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# Respirator Usage and Effectiveness in Bituminous Coal Mining Operations

H. E. HARRIS, W. C. DeSIEGHARDT, W. A. BURGESS\* and P. C. REIST\*†

*Eastern Associated Coal Corp., Everett, Massachusetts, and the Department of Environmental Health Sciences, Harvard School of Public Health, Boston, Massachusetts*

**The results of an in-the-field survey on the use of respirators in coal mines are presented and discussed. An effective protection factor (EPF) for respirators was determined under use conditions by relating dust concentrations in the ambient air and in the filtered air inside the facepiece of the respirator. Data are given for the EPF distributions in the four mines studied.**

## Introduction

IN THE AMERICAN COAL MINING INDUSTRY, there has been a long history of using protective devices, including that of dust respirators. Clearly, respirators were employed before 1934, when the Bureau of Mines first established performance requirements for dust respirators under Schedule 21.<sup>1</sup> However, it is fair to say that the use of respirators was limited and, although better respirators have been developed by manufacturers, it is questionable whether their usage has increased.

Understandably, the employment of respirators has been limited in coal mines in the past. It was believed coal dust *per se* did not cause pneumoconiosis; rather, silicosis was caused by a high silica content in coal dust and few bituminous coal dusts exhibited high silica dust contents. Although Gough<sup>2</sup> showed that British coal trimmers working with coal containing a minimal silica content had lungs laden with coal dust and had developed radiological abnormalities resembling silicosis, it was not immediately recognized that silicosis and coal workers' pneumoconiosis are distinct entities.<sup>3</sup> Further, probably most miners

found respirators to be uncomfortable as well as a hindrance when working, and consequently, their use was avoided except when the discomfort from dust exceeded that from the respirator.

With the publicity in recent times about the relationship between respirable coal dust and coal workers' pneumoconiosis, there has been an increased awareness of the value of using respirators. Moreover, respirator wearing has been actively encouraged by the mining companies. Undoubtedly, all this has resulted in miners making greater use of respirators than in the past.

Moreover, the Federal Coal Mine Health and Safety Act of 1969, requires that approved respirators "be made available to all persons whenever exposed to concentrations of respirable dust in excess of levels required to be maintained under this act".<sup>4</sup> So much for yesterday, and today, but what about the future with respect to respirators?

It is, of course, not within the scope of intent of this paper to make a detailed forecast, but in general it is very likely that there will be an increased need for respirators, and, perhaps, new respiratory protective devices. While much work is being done, the technology is still being developed to meet dust standards by environmental control means. Consequently, it may be some time before we are able to achieve consistent-

\*Harvard School of Public Health.

†Present address: Department of Environmental Science and Engineering, University of North Carolina, Chapel Hill, North Carolina.

ly the 2.0 mg/m<sup>3</sup> level for respirable dust that is now required, under provisions of the present law. Non-compliance permits can be obtained which will extend this deadline, on a year-to-year basis, to December 31, 1975. Even then, there is a possibility that in certain operations the 2.0 mg/m<sup>3</sup> will not be met, and, consequently, other means of protection will have to be employed.

With all this in mind, the National Institute for Occupational Safety and Health, Public Health Service, funded a research contract with Eastern Associated Coal Corp., with the Harvard University School of Public Health assisting as a sub contractor. The major objectives of this sponsored research project were as follows:

- (a) to determine the current status of respirator usage with respect to duration and frequency, types and maintenance;
- (b) to determine acceptability of currently used units;
- (c) to determine protection factors provided by respirators worn by working miners;
- (d) to make recommendations on ways to improve existing units, or on research needed to develop new types of respiratory protective devices for coal miners; and
- (e) to provide recommendations to mine management on more effective use of respiratory protective devices.

This project is divided into two major parts, namely, an in-the-field survey on respirator usage, acceptability, etc., and an in-mine testing program. The in-the-field survey has been completed, and the results of this survey published.<sup>5</sup>

A considerable amount of in-mine testing to determine the effectiveness of the presently available approved respirators has now been completed and as a result, the balance of this paper will be mainly concerned with this phase of the project. However, two points should be emphasized. First, although much in-mine testing has already been done,

undoubtedly more such work will be done. Secondly, not only has the in-mine testing phase of this survey been completed, but this work has resulted in the generation of a rather considerable quantity of data; hence, it will be some time before all the analyses and evaluations of these data have been completed. Therefore, this paper will present a discussion of the analyses done thus far and consequently, should be considered as a progress report.

### **In-Mine Testing Program**

As mentioned, one of the major tasks in the study was the determination of respirator effectiveness under field conditions, that is, protection provided by respirators worn by working miners. This necessitated the development and execution of an in-mine testing program.

#### *Experimental Equipment and Procedures*

To determine the protection provided in the field by presently available respirators, of respirable dust that a working miner would inhale with and without a respirator, it was necessary to measure the concentration. The best means to do so was sampling separately, but concurrently, the ambient mine air and the air inside the respirator facepiece. The concentration of respirable dust was measured for both samples. The ambient air was sampled for respirable dust using the standard mass sampling equipment in general use throughout the coal mining industry. This equipment consists of a sampling pump calibrated to sample at a rate of 2 liters/min, a 10-mm cyclone that separates the dust sampled into a respirable and non-respirable fraction, and a cassette containing a membrane filter on which the respirable fraction of dust is collected. Inside the respirator facepiece the air was sampled using comparable equipment. However, in this case the cyclone is mounted directly on the respirator facepiece, Figure 1, and the sampling part on the inside of the respirator was positioned as shown in Fig-

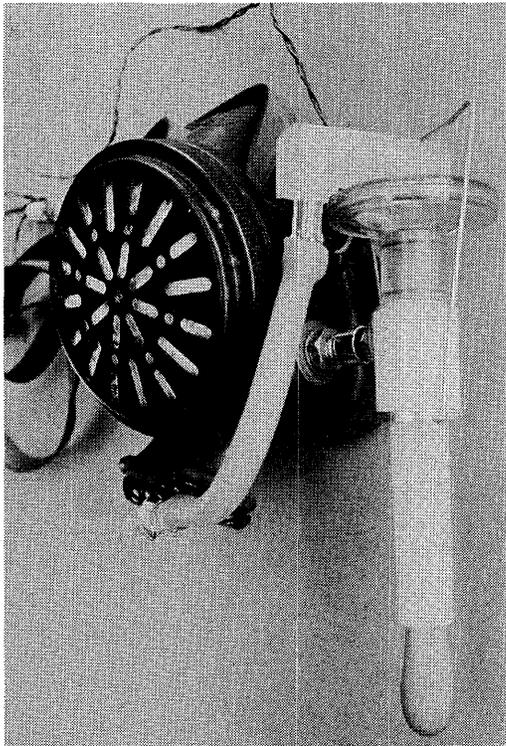


Figure 1. Cyclone collector mounted directly on the respirator facepiece.

ure 2. Also, shown in Figure 2, a thermistor is placed within the respirator facepiece. This thermistor is a part of the time-of-wearing device used to obtain an accurate record of the time respirators are actually being worn. The time-of-wearing device incorporates an active thermistor, located in the facepiece, and a reference thermistor, located in the electronic package worn on the miner's belt, in a Wheatstone bridge circuit. The active unit senses the temperature of the miner's breath when the respirator is worn and the reference thermistor the temperature of the ambient air in the mine. A coulometric device integrates the total time the bridge is unbalanced, *i.e.*, the time the in-mask thermistor is exposed to the temperature of the miner's breath. A test subject wearing both sampling systems is shown in Figure 3.

Five different types of respirators were equipped with in-mask sampling systems:

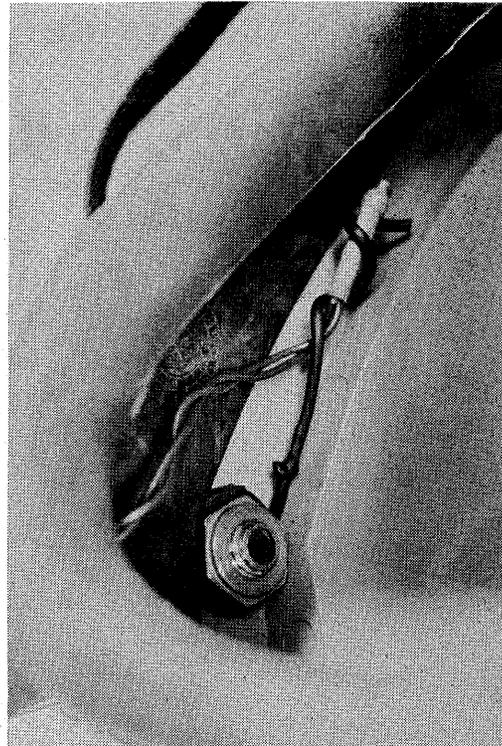


Figure 2. Inside of respirator facepiece showing positioning of the thermistor.

- (1) American Optical R-2090
- (2) Mine Safety Appliances Dustfoe 66
- (3) Mine Safety Appliances Dustfoe 77
- (4) Welsh 7100
- (5) Welsh 7400

For each miner wearing a test respirator, both in-mine and in-mask sampling was done from the time the miner arrived at the working face until his departure, except during the lunch period. Upon arrival at the face, each participant was issued a test respirator and an ambient-air sampling system. Once the equipment was in place, both sampling pumps were turned on concurrently and ran continuously until the end of the shift, except during the lunch period. At the end of the shift, the test equipment was removed and transported to the surface where sample filters were removed and the equipment re-conditioned for use the next day. The same test equipment was used by each miner each day.

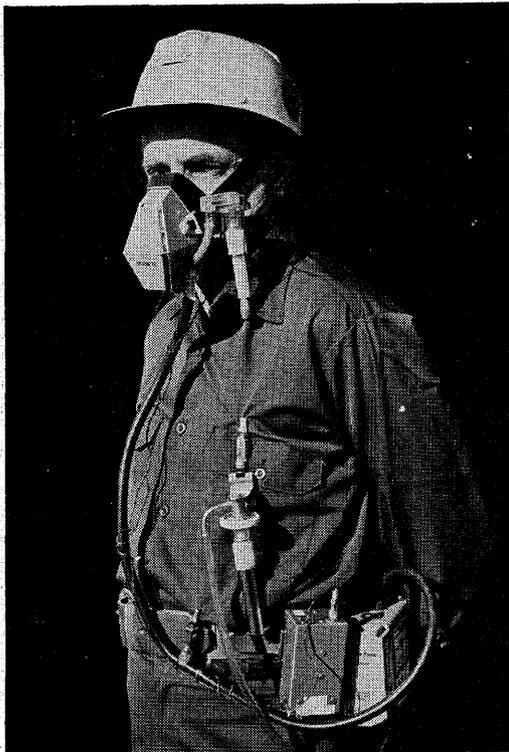


Figure 3. Test subject wearing the sampling equipment.

### *In-Mine Testing*

In-mine testing was carried out in four different mines of Eastern Associated Coal Corp. Pertinent data concerning this testing is presented in Table I.

At each of the four mines, testing was carried out concurrently on two mining sections for a five-day period, except in Mine No. 1 where testing was done for only four days. On each mining section, five persons were equipped with test respirators; four of the test personnel were working miners representing different job classifications. The fifth test subject was an observer, who was one of the personnel assigned to the research project and also monitored the actual testing work.

### **Test Results and Discussion**

In order to determine the protection provided the working miner wearing a respirator, an effective protection factor was cal-

TABLE I  
In-Mine Test Data

<b>A. Mines</b>	
Number	4
Seams	3
Seam Heights, inches	54,60,84,120
Sections	
Continuous	5
Conventional	2
Longwall	1
	Total
	8
<b>B. Test Subjects, Job Classification</b>	
Mining Machine Operator	5
Mining Machine Helper	1
Loading Machine Operator	6
Shuttle Car Operator	7
Roof Bolter	3
Brattice Man	2
Cutting Machine Operator	2
Drill Operator	2
Head Operator	1
Tail Operator	1
Jack Setter	2
Observer	5
	Total
	37
<b>C. Days of Testing</b>	19
<b>D. Man-Shifts of Testing</b>	187
<b>E. Respirator Models</b>	5
<b>F. Man Shifts of Testing the Model</b>	
Model A	48
Model B	53
Model C	40
Model D	28
Model F	18
	Total
	187

culated as follows:

$$EPF = \frac{DC_A}{DC_R}$$

where:

EPF = Effective Protection Factor

DC<sub>A</sub> = Dust Concentration in Mine Air

DC<sub>R</sub> = Dust Concentration in Mask

(DC<sub>A</sub> and DC<sub>R</sub> are given as measured by Personal Sampler and are reported as Personal Sampler concentration and not in MRE, Mining Research Establishment, equivalent.)

In Figure 4 is shown the effective protection factor distribution for all test subjects in all four mines. A mean EPF of 5.7 was

obtained but the median value of 3.2 was somewhat lower. Similar data for each of the four different mines in which testing was done are shown in Figures 5 through 8. For Mines 2, 3, and 4, while there was a spread in EPF's, the larger concentrations of EPF's was in the lower range of values, which was reflected in lower median values. Also, the higher mean value in Mines 1 and

in average EPF among the four job classifications. Interestingly, when comparing averages, the roof bolters and mining machine operators wore the respirators essentially the same percentage of time, but the

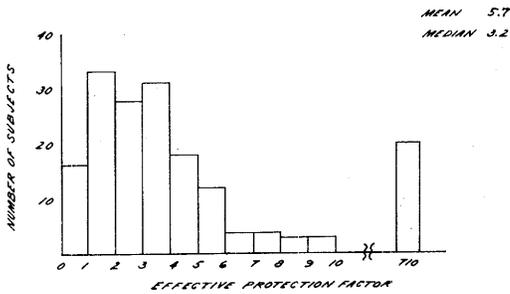


Figure 4. Effective protection factor (EPF) distribution in all mines.

4 is influenced by the higher number of cases where the EPF was ten (10) or more. At the time this paper was prepared, much of the data evaluation and analysis had not been completed, and, consequently, we are not able to suggest the reasons for the differences.

As shown in Table II, there are differences

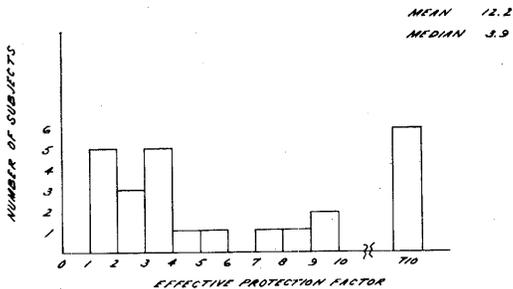


Figure 5. Effective protection factor (EPF) distribution in Mine No. 1.

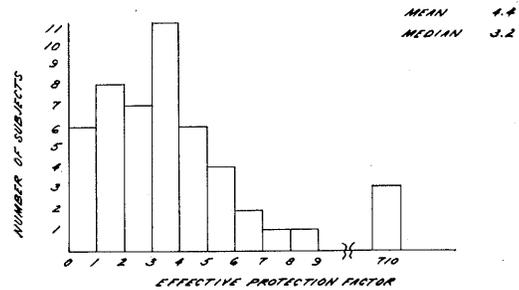


Figure 6. Effective protection factor (EPF) distribution in Mine No. 2.

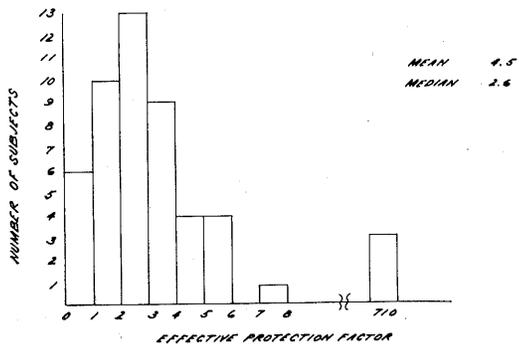


Figure 7. Effective protection factor (EPF) distribution in Mine No. 3.

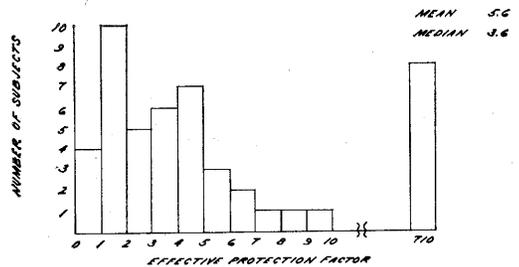


Figure 8. Effective protection factor (EPF) distribution in Mine No. 4.

TABLE II

Job Classification	No. of Subjects	No. of Measurements	Avg. <sup>a</sup> DC <sub>A</sub>	Avg. EPF	Avg. of time Respirator was worn
Mining Machine Operator	5	22	1.9	9.0	60
Loading Machine Operator	6	25	1.9	4.3	51
Shuttle Car Operator	7	30	1.3	6.6	42
Roof Bolter	3	12	2.1	3.2	60

<sup>a</sup>As measured by Personal Sampler.

roof bolters had an average EPF of only 3.2.

Also, the shuttle car operators averaged the lowest wearing times but had the second highest EPF. This suggests that while the length of time a respirator is worn may be important, other factors are also probably significant. In this connection, some observations made during the considerable amount of underground testing are likely pertinent. Although the respirator was put on initially each day so that the head harness or straps were placed in the position recommended by the manufacturer, respirators with two straps were soon converted to a one-strap arrangement. Virtually every miner wears his respirator only intermittently, and when the unit is not worn, it hangs loosely around the neck. When dust is visibly present, the head harness is pushed up the neck to below the ears, and it is fair to say, it is really not convenient nor feasible for the working miner to remove his hard hat with lamp and cord attachment to position the head harness in the recommended manner. Moreover, it was observed (as well as measured) that use of respirators was only intermittent and that by and large, when the miner could not see dust the respirator was not worn.

As mentioned, this paper is a progress report, since a considerable amount of data obtained in the mine studies must be ana-

lyzed and evaluated. Also, it is planned, among other things, to determine effective protection factors in other job classifications not yet studied, e.g., rock dusters, and to determine variations in dust concentrations over a working shift at different mining locations and for different job classifications.

#### Acknowledgement

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#### Short Courses on Reduction of Machinery Noise

Two short courses on the reduction of machinery noise will be held at Purdue University, May 13-17, 1974. The first course, May 13-14, will discuss *Fundamental Approaches to Noise Control*. The registration fee is \$100. The second course, May 15-17, will discuss *Reduction of Noise from Machinery*. The registration fee for this course is \$160, which includes the symposium dinner. Participants may attend either or both courses.

For further information contact: Professor Malcolm J. Crocker, Herrick Laboratories, Purdue University, West Lafayette, Indiana 47907. Telephone: (317) 749-2155.