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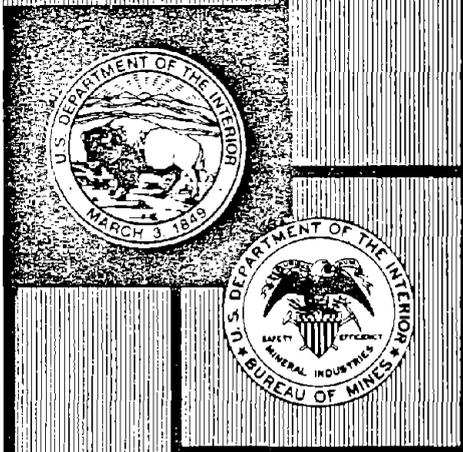


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Longwall and Room-and-Pillar Productivity: A Review of U.S. Coal Mines

By Suresh K. Bhatt



UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

Gt billion metric tons

t metric ton

m meter

t/w-h metric ton per worker-hour

Mt million metric tons

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LONGWALL AND ROOM-AND-PILLAR PRODUCTIVITY: A REVIEW OF U.S. COAL MINES

By Suresh K. Bhatt¹

ABSTRACT

Although overall worker productivity for U.S. underground coal mines is available, productivity by mining method and seam thickness is not. Mining technology has gone through dramatic changes in the past decade, and the industry has experienced a lack of accurate productivity figures addressing these changes. This information is of great interest in planning for future mining systems as thick and shallow coal seams currently being mined are depleted and exploitation of thinner, deeper, and better quality seams is considered to partially meet the requirements of the 1990 Clean Air Act Amendments. In a cooperative program, the U.S. Bureau of Mines obtained raw mine level production and related data from the U.S. Energy Information Administration for 1989 and 1990 and performed the needed statistical analysis. Base criteria, parameters, and salient results of the mine productivity analysis are presented in this report.

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INTRODUCTION

Coal mining technology has gone through dramatic changes during recent years. Longwall mining has provided significant increases in U.S. underground coal productivity since the late 1970's, with an increasing degree of automation and the utilization of larger panels. Continuous mining machines in room-and-pillar mining have also performed extremely well, where supersections and deep cuts (12.2-m typical cut depth) are being utilized.

Changes are expected in the coal mining industry in the future. In 5 to 10 years, the U.S. coal mine operators will be forced to mine difficult reserves—deep, steeply pitched, and thick seams—for two main reasons. First, good quality reserves with good physical conditions at shallow depths are being depleted. Second, the 1990 Clean Air Act Amendments, with the Phase II compliance deadline in the year 2000, have put further emphasis on mining these difficult reserves, most of which are not economically minable with existing mining and environmental technology. For the purpose of discussion, seams at greater depth than 457 m, seams with dip greater than 15°, and thickness greater than 6.1 m are considered difficult coal reserves. The Appalachian coalfields contain about 8 Gt of low-sulfur, good-quality coal recoverable by underground mining methods.

Extensive mining in the low-sulfur areas will be seen in the future. Blending high-quality, high-sulfur coals with low-quality, low-heating value, low-sulfur coals in various combinations will be necessary to meet the demands of electric utilities that consume about 80% of the total U.S. coal demand.

According to Industrial Information Services,² switching to low-sulfur coal is proving to be, by far, the most popular option for utilities meeting clean air compliances

(91 Mt higher in the year 2000 than in 1992). Switching fuel (from coal to gas or oil) is the second option, followed by scrubbing. To meet future demands, vast low-sulfur reserves in Appalachia have already been bought.

To plan for future mining needs, a thorough examination of various mining techniques is needed for specific reserve conditions, keeping in view health, safety, and productivity requirements of the future. In addition, a comprehensive productivity analysis is needed to establish a realistic and current data base that can be used to conduct routine technoeconomic feasibilities for decisionmaking by all involved in coal mining.

Knowledge of current worker productivity by seam thickness and mining method will allow engineers and others within and outside the U.S. Bureau of Mines (USBM) to define the parameters needed for mine and equipment design and assist in prioritizing areas for future research. This knowledge will further enable better planning so that the health, safety, and productivity of the mine worker can be improved now and in the future.

The Energy Information Administration (EIA), U.S. Department of Energy, and other agencies publish coal mine productivity and related data annually. The data list overall worker productivity for underground coal mines in the United States, but not by mining method and seam thickness. To provide these data, USBM and EIA entered into a cooperative program so that worker productivity by mining method and seam thickness could be determined. This report presents results of statistical analyses performed on mine production and related data provided by EIA for 1989 and 1990. This research was conducted under the USBM Advanced Mining Systems program.

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The author thanks Noel C. Balthasar, chief, Coal and Uranium Data Systems, EIA, for assistance in providing raw mine-level productivity and related data, and

Patricia J. Lenart and Edward F. Fries, computer specialists at the USBM's Pittsburgh Research Center, for their help in the data analysis.

BASE CRITERIA, PARAMETERS, AND METHODOLOGY FOR PRODUCTIVITY ANALYSIS

In performing the productivity analysis, U.S. underground mines with annual coal production of 9,070 t or more were evaluated for 1989 and 1990. Mine worker productivity (metric tons per worker-hour) was estimated

by mining method and seam thickness for all such mining operations with or without coal preparation plants or tipples. For each mine, the productivity was obtained by dividing its annual production by the total annual direct labor hours.

²COAL. Coal in the News. Aug. 1992, pp. 7-9.

The direct labor data include hours worked by all employees engaged in production, preparation, development, maintenance, management, engineering, repair, and yard work; it excludes office workers. It also excludes vacation and leave hours.

These productivity figures are grouped in the categories continuous, conventional, longwall, and shortwall, and an average calculated for each category. For example, all mines with the continuous-mining method, when grouped and averaged, provided the representative productivity for that method. Similarly, mines with the conventional method provided the figure for only conventional-type mining. Both the continuous- and conventional-mining methods are used in the most common type of mine—room-and-pillar. A longwall mine, however, is developed employing room-and-pillar mining and has varying proportions of longwall-mined coal to room-and-pillar-mined coal, depending on the mine's development stage. There is generally a mix of coal by type of mining, and it is not

possible to have all longwall-mined coal. For purposes of the analysis, mines listed in the raw data as having more than 80% longwall-mined coal were considered as employing purely the longwall-mining method. The productivity average, therefore, represents longwall-method productivity since it is hard to find mines with 100% longwall mining. Also, in addition to development sections, some areas of a so-called longwall mine can only be mined employing continuous or conventional methods.

The mines employing shortwall mining, although insignificant in this study, were kept separate for productivity analysis.

To estimate the productivity by seam thickness, mines were grouped in different seam thickness categories—less than 0.91 m, between 0.91 and 1.22 m, between 1.22 and 1.52 m, between 1.52 and 1.83 m, between 1.83 and 2.29 m, and more than 2.29 m—and an average taken for each group.

PRODUCTIVITY ANALYSIS

MINE PRODUCTION

1990

In 1990, underground coal mines in the United States produced about 385 Mt coal, representing 1,422 underground coal mines. Table 1 gives the percentage production breakdown by mining method. Of the 1,422 mines producing coal in 1990, 1,021 mines, producing 357 Mt of coal, provided a breakdown by mining method to EIA. These mine data were thoroughly analyzed resulting in the following: Longwall mines, including room-and-pillar-mined coal, accounted for 143 Mt or 40% of annual underground production. Room-and-pillar-mined coal, including development coal, in these longwall mines is approximately 27% or 39 Mt. Coal produced by longwall mining in a longwall mine is estimated as 73%. The majority (92%) of longwall mines were developed by continuous mining machines; conventional mining developed about 8%.

1989

In 1989, underground coal mines in the United States produced about 357 Mt coal, representing 1,423 underground coal mines. Table 2 gives the percentage production breakdown by mining method. Of the 1,423 mines

producing coal in 1989, 852 mines, producing 308 Mt of coal, provided a breakdown by mining method to EIA. These mine data were analyzed, resulting in the following: Longwall mines, including room-and-pillar-mined coal, accounted for 129 Mt or 42% of annual underground production. Room-and-pillar-mined coal, including development coal, in these longwall mines is approximately 26% or 34 Mt. Coal produced by longwall mining in a longwall mine is estimated as 74%. Coincidentally, 92% of the longwall mines were developed by continuous mining machines and 8% by conventional mining in 1989.

Table 1.—Underground coal production for 1990, by decreasing order of production

Mining method	Production, %
Continuous	59.0
Longwall	27.1
Conventional	5.9
Shortwall	.7
Other ¹	7.3
Total	100.0

¹Includes scoop loading, hand loading, and any other method not listed above, and mines that did not provide production breakdown.

Table 2.—Underground coal production for 1989, by decreasing order of production

<i>Mining method</i>	<i>Production, %</i>
Continuous	52.2
Longwall	26.8
Conventional	6.8
Shortwall5
Other ¹	13.7
Total	100.0

¹Includes scoop loading, hand loading, and any other method not listed above, and mines that did not provide production breakdown.

MINING METHOD VERSUS PRODUCTIVITY

1990

For 1990, the U.S. underground coal production of 357 Mt was analyzed for productivity. Table 3 presents the productivity in metric tons per worker-hour for various mining methods. Table 3 shows that productivity of mines employing the continuous-mining method was the same as the longwall-mining method, or 2.7 t/w-h. The conventional mining productivity was about 11% less than that for continuous and longwall mining. Figure 1 shows the relationship of productivity and method of mining for 1990.

Table 3.—Underground coal mine productivity for 1990, by decreasing order of productivity

<i>Mining method</i>	<i>Productivity, t/w-h</i>
Continuous	2.7
Longwall	2.7
Conventional	2.4
Shortwall	1.5

1989

For 1989, the U.S. underground coal production of 308 Mt was analyzed for productivity. Table 4 presents the productivity in metric tons per worker-hour for various mining methods. Table 4 shows that productivity of mines employing the continuous-mining method was somewhat lower than the mines using the longwall-mining method. The conventional mining productivity was about 11% less than continuous mining productivity. Figure 2 shows the relationship of productivity and method of mining for 1989.

Table 4.—Underground coal mine productivity for 1989¹

<i>Mining method¹</i>	<i>Productivity, t/w-h</i>
Continuous	2.7
Longwall	3.0
Conventional	2.4
Shortwall	2.3

¹For comparison, arranged same as table 3.

SEAM THICKNESS VERSUS PRODUCTIVITY

1990

The U.S. productivity analysis of 357 Mt of coal by seam thickness is given in table 5. Mine productivity consistently increased as the coal seam thickness increased, indicating that thick seams are more productive than thin seams. Figure 3 shows the relationship of productivity and coal seam thickness for 1990.

Table 5.—Underground coal mine productivity by seam thickness for 1990

<i>Seam thickness range, m</i>	<i>Productivity, t/w-h</i>
Less than 0.91	2.5
0.91 to 1.22	2.6
1.22 to 1.52	2.9
1.52 to 1.83	3.0
1.83 to 2.29	3.1
More than 2.29	3.8

1989

The U.S. productivity analysis of 308 Mt of coal by seam thickness is given in table 6. Mine productivity generally increased as the coal seam thickness increased, again indicating thick seams are more productive than thin seams. Figure 4 shows the relationship of productivity and coal seam thickness for 1989.

Table 6.—Underground coal mine productivity by seam thickness for 1989

<i>Seam thickness range, m</i>	<i>Productivity, t/w-h</i>
Less than 0.91	2.3
0.91 to 1.22	2.5
1.22 to 1.52	2.7
1.52 to 1.83	2.9
1.83 to 2.29	2.9
More than 2.29	3.4

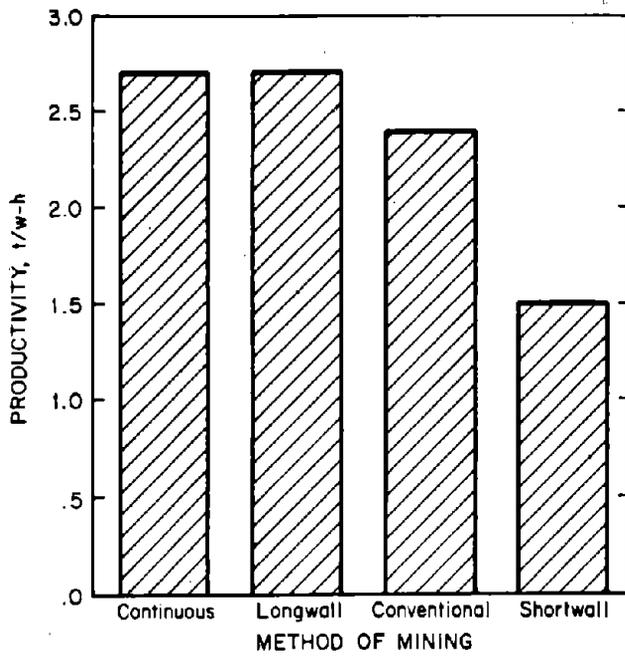


Figure 1.—Relationship of productivity and method of mining for 1990.

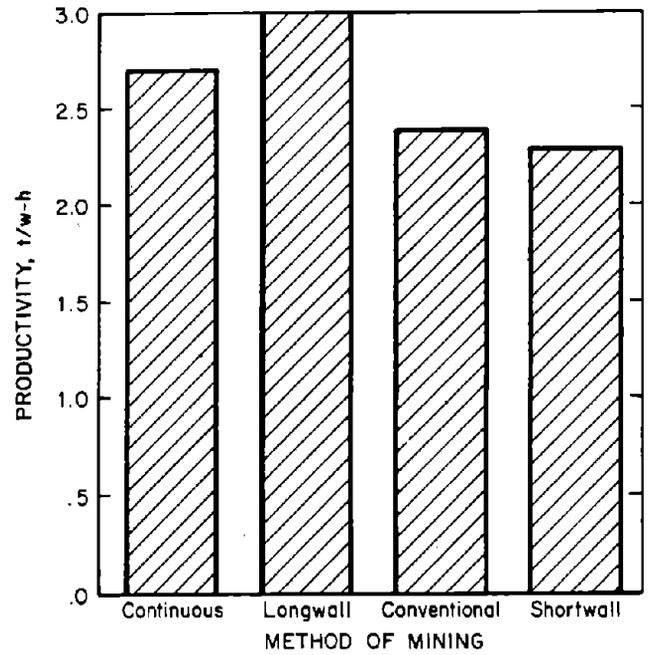


Figure 2.—Relationship of productivity and method of mining for 1989.

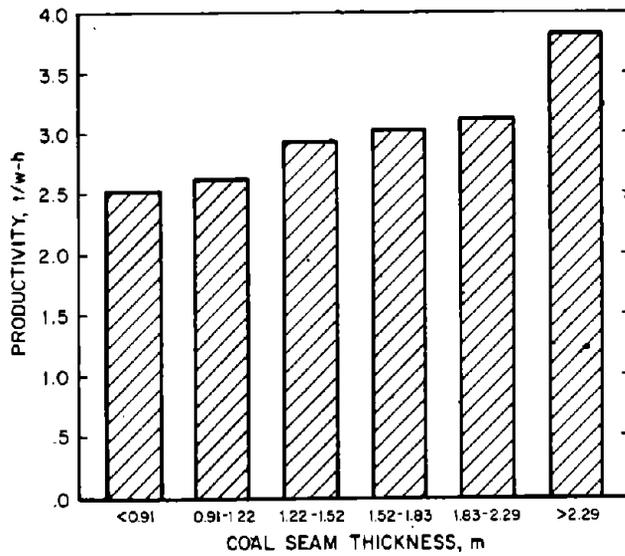


Figure 3.—Relationship of productivity and coal seam thickness for 1990.

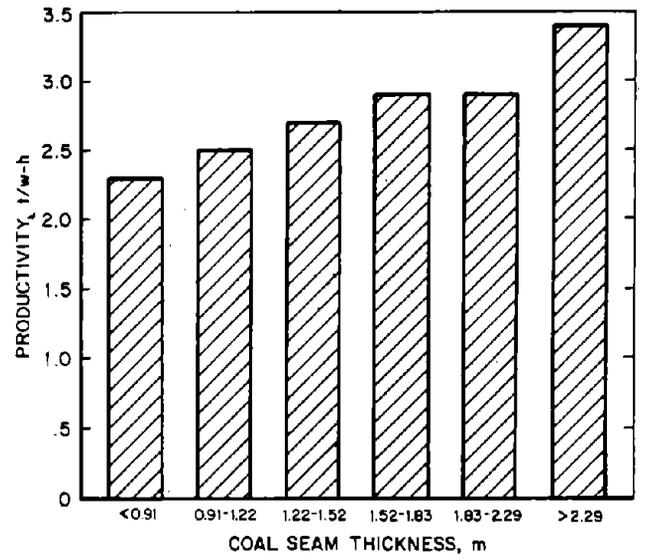


Figure 4.—Relationship of productivity and coal seam thickness for 1989.

SALIENT RESULTS

In both 1989 and 1990, continuous mining was the most dominant method of underground mining in the U.S. coal industry. Continuous mining methods produced about twice the coal produced by longwall mining, with conventional mining a distant third, approximately 6% of the total underground coal; shortwall mining produced less than 1%, the least employed mining method.

Longwall mines, including room-and-pillar-mined coal, accounted for 40% of annual production. Room-and-pillar-mined coal, including development coal, varied between 26% and 27% in the longwall mines; the remainder was longwall coal.

In 1989, 10 mines employed purely longwall-mining method (mines having 100% longwall-mined coal). The

productivity of these 10 mines averaged 2.8 t/w-h, which is also the average productivity of 10 mines that utilized only continuous-mining method. This comparison could not be made for 1990 since there were no mines that employed purely longwall-mining method.

The majority (92%) of longwall mines were developed by the continuous-mining method; conventional mining developed approximately 8%. The productivity of longwall- and continuous-mining methods remained about the same or 2.7 t/w-h during 1989 and 1990. Also, during the 2 years, mine productivity increased as the coal seam thickness increased. It appears that longwall mining has potential; however, it is not shown by the data analyzed.

CONCLUSIONS

- Continuous mining remains the most dominant method in the underground coal mining industry of the United States.

- Productivity of longwall- and continuous-mining methods is estimated to be equal or approximately 2.7 t/w-h.

- Longwall mining has not yet reached its full potential.

- Mine productivity increases as coal seam thickness increases.