645	0	0	100.0	0	0	0	100.0	0	0
Sullivan	2,575,053	0	0	579,036	1,059,722	719,139	217,156	100.0	0	0	22.5	41.1	28.0	8.4
Vanderburg	142,789	0	0	0	142,789	0	0	100.0	0	0	0	100.0	0	0
Vermillion	813,738	0	0	258,246	555,492	0	0	100.0	0	0	31.7	68.3	0	0
Vigo	3,380,179	1,550[b]	440,946	1,222,053	1,715,630	0	0	100.0	*	13.1	36.2	50.7	0	0
Warrick	1,161,306	0	0	0	1,161,306	0	0	100.0	0	0	0	100.0	0	0
1937, total	16,385,751	916,673	874,429	2,756,349	10,614,237	1,043,174	180,889	100.0	5.6	5.3	16.8	64.8	6.4	1.1
Clay	1,014,925	749,555	203,939	750	60,681	0	0	100.0	73.8	20.1	0.1	6.0	0	0
Gibson	1,212,847	0	0	0	1,212,847	0	0	100.0	0	0	0	100.0	0	0
Greene	1,409,532	0	0	652,584	703,525	53,423	0	100.0	0	0	46.3	49.9	3.8	0
Knox	1,765,115	0	0	161,817	1,603,298	0	0	100.0	0	0	9.2	90.8	0	0
Owen	146,722	146,722	0	0	0	0	0	100.0	100.0	0	0	0	0	0
Pike	3,159,101	0	0	0	3,159,101	0	0	100.0	0	0	0	100.0	0	0
Spencer	14,242	14,242	0	0	0	0	0	100.0	100.0	0	0	0	0	0
Sullivan	2,494,028	0	0	545,809	811,963	962,664	173,592	100.0	0	0	21.8	32.6	38.6	7.0
Vanderburg	144,876	0	0	0	144,876	0	0	100.0	0	0	0	100.0	0	0
Vermillion	562,710	0	0	133,333	402,290	27,087	0	100.0	0	0	23.7	71.5	4.8	0
Vigo	3,265,860	6,154	670,490	1,262,056	1,319,863	0	7,297	100.0	0.2	20.5	38.7	40.4	0	0.2
Warrick	1,195,793	0	0	0	1,195,793	0	0	100.0	0	0	0	100.0	0	0

[a] Computed from *Report of Coal Production at Shipping Mines in the State of Indiana, Classified by Counties, Railroads, Veins of Coal, and Character of Operation,* Jonas Waffle, Managing Director, Coal Trade Association of Indiana, March 15, 1938.

[b] Includes 296 tons from Minshall bed.

*Less than 0.05 percent.

Mechanical loading is concentrated chiefly in the No. V and No. IV seams, and stripping in the No. V. The following tabulation is based on production reports received by the National Bituminous Coal Commission from Indiana coal operators for the year 1936. These reports have been compiled with reference to the seams worked by each mine.

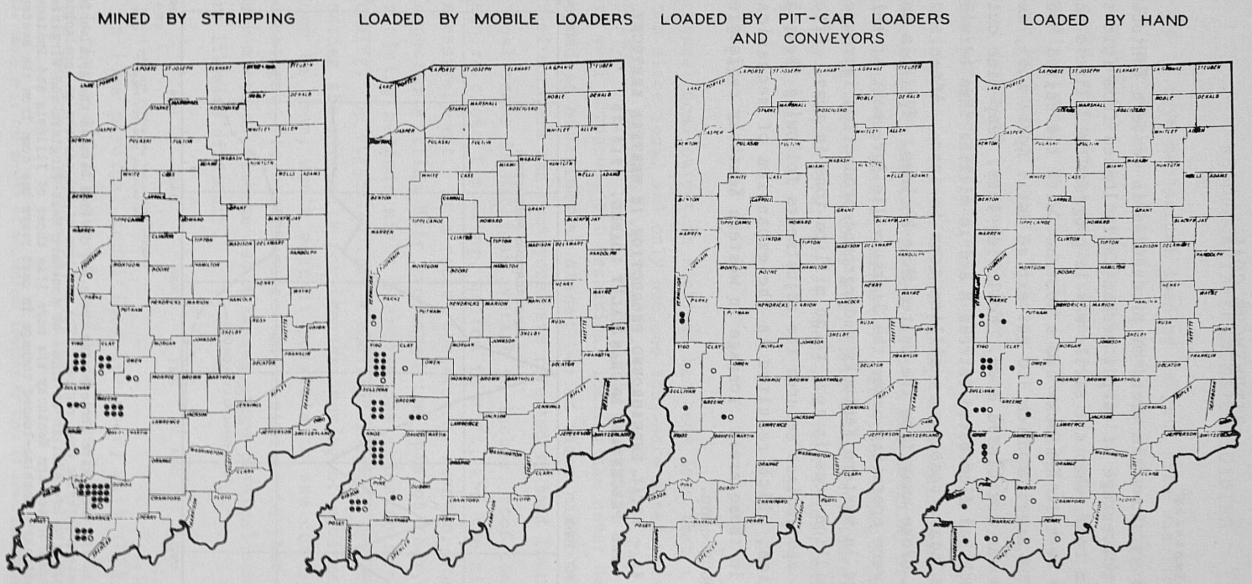
Seam number	Mechanical loading in underground mines		Strip mining	
	Tons	Percent	Tons	Percent
Block	33,000	0.5	939,382	12.2
III	443,157	6.2	0	0
IV	2,098,115	29.4	637,975	8.3
V	4,389,165	61.4	4,906,052	63.9
VI	147,170	2.0	809,924	10.6
VII	0	0	0	0
Unidentified	35,483	0.5	386,468	5.0
Total	7,146,090	100.0	7,679,801	100.0

All Indiana coal areas lie along the western margin of the State and are generally divided into a northern and a southern field. The boundary between the two runs from Vincennes eastward through Knox and Daviess Counties.

Figure 32 shows by county the methods of production in 1936. Mechanical loading in Indiana is more widely distributed than in Illinois because the two most important seams, Nos. IV and V, are adaptable to mechanized loading and are mined in nearly all counties.

Indiana seams average close to 5 feet in thickness, although there is considerable variation from a low of 3 feet in the Block seams in Clay County to a high of 7 feet in the No. IV and No. V seams in the same county. The No. V seam, workable nearly everywhere in the Indiana coal field, is the most important producing seam. It averages close to $5\frac{1}{2}$ feet, with a range of 4 to 7 feet. The No. IV seam, second in importance, is comparable with No. V in average thickness and in range. Roof is generally good in these important producing seams. The No. V seam is generally free of impurities, but the others usually carry shale and bone partings.

Figure 32.- INDIANA COUNTY DISTRIBUTION OF TONNAGE MINED BY STRIPPING AND UNDERGROUND TONNAGE LOADED BY MOBILE LOADERS, BY PIT-CAR LOADERS, AND BY HAND, 1936



MINED BY STRIPPING

LOADED BY MOBILE LOADERS

LOADED BY PIT-CAR LOADERS AND CONVEYORS

LOADED BY HAND

LEGEND-

EACH SOLID CIRCLE (●) REPRESENTS 200,000 TONS OR MAJOR FRACTION THEREOF

EACH OPEN CIRCLE (○) REPRESENTS 100,000 TONS OR LESS

BASED ON DATA OF THE NATIONAL BITUMINOUS COAL COMMISSION

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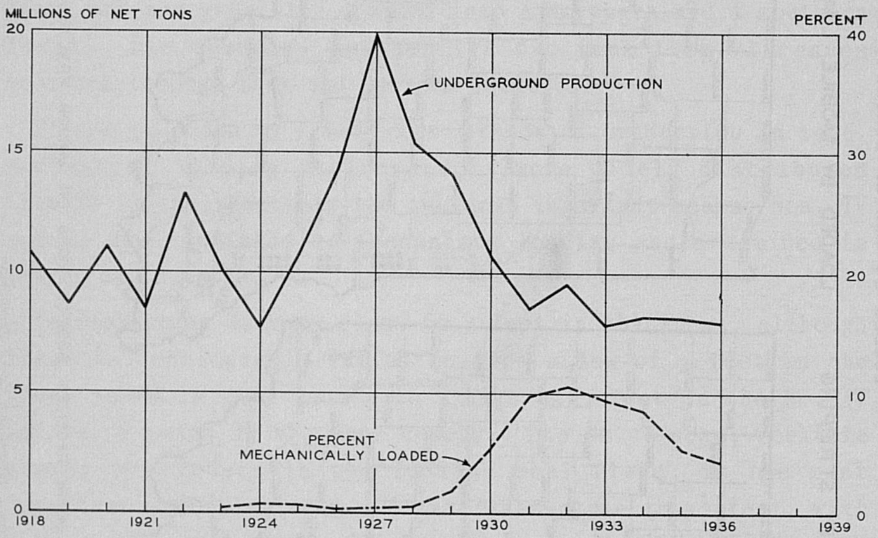
Western Kentucky[5]

Figure 33 shows the trend of production in western Kentucky and the percentage of output mechanically loaded from 1918 to 1936. In 1922, when the strike was in progress in Illinois and Indiana, western Kentucky had a contract with the United Mine Workers of America which did not expire until April 1923, and the area was not closed down. Following this, deep-mine output, which had fluctuated between 8 and 10 million tons between 1918 and 1921, rose to 13 million tons in 1922. After 1925 the area broke away from the United Mine Workers. Illinois and Indiana were operating under the Jacksonville Agreement at this time, and in western Kentucky underground production increased from 8 million tons in 1924 to 20 million tons in 1927. After Illinois and Indiana secured the adjustments following the 1927 suspension, which resulted in the expansion of mechanical loading in those areas, tonnage in western Kentucky registered an enormous drop.

Figure 33.- TOTAL UNDERGROUND PRODUCTION IN WESTERN KENTUCKY AND PERCENTAGE MECHANICALLY LOADED, 1918-36



BASED ON TABLE B-14

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[5] Kentucky is the only State whose mining areas are divided between the Appalachian and the Eastern Interior coal regions. The problems of the eastern or Appalachian area in Kentucky are similar to those of southern West Virginia and Virginia, whereas those of western Kentucky are more like those of Illinois and Indiana. Most of Kentucky's machine-loaded tonnage in past years has come from the western part of the State.

Up to 1936 mechanical loading in this area was limited by low wage scales. Although in one year, 1932, approximately 11 percent of the underground output had been mechanically loaded, the percentage declined to 4 in 1936. Nearly all the machine tonnage in this period was loaded by pit cars and came from Muhlenburg County.[6] Sales of new loading equipment in 1937 and 1938 indicate that western Kentucky operators are actively experimenting with duckbills and mobile loaders.

Resource conditions, though perhaps not so favorable as in the adjoining fields of southern Illinois and Indiana, are no bar to the use of loading machinery. The three most significant seams in western Kentucky are, in order of importance, No. 9, nearly 5 feet thick; No. 11, nearly 6 feet thick; and No. 6, $3\frac{1}{2}$ feet thick.

Michigan

Annual coal output in Michigan has been less than 1 million tons since 1923, and only 626,000 tons were mined underground in 1936. Mechanization of cutting, drilling, and hauling are well advanced, but mechanical loading has never developed beyond an experimental stage; two or three mines that have tried scrapers and conveyors have reverted to hand loading.

Coal seams in Michigan average 34 inches, roof conditions require close timbering, bottom is soft, and the mines are excessively wet. In a recent conference, however, State Mine Inspector William Muir expressed the opinion that changes in mining methods might overcome obstacles to mechanical loading. He suggested that a modified longwall system, eliminating the necessity for frequent moving of equipment from room to room, would make it possible to use conveyors to advantage. The system suggested is similar to that used in many mines of Alabama and Arkansas where physical conditions are likewise difficult.

Iowa

In Iowa physical conditions are poor, with thin seams, relatively difficult roof, and many impurities intermingled with the coal. Mechanical loading has never been important,

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[6] See table B-14 for growth of mechanical loading by type of loading equipment.

and in 1934 and 1935 no mine reported using mechanical loaders, although the use of conveyors reappeared at one mine in 1936.

Kansas

Kansas seams are thin, and the competitive position of underground mines was early made difficult by the rise of strip mining on a large scale. Since 1931 the deep mines of Kansas have produced less than a million tons annually. There were no records of any mechanical-loading equipment in the State up to 1937. Mechanization has centered entirely on large-scale surface stripping operations.

Missouri

Conditions in Missouri are similar to those in Kansas, with mechanization concentrated in the stripping industry. Mechanical-loading experience has been limited. In the peak year, 1929, only 126,000 tons were loaded, and this dropped to 35,000 tons in 1935. No mechanical loading was reported in 1936.

Arkansas

Among the low-tonnage areas in which mechanical loading has been tried, Arkansas is perhaps the most important from the standpoint of the value of its experience to other areas. Adverse physical conditions probably have greater influence on productivity than they do in any other State in the Mississippi Valley. Because of the variety and difficulty of the resource conditions which surround Arkansas coal production, they are given greater attention than would be justified on the basis of current or prospective tonnage. Despite difficult resource conditions inherent to thin pitching beds, distance from markets, and severe competition with gas and oil, mechanization in Arkansas has made distinct progress, advancing from 17 percent in 1933 to over 33 percent in 1937. Conveyors and scrapers are the principal types of equipment used. Shipments of new equipment into the State indicate that the advance continued through 1938.[7]

Total Arkansas output in 1936 was slightly more than 1,623,000 tons; it was about the same in 1937. Approximately 3 percent

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[7] See table B-15 for growth of mechanical loading by type of equipment.

of the total was strip mined in 1936. Mining is centered in six counties, and in 1936 Sebastian produced 41.5 percent, Logan 28.8 percent, Johnson 14.1 percent, and Franklin 11.8 percent, with Pope and Scott together producing 3.8 percent.

Only a small part of Arkansas is underlain by coal. The total area is estimated at 1,620 square miles, of which 300 to 350 square miles are workable. The lignite area in the southeastern part of the State has never been a market factor and has no prospect of becoming one.

Most of the Arkansas coal comes from the Hartshorne and Paris seams, the former producing about 69 percent and the latter 28 percent of the total output. The Charleston seam produces about 3 percent of the State's total output. The Hartshorne seam is mined in the Spadra and Russellville district in Johnson and Pope Counties and in the Sebastian district. The Paris seam is mined only in Logan County and covers nearly all the output of that county. Markets for coal from this seam have grown rapidly in recent years. The Charleston seam is mined locally in Franklin County, and strip mining has occurred there.

Generally speaking the quality of Arkansas coal is excellent, and for this reason it has been able to compete in Missouri, Kansas, and even in Nebraska and Minnesota with coals which have lower mining costs and lower freight rates. Proximity to the midcontinent oil and gas fields, however, greatly restricts potential markets.

Practically all Arkansas coal is produced in either shaft or slope mines. Because of heavy pitch, slopes with electric hoists are employed in many areas. Shafts ranging in depth from 50 to 450 feet have been utilized.

The chief obstacle to high man-hour output lies in thinness of seams which range from 14 to 48 inches of workable coal. In characteristic areas of the Hartshorne seam shale partings occur which divide the coal into two or more benches. In Sebastian County, where this seam locally reaches a maximum gross thickness of 7 or 8 feet from roof to floor, these partings are as much as 36 inches thick and divide the coal into benches 4 feet or less in thickness. Ordinarily only the coal from the thicker bench is mined and the remainder of the seam is lost. At best, the Hartshorne seam affords only 48 inches of minable coal, and in many places 30-inch coal is recovered. In the thicker parts of this seam the coal above the binder contains dirt bands, but the bottom bench is clean and of excellent quality.

The Paris seam ranges from 18 to 34 inches thick. Coal is overlain by 2 inches of hard slate which is separated from the main shale roof by a mud band. When the machine cut is made in the rock bottom the coal drops to the floor without shooting or wedging. This system of cutting, used with longwall mining, has made practical the use of scows which operate on the principle of scrapers.[8]

The earth movements by which the mountains that border the Arkansas coal fields were formed have caused folding and faulting so that the coal seams dip as much as 17 degrees at outcrop. In some of the individual basins the dip is slight for small distances at the bottom. Vertical and horizontal displacements also add to the difficulties of mining. Roof conditions in Arkansas are generally controllable. This is indicated by the practice of longwall mining, which is used at practically all mines working the Paris seam in Logan County and is spreading into Sebastian County. The largest producer in Pope County was using longwall mining in 1936. Room-and-pillar mining is used elsewhere in the State. The significance of the distinction between the two systems is that longwall mining is suited to mechanization, whereas extremely thin seams are more difficult to mechanize with room-and-pillar systems.

The future of mechanical loading seems to depend in considerable measure on technical developments in cutting as well as in loading. It is a frequent practice to cut the rock beneath the coal. If present experiments in the cutting of rock bands 12 to 24 inches thick are successful, such machines will have wide applicability in Arkansas mines and should lead to more intensive mechanized loading.

Although thin seams and other difficulties are likely to preclude high productivity in Arkansas in the future as they have in the past, it should be noted that Arkansas operators have applied mechanization to conditions which, in States like Illinois and Indiana, would have been considered impossible a few years ago. Experiments now being carried on under the wide variety of physical conditions will probably lead to

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[8] For details of this operation see Albert L. Toenges, *Longwall Mining Methods in Some Mines of the Middle Western States* (U. S. Dept. Int., Bur. Mines I. C. 6893, mimeo., June 1936).

significant advances in mechanization if economic possibilities enlarge the market for Arkansas coals.

Standard data showing comparative performance under hand- and machine-loading were compiled for Arkansas deep mines, but the data bore evidence of faulty reporting, and it was believed that no conclusive results could be drawn. Only a rough idea can be given of the difference in productivity between Arkansas mines in a machine-loading versus a hand-loading period. In an effort to secure some basis of judgment, a few mines in which reporting seemed to be reasonably accurate were selected, and output per man-hour in a highly mechanized and in a hand-loading period was tabulated:

Mine	Hand-loading period	Machine-loading period	Percentage increase
A	0.214	0.316	47.7
B	.235	.319	35.7
C	.234	.292	24.8
D	.296	.351	18.6

Oklahoma

Whereas in Arkansas mechanical loading advanced materially, in Oklahoma, so far as is shown by the reports, it did not reach significant proportions by the end of 1936. In the Oklahoma counties producing low-volatile coal physical conditions are much the same as in Arkansas; all the coal is excellent, but competition with other fuels is severe. The developments of mechanical loading in Arkansas may in time extend to these portions of Oklahoma.

In the fields of Oklahoma producing high-volatile coal there is considerable strip mining. Over 22 percent of the State's output was mined by stripping in 1936. The chief stripping counties are Wagoner, Haskell, and Rogers, located in the northeastern portion of the State adjacent to Kansas fields.

Texas

Stripping of lignite is the only form of mechanization in Texas. There are no records of mechanical loaders in use in underground mines.

COAL FIELDS OF THE ROCKY MOUNTAINS

This region, richly endowed with ores of the major metals, contains two-thirds of the Nation's coal reserve, much of it of low rank and located in areas of sparse population. Although the dip of the beds varies from moderate to steep, most of the mining is confined to thick seams which more than offset the handicaps imposed by dip. Coal is mined almost entirely by underground methods, except in Rosebud County in Montana, Campbell County in Wyoming, and in North Dakota in adjacent counties on the Great Plains, where resource conditions favor strip mining.

Two of the States in this region - Wyoming and Montana - have reached a high degree of mechanization, and Utah and Colorado are now making rapid strides. Washington, with nearly the most difficult physical conditions of any State mining bituminous coal, loaded 42 percent of its output by machine in 1937.

Mechanized loading in the far West has been fostered to a large extent by five important considerations: favorable resource factors, progressive management, captive mines with assured outlets for their coal, relatively high wage scales, and cooperation between capital and labor.

Wyoming

The coal fields of Wyoming contain the largest reserves of any State in the country. Ninety-five percent of these reserves consist of sub-bituminous coal, but production today comes largely from the Rock Springs, Kemmerer, and Hanna districts (bituminous areas) in the southern part of the State. In recent years the output from the southern section has been from three-fourths to four-fifths of the total for the State. The Sheridan and Gebo districts are the most important producing areas in northern Wyoming.

Coal in the Hanna field in Carbon County ranges from 30 to 34 feet - one of the thickest coal deposits in the country. Although the seam pitches heavily, other factors are favorable to mechanical loading, and management has been highly successful in adapting mechanization and mining methods to local conditions. This field was one of the first in the United States to experiment with mechanical loading. Thickness of the coal in the Rock Springs field in Sweetwater County ranges from 5 to 8 feet with floor and roof of shale or sandstone, advantages which are partly offset by pitching seams. The Sheridan field in the north has ideal conditions for mechanical loading (thick and level seams with good roof conditions), and mobile loaders were used here successfully as early as 1924.

Montana

Montana, like Wyoming, produces the major portion of its tonnage in captive mines. The commercial market for Montana coal is largely limited to the State since nearby areas have an abundance of coal within their borders or are served by other forms of energy. Much of the coal produced is sub-bituminous. Lignite fields in the eastern part of the State are not at present commercially important. Deep-mine output comes largely from thick seams in which resource factors are favorable to underground mechanization.

Utah

Mechanical loading has been increasing rapidly in Utah, rising from 21 percent in 1933 to about 50 percent in 1937. Mining is concentrated largely in Carbon County, which produced 86 percent of the output in 1936. Emery is the only other county having a significant output. Resource conditions and mining methods are suited to machine loading. Mobile loaders have predominated, conveyors have been used, and duckbills were being tried in 1937 and 1938.

Resource conditions in Utah may be indicated by quoting from two publications of the U. S. Bureau of Mines:

> Utah's principal producing coal mines . . . . have comparatively thick beds. Little coal under 5 feet thick is being worked and practically none under 4 feet; much, if not most, of the coal comes from beds in excess of 8 feet, some running as high as 30 feet. Some mines have a difficult . . . . problem in the mining of two or more beds with only a few feet of rock between them. . . . . Most of the mines are working under heavy cover, which approximates 3,000 feet in some instances.[9]
>
> The dip of the coal beds . . . . range from less than 1 degree to about 10 degrees. . . . . Mining . . . . thick seams presents unusual difficulties.

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[9] A. L. Murray and D. Harrington, *Accident Experience of the Coal Mines of Utah for the Period 1918 to 1929* (U. S. Dept. Com., Bur. Mines I. C. 6530, mimeo., Nov. 1931), pp. 1-2.

> . . . . The method pursued has been to drive the advance heading of the rooms about 7 feet high, then to take a second cut of about the same height, making the rooms when completed 12 to 14 feet high. The remainder of the coal in the roof is taken down as the pillars are pulled.[10]

In some of the mining operations in thick seams top and bottom coal is left in place.

Washington

Difficult resource conditions (steep pitches, bad roof, and other handicaps) until recently retarded all forms of mechanization in Washington. Even machine undercutting is a relatively recent development in this State. Washington experience is significant to the coal industry as a test of management's ability to overcome difficulties.

Colorado

Colorado is the most important coal-producing State west of the Mississippi River. Seasonal production in parts of the State, pitching seams, and low wage scales at some mines have until recently retarded mechanization, but a large amount of new equipment was installed in 1936 and 1937, and in the latter year a million tons of coal were mechanically loaded. This was more than five times the amount in 1935. Obstacles to mechanical loading are no greater than those that have been overcome in other Rocky Mountain States, and recent experience indicates an increase in mechanical loading in the years ahead. Until 1938 no particular type of equipment was used predominantly.

New Mexico

New Mexico produces between 1 and 2 million tons of coal annually. The State contains nearly all ranks of coal, but most of the output is bituminous or sub-bituminous. Like Colorado, New Mexico has until recently had a relatively low wage scale. The mines of the State present substantial handicaps to mechanization. Two companies in Colfax County, the largest center of production, have installed mobile loaders and scrapers.

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[10] C. A. Allen, *Analyses of Utah Coals* (U. S. Dept. Int., Bur. Mines Tech. Paper No. 345, 1925), pp. 3-4.

North Dakota[11]

North Dakota has a large stripping industry which has produced over a million tons annually since 1930. Between 1930 and 1934 the annual deep-mine production was about 700,000 tons; it increased to 844,000 tons in 1936. Coal resources are lignite which islargely used in the State as domestic fuel. Few of the underground mines have developed mechanical loading; however, two mines were using mobile loaders for more than two-thirds of their output in 1935.

COAL FIELDS OF THE APPALACHIANS

Coal is the great mineral resource of this area. Within its hills and mountains lie a little over one-sixth of the Nation's reserves of coal. The value of these coal deposits is greatly enhanced by their proximity to the important centers of consumption. In 1937 the Appalachian States produced three-quarters of the bituminous and anthracite output. The early experience of Illinois, Indiana, Wyoming, and Montana will be helpful to the mines in this area, but more significant will be the knowledge gained by early mechanization of the more difficult seams which are mined from Ohio and Pennsylvania south to Alabama.

More than 20 million tons of West Virginia coal were loaded mechanically in 1938. The significant factor today, however, is the prospect of still greater mechanization which current competitive conditions are stimulating. If the advances made since 1935 are continued in the years immediately ahead, West Virginia will have as important a place in mechanical production during the early forties as Illinois and Indiana had during the period which ended in 1935.

Although eastern Kentucky has shown comparatively little interest in mechanization, the importance of this area from the standpoint of production is such that when economic demands become effective this field will probably become an important mechanization center.

Pennsylvania has already progressed far enough to remove any serious doubt concerning the future of mechanization both in the western and in the central portions of the State.

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[11] The lignite fields of North Dakota are adjacent to the coal fields of Montana, and they are discussed here rather than in the section dealing with conditions in the Mississippi Valley.

A wide variety of physical conditions is found in this area. Thick, medium, and thin seams are worked; roof conditions run the whole range from bad to excellent; seams are generally flat although some are encountered that dip moderately. All types of loading equipment are in use under a greater variety of conditions than in any other section of the country. Except for a few areas in parts of Pennsylvania, Ohio, and Alabama, mechanization was relatively unimportant up to 1935. Increased wage scales were just becoming an important consideration at that time. Since then mechanization has forged ahead, particularly in West Virginia. In general, this mechanization has advanced under physical conditions much more adverse than those in the Mississippi Valley.

Mines are opened principally by drifts, although there are many shaft mines. Deep mining predominates; sites for profitable strip mining are not numerous.

The Appalachians may be divided into three areas - northern (Pennsylvania, Ohio, and Maryland), southern (West Virginia, Virginia, eastern Kentucky, and northern Tennessee), and Alabama (including Georgia and southern Tennessee). Within each division is to be found a diversity of physical conditions and past experience and differing immediate prospects for mechanization of loading.

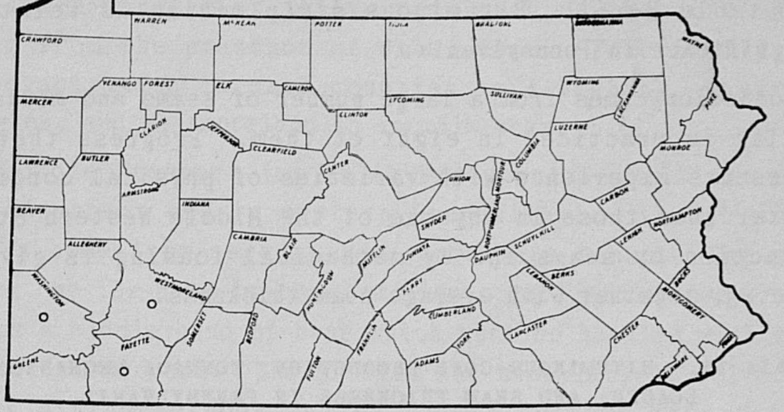
Pennsylvania

Counting both bituminous and anthracite tonnage, Pennsylvania heads the country in coal production. A significant market factor in connection with Pennsylvania coal deposits is the geographical location of abundant coal reserves of good quality in close proximity to major centers of consumption.

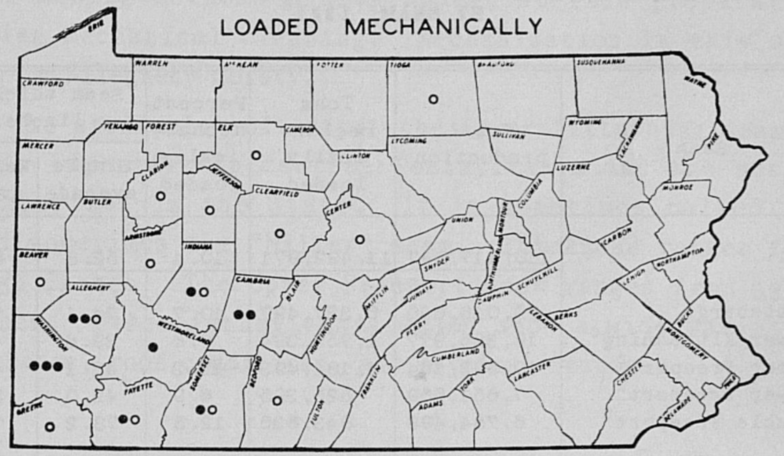
Pennsylvania is extensively underlain by coal-bearing formations but, as in many States, production centers in relatively few counties. The bituminous coal fields of the State are divided into two areas - western and central. Western Pennsylvania produces high-volatile coal, and the seams are relatively thick; central Pennsylvania produces low- and medium-volatile coal from relatively thin seams. Mechanical loading is concentrated most heavily in western Pennsylvania, principally in Washington, Allegheny, and Fayette Counties. In the central part of the State Cambria, Somerset, and Indiana Counties are the principal producers of mechanically loaded

Figure 34.- PENNSYLVANIA COUNTY DISTRIBUTION OF TONNAGE MINED BY STRIPPING AND UNDERGROUND TONNAGE LOADED MECHANICALLY AND BY HAND, 1937

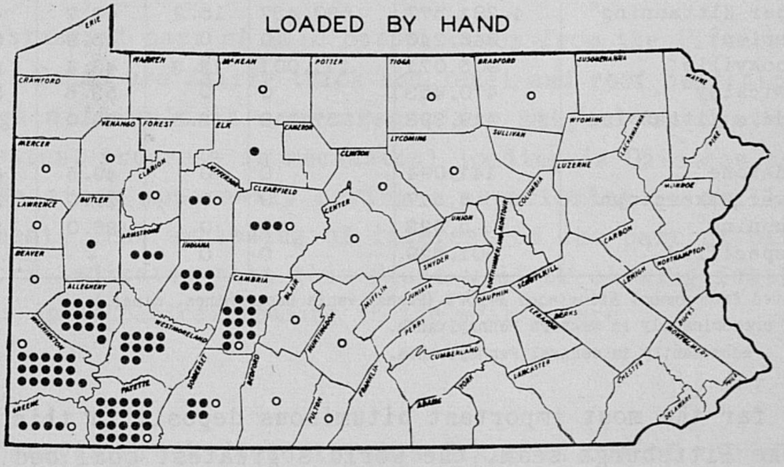
MINED BY STRIPPING



LOADED MECHANICALLY



LOADED BY HAND



LEGEND-

EACH SOLID CIRCLE (●) REPRESENTS 1,000,000 TONS OR MAJOR FRACTION THEREOF

EACH OPEN CIRCLE (○) REPRESENTS 500,000 TONS OR LESS

BASED ON DATA OF THE
PENNSYLVANIA DEPARTMENT OF MINES

MINERAL TECHNOLOGY AND OUTPUT PER MAN STUDIES
WPA - NATIONAL RESEARCH PROJECT E-160

coal. Figure 34 shows graphically the important producing counties and the amount mechanically loaded in each (see also table B-16). Bituminous strip mining is relatively insignificant in Pennsylvania.

Production comes from a large number of seams and mechanical loading is practiced in eight of them. Progress therefore represents experience with varieties of physical conditions greater than those in any one of the Middle Western States. Production by seams and by mechanical loading is given in table 15, together with average seam thickness.

Table 15.- BITUMINOUS-COAL PRODUCTION, TONNAGE MECHANICALLY LOADED, AND SEAM THICKNESS IN PENNSYLVANIA, BY SEAM, 1937[a]

Seam	Total production	Tons mechanically loaded	Percent mechanically loaded	Seam thickness (inches)	
				Simple average	Weighted average
Total	110,417,947	11,492,971	10.4	52.8	64.8
Pittsburgh[b]	59,016,636	6,337,497	10.7	74.1	77.4
Lower Kittanning[c]	18,325,977	1,753,394	9.6	39.6	41.5
Upper Freeport[c]	10,593,164	1,184,493	11.2	43.1	47.1
Lower Freeport[c]	7,651,669	525,395	6.9	42.0	50.9
Double Freeport[b]	6,754,498	843,636	12.5	78.2	79.1
Upper Kittanning[c]	4,281,577	680,437	15.9	43.7	47.1
Clarion[c]	946,246	0	0	45.9	57.9
Brookville[c]	905,071	111,001	12.3	43.4	40.0
Sewickley[b]	470,453	0	0	53.6	57.5
Middle Kittanning[c]	419,393	57,118	13.6	33.0	35.4
Redstone[b]	141,094	0	0	49.5	53.4
Lower Bakerstown[c]	5,517	0	0	32.0	32.0
Mahoning[c]	5,023	0	0	26.0	26.0
Unspecified	901,629	0	0	-	-

[a] Computed from *Annual Bituminous Report* (Pennsylvania Dept. Mines, mimeo.).
[b] Mined predominantly in western Pennsylvania.
[c] Mined predominantly in central Pennsylvania.

By far the most important bituminous deposit in this State is the Pittsburgh seam, the world's greatest coal bed. Its physical characteristics have received wide attention in technical discussions. It not only furnishes a large part of the output in western Pennsylvania but likewise in the adjoining States of Ohio and West Virginia. The Pittsburgh seam is consistently thick enough to permit the use of any type of loading device, but the limiting factor is the draw slate which characterizes the roof. Persistent effort, however, has enabled management to overcome much of the difficulty arising from the presence of draw slate. Practically all the mechanization in such counties as Allegheny, Fayette, Washington, and Westmoreland is in this seam.

The Double Freeport (or Thick Freeport) seam is the only other important one in western Pennsylvania, though minor tonnages come from several less important seams. The seam is thick, as the name implies, and has a good roof; however, it contains a middle band of bone which must be handled with care to insure clean coal. The problem has been largely solved by careful mining methods and by modern surface preparation including mechanical cleaning. Mechanization in this seam centers in Allegheny County.

From the standpoint of output the Lower Kittanning seam is the most important in central Pennsylvania and the second most important in the State. It is sometimes called the "B" and sometimes the "Miller" seam. Thickness ranges from 30 to 56 inches. The Upper Freeport seam ranges from 33 to 66 inches. Other Pennsylvania seams show a wide variation in thickness, roof conditions, and physical factors.

Ohio

A substantial part of Ohio output comes from the Pittsburgh seam.[12] Seams are fairly thick and level and roof conditions, although difficult in some areas, are subject to control. The greatest progress in mechanical loading in Ohio has been at those mines apparently having a superiority in skillful management. The awakening of interest on the part of other operators indicates that this State will be showing further progress in mechanical loading in the near future.

Maryland

The Georges Creek field in this State is one of the oldest mining districts in the country. The Big Vein, as the Pittsburgh seam is called in Maryland, has been reworked a second and even a third time by removing top coal, bottom coal,

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[12] In Ohio the Pittsburgh seam is variously referred to as the No. 8 and the Pittsburgh No. 8.

and pillars left from the original mining. Other Maryland seams are medium or thin. Mechanical loading has been confined to the use of conveyors in mines of two of the larger companies operating in the thinner seams. Depletion of the Big Vein is an important factor in the State's position and will probably preclude any great extension of mechanical loading until such time as the thinner Maryland seams are more intensively developed.

West Virginia

The coal fields of West Virginia fall into three natural divisions - northern, southern high-volatile, and southern low-volatile. The production of any one of these three divisions exceeds, with few exceptions, the output of nearly every one of the other coal States.

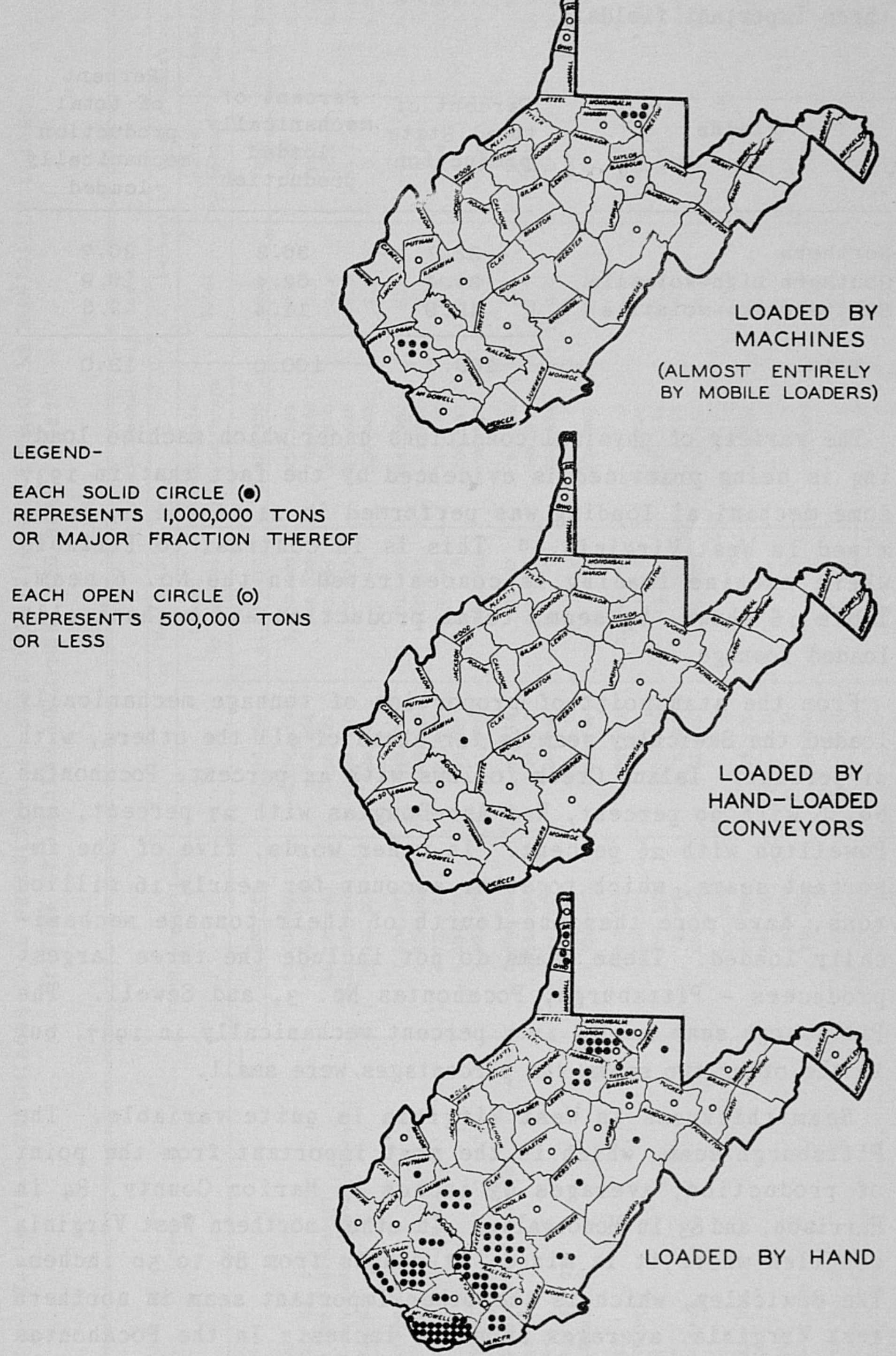
The same advantage of proximity to consuming markets which was noted for Pennsylvania applies to West Virginia, though in lesser degree, and this advantage is supported by the exceptionally high quality of West Virginia coal. In addition to the outlets in many markets, skillfully developed by selling agents and based upon the high reputation of West Virginia steam, gas, and coking coals, many of the operating companies enjoy trade outlets favored by intercorporate relations.

During the late twenties and early thirties wage scales in West Virginia were relatively low and offered little incentive to mechanize; hence the State's experience through 1935 throws little light upon probable future trends. Higher wage rates have placed upon management the burden of holding costs at a competitive level. The result is that physical conditions formerly considered not amenable to loading machinery are now being successfully mechanized.

West Virginia has an advantage in that it installed mechanization at a time when the design of loading equipment was in a fairly advanced stage. This and the accumulated experience of other areas have made it possible for West Virginia operators who have recently taken up mechanical loading to avoid some of the costly experiences which burdened earlier efforts.

Figure 35 shows graphically, by county, production and centers of mechanical loading (see also table B-17).

Figure 35.- WEST VIRGINIA COUNTY DISTRIBUTION OF UNDERGROUND TONNAGE LOADED BY MACHINES, BY HAND-LOADED CONVEYORS, AND BY HAND, 1937



BASED ON DATA OF THE WEST VIRGINIA DEPARTMENT OF MINES

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The following tabulation shows the 1937 percentage distribution of total tonnage and tonnage mechanically loaded in the three important fields:

Fields	Percent of total State production	Percent of mechanically loaded production	Percent of total production mechanically loaded
Northern	22.7	36.2	20.7
Southern high-volatile	34.4	52.4	19.9
Southern low-volatile	42.9	11.4	3.5
Total	100.0	100.0	13.0

The variety of physical conditions under which machine loading is being practiced is evidenced by the fact that in 1937 some mechanical loading was performed in 21 of the 29 seams mined in West Virginia.[13] This is in contrast to Illinois where machine loading is concentrated in the No. 6 seam. Table 16 shows, by seam, total production and mechanically loaded tonnage.

From the standpoint of proportion of tonnage mechanically loaded the Sewickley seam is far ahead of all the others, with 91 percent. Island Creek follows with 44 percent, Pocahontas No. 6 with 29 percent, Red Ash-Douglas with 27 percent, and Powellton with 26 percent. In other words, five of the important seams, which together account for nearly 16 million tons, have more than one-fourth of their tonnage mechanically loaded. These seams do not include the three largest producers - Pittsburgh, Pocahontas No. 3, and Sewell. The Pittsburgh seam loaded 17.5 percent mechanically in 1937, but in the other two seams the percentages were small.

Seam thickness in West Virginia is quite variable. The Pittsburgh seam, which is the most important from the point of production, averages 93 inches in Marion County, 84 in Harrison, and 83 in Monongalia. In other northern West Virginia counties where it is mined, it ranges from 86 to 50 inches. The Sewickley, which is the other important seam in northern West Virginia, averages about 70 inches. In the Pocahontas

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[13] The distinctions between coal seams in various parts of West Virginia present an intricate problem. The same seam is frequently designated by different names where it appears in different areas. For simplicity the groupings used in the West Virginia Department of Mines reports are followed.

Table 16.- BITUMINOUS-COAL PRODUCTION IN WEST VIRGINIA AND TONNAGE MECHANICALLY LOADED, BY TYPE OF LOADING EQUIPMENT AND SEAM. 1937[a]

Seam	Total production	Tonnage mechanically loaded					
		Net tons			Percent of total production		
		Total	Loaded by machine[b]	Hand-loaded into conveyors	Total	Loaded by machine[b]	Hand-loaded into conveyors
Total	118,965,066	15,490,863	11,497,410	3,993,453	13.0	9.6	3.4
Pittsburgh	24,004,562	4,212,359	3,953,468	258,891	17.5	16.4	1.1
Pocahontas No. 3	17,506,892	72,304	34,036	38,268	0.4	0.2	0.2
Sewell (Davy) (Bradshaw)	12,136,483	515,632	261,954	253,678	4.3	2.2	2.1
Island Creek-Cedar Grove (Thacker)	10,965,926	4,821,416	4,280,871	540,545	44.0	39.1	4.9
Pocahontas No. 4	8,195,204	129,661	0	129,661	1.6	0	1.6
Beckley (War Creek)	7,804,872	643,185	101,705	541,480	8.2	1.3	6.9
Eagle	6,474,999	290,413	226,006	64,407	4.5	3.5	1.0
Dorothy-Winifrede (Black Band)	4,730,159	421,873	302,136	119,737	8.9	6.4	2.5
Chilton	4,183,106	793,937	0	793,937	19.0	0	19.0
No. 2 Gas	3,920,978	441,547	363,050	78,497	11.3	9.3	2.0
No. 5 Block-Lower Kittanning	3,676,488	39,119	17,839	21,280	1.1	0.5	0.6
Powellton	2,831,358	726,615	477,242	249,373	25.7	16.9	8.8
Fire Creek	2,446,850	220,484	0	220,484	9.0	0	9.0
Pocahontas No. 5	1,753,243	0	0	0	0	0	0
Belmont-Lewiston	1,718,025	292,899	0	292,899	17.0	0	17.0
Sewickley	1,519,576	1,386,276	1,386,276	0	91.2	91.2	0
Upper Freeport	1,036,251	8,838	0	8,838	0.9	0	0.9
Coalburg	989,232	193,073	14,010	179,063	19.5	1.4	18.1
Hernshaw	720,934	2,625	0	2,625	0.4	0	0.4
Alma-Peerless	652,095	92,652	78,817	13,835	14.2	12.1	2.1
Welch	508,668	0	0	0	0	0	0
Pocahontas No. 6	503,597	147,928	0	147,928	29.4	0	29.4
Redstone	245,162	0	0	0	0	0	0
Bakerstown	191,239	0	0	0	0	0	0
Red Ash-Douglas	138,938	38,027	0	38,027	27.4	0	27.4
Pocahontas No. 9	55,019	0	0	0	0	0	0
Upper Kittanning	35,611	0	0	0	0	0	0
Middle Kittanning	19,199	0	0	0	0	0	0
Waynesburg	400	0	0	0	0	0	0

[a] Computed from *Annual Report of the Department of Mines, 1937* (West Virginia Dept. Mines).

[b] Almost entirely by mobile loaders.

and New River districts of the southern low-volatile field the thickness of important seams ranges as follows: Pocahontas No. 3, 39 to 69 inches; Sewell, 36 to 52; Pocahontas No. 4, 41 to 72; Beckley, 47 to 69; Fire Creek, 36 to 40; and Pocahontas No. 5, 63. In the southern high-volatile field the range of thickness for the important seams is as follows: Island Creek, 68 inches; Eagle, 37 to 66; Dorothy, 56 to 63; Winifrede, 35 to 48; Chilton, 52; No. 2 Gas, 44 to 48; No. 5 Block, 55 to 107; Powellton, 28 to 86; and Cedar Grove, 34 to 72.[14]

The major portion of the output of the northern field comes from the Pittsburgh seam, which produced 24 million tons in 1937, followed by the Sewickley seam with only 1½ million tons. Mechanical loading has been successful under a variety of physical conditions in this field and there are no technical reasons why it should not expand. However, skillful management in some of the large mines of the area has attained especially high man-hour output with hand loading, and even with the higher wage scales this may temper enthusiasm for mechanization.

In the southern high-volatile field the Island Creek seam is the most important, but it does not overshadow the others as does the Pittsburgh seam in the northern field. Mechanical loading has occurred under an even greater variety of physical conditions than it has in the northern part of the State. Considering the joint influence of physical and economic conditions, it is highly probable that mechanization in this area will continue to expand.

In the southern low-volatile field the famous Pocahontas No. 3 is the most important coal seam, followed by Sewell, Pocahontas No. 4, and Beckley, in the last of which most of the mechanization hitherto has occurred. Coals from this field are soft and friable. The area is well supplied with cleaning plants, but under present marketing conditions the larger sizes sell at a premium, and this fact tends to retard any type of mechanization which increases degradation.

Virginia

The Virginia coal fields are located in the southwestern part of the State, adjacent to the coal fields of West Virginia and

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[14] For a more detailed correlation between counties, seams, thickness, and mechanical loading see the *Annual Reports of the Department of Mines* of West Virginia.

Kentucky. Although the Pocahontas district in Tazewell County pioneered in the early stages of mechanization, nearly all the present mechanical loading centers in the harder structure, high-volatile coals, particularly in the Grundy field of Buchanan County. Marketing and corporate factors in Virginia are similar to those in West Virginia.

The Pocahontas seams, like those in West Virginia, are friable and suffer degradation unless handled with care. The Pocahontas Fuel Company, however, was a pioneer in mechanical loading, having installed machines in Virginia as early as 1918. It was also the first company to approach an annual mechanically loaded output of a million tons. This early interest in the movement was no doubt encouraged by the thickness of seams and other favorable physical conditions. The small net differential between hand-loading and machine-loading costs, however, naturally retarded the movement, and it was practically abandoned during the depression. As long as the larger sizes of low-volatile coal sell at a premium and wage rates remain stationary, great advances in mechanization in the fields which produce these coals are unlikely.

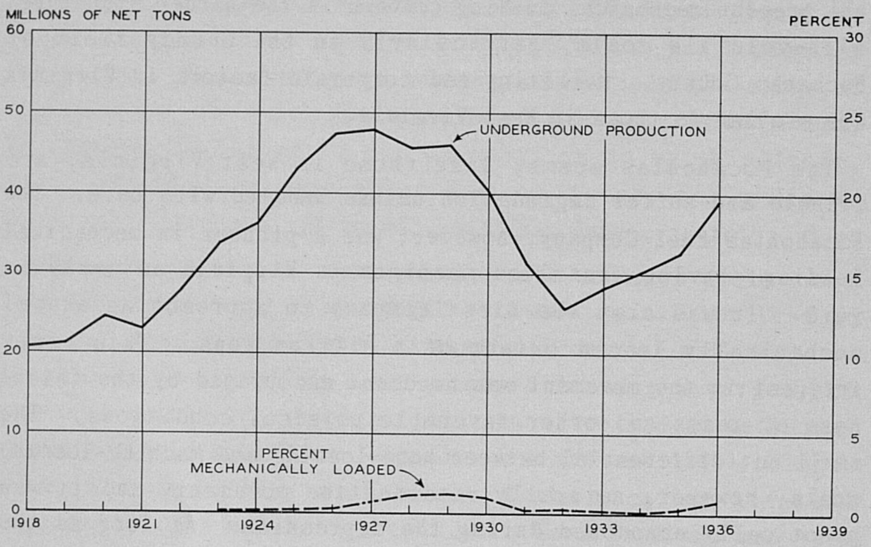
Eastern Kentucky

Eastern Kentucky is one of the great coal-producing areas of the country. As in southern West Virginia, coal is mined from many seams, the most important of which are referred to as the Elkhorn and the Harlan groups. Physical conditions do not present handicaps that make mechanical loading impossible. The coal seams average about 51 inches in thickness and range from 32 to 60 inches.

Low wage rates in this area prior to NRA offered little incentive for installing mechanical loading, and the movement is still slow in getting under way. In 1935 and 1936 less than 1 percent of the deep-mined output was loaded mechanically.

Figure 36 shows the course of production in underground mines for the period of this study; as strip tonnage has always been negligible, underground output is practically the record of total output. The upward course of production from 1921 to 1927 reflects largely the ability of an area paying relatively low wages at that time to increase its markets in competition with its northern neighbors with their higher labor costs.

Figure 36.- TOTAL UNDERGROUND PRODUCTION IN EASTERN KENTUCKY AND PERCENTAGE MECHANICALLY LOADED, 1918-36



BASED ON DATA OF THE U.S. BUREAU OF MINES

MINERAL TECHNOLOGY AND OUTPUT PER MAN STUDIES
WPA–NATIONAL RESEARCH PROJECT E-162

Three mines in eastern Kentucky did a substantial amount of mechanical loading in 1935, and over the whole period of the study 48 mines experimented with it. For the most part the experimenting was done in the years 1927-30.

Tennessee

Tennessee coal seams are generally thin and overlain by strata which are unfavorable to mechanical loading. Moreover, they are surrounded by fields in other States which are closer to important markets.

Of somewhat more than 5 million tons produced in 1936, only 290,000, or 5.7 percent of the total, were loaded mechanically. No stripping occurred.

Alabama

Alabama has been and still is a melting pot of experimentation in mechanical loading. Despite difficult physical conditions, such as pitching beds, impurities, and varying seam thickness, the State loaded about one-sixth of its output by machines in 1937. Mechanization made considerable progress even under low wage scales. A large proportion of the output is from captive mines and others with good marketing outlets.

Alabama coal fields form the southern end of the great Appalachian coal region. The three important districts are the Coosa Basin, Cahaba Basin, and the Warrior Basin. More than 40 coal seams have been identified in the State but none has been correlated or traced throughout the various basins. In general, seams vary in thickness from place to place and in many cases partings will appear and disappear within short distances. Warrior Basin coals are more regular and less disturbed by faults than those in the other districts.

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AUTHOR
Mineral technology and output
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per man studies

DATE DUE	BORROWER'S NAME
Apr 15'48	Joe F Rice
NOV 14 '50	Freeland Harris
NOV 1 '51	Willis Gray