COAL MINE DUST RESPIRATORY PROTECTIVE DEVICES

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PREFACE

This study was conducted by the Eastern Associated Coal Coporation under contract CPE 70-127 with the Division of Laboratories and Criteria Development, National Institute for Occupational Safety and Health, Department of Health, Education, and Welfare. Technical monitoring was provided by two NIOSH project officers, initially by Mr. J. R. Lynch followed by Mr. A. K. Gudeman of the Engineering Branch, Division of Laboratories and Criteria Development.

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FOREWARD

Mainly as a result of considerable activities both in and outside government for several years previously, Congressional hearings on coal mine health and safety began on February 27, 1969. In late December of 1969, the legislative process was concluded when the Federal Coal Mine Health and Safety Act of 1969 was signed into law by the President of the United States. This legislation is unique in a number of important aspects.

For one thing, it established, for the first time in the United States, allowable standards for respirable dust concentrations found in coal mines. Importantly, it placed upon the Department of Health, Education and Welfare (HEW), broad responsibilities in the "field of coal mine health" including carrying out research in this area; the National Institute (formerly Bureau) for Occupational Safety and Health (NIOSH) was the agency in HEW given this research responsibility.

The program described in this report was initiated by NIOSH and the work performed under Contract CPE 70-127 during the period June 30, 1970 to September 30, 1973 by Eastern Associated Coal Corp. (EACC) with sub contract assistance from the Harvard School of Public Health (Harvard). The EACC-Harvard teaming arrangement was particularly suitable and effective because it provided the diverse capabilities required and functioned efficiently throughout the contract period.

The overall project was under the direction of Mr. H. E. Harris, Director of Research - EACC. Mr. W. C. De Sieghardt, was the principle investigator for EACC; as such he conducted the field survey activities and had direct supervision of the in-mine testing work. Prof. W. A. Burgess, who headed the work done by Harvard, was assisted by Dr. Parker C. Reist.*

The NIOSH Project Officer initially was Mr. J. R. Lynch and later on Mr. A. K. Gudeman. Other organizations and personnel outside the project staff who contributed to or participated significantly in the project are mentioned in the Acknowledgement Section of this report.

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ABSTRACT

Under the sponsorship of the National Institute for Occupational Safety and Health (NIOSH), Eastern Associated Coal Corp., with the Harvard School of Public Health as subcontractor, has completed a 39-month long project on the usage and effectiveness of dust respiratory protective devices in underground coal mines. The first part of the project involved a survey of 511 mining personnel at 47 different underground mining operations located in eight different states. Importantly, as far as is known, for the first time the effectiveness of currently available, approved dust respirators was determined under actual working conditions. Also included was a field evaluation of three different single-use dust respirators that had recently received Bureau of Mines approval for use.

Most miners felt there is a definite need for respiratory protective devices, and half-mask respirators are in general use throughout the underground bituminous coal mining industry. Use of respirators is voluntary and generally limited to those miners working in the vicinity of where the coal is being extracted from the coal face. Respirators are worn intermittently, and the total time of wearing during the work period varies considerably and is affected by a number of factors. The large majority of respirators found in use had the required approval, but about five percent were non approved.

While most miners felt presently available respirators are acceptable for intermittent use, over a third of the miners indicated these respirators are unacceptable or marginally acceptable. Wearing discomfort and breathing resistance are the major disadvantages cited by miners, and the two-strap head harness is not suitable for coal mine use.

Several hundred man shifts of testing were done underground to determine the protection provided by respirators worn by working miners; two different protection factors were determined. The Effective Protection Factor (EPF), determined by sampling separately, but concurrently, the ambient air and air inside the respirator facepiece, over the entire shift, indicated the level of protection obtained by a working coal miner when the respirator was intermittently worn in accordance with the miner's work habits. On the other hand, True Protection Factor (TPF), also obtained by separate but concurrent sampling, showed the protection the miner received when the respirator was actually being worn and in accordance with the manufacturer's instructions. The mean average EPF obtained was 5.7, indicating an average of about 70 percent of the respirable dust present was not inhaled. The mean average TPF obtained was 9.7. EPF values not only varied considerably from miner to miner but from day to day for a particular miner. Moreover, EPF values were significantly lower than TPFs, and it appears that miners have difficulty in maintaining a proper seal between the respirator facepiece and the miner's face under usual working conditions found among face miners. This probably accounts to large extent for the lower protection found under normal working conditions compared to higher values found under the "ideal" conditions in the laboratory.

Although overall there seemed to be no significant differences among the six approved respirators tested, it is evident that the facial size and shape of the individual miner can affect protection provided.

Of the three single-use approved respirators tested, only one was found acceptable by working coal miners and suitable for use in coal mines.

There is a definite need for improved dust respirators suitable for use in coal mines. Likewise, government approval schedules of respirators should be revised to include field evaluation programs, or equivalent, to insure worker acceptability and that the respirator is suitable for the environment of the work place. Importantly, improved training programs in respirator use and maintenance should be developed and put in use.

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1. INTRODUCTION AND PROJECT OBJECTIVES

1.1 Introduction

As a result of the enactment of the Federal Coal Mine Health and Safety Act of 1969,[1/] the Department of Health, Education, and Welfare (HEW) has been carrying out research in the "field of coal mine health." The National Institute (formerly Bureau) for Occupational Safety and Health (NIOSH) was designated as the agency with HEW to be responsible for such research activities.

One of the early research projects sponsored by NIOSH was on Coal Mine Respiratory Protective Devices; this project was undertaken by Eastern Associated Coal Corp., with the Harvard University School of Public Health participating as a sub contractor to Eastern.

There has been a long history in the United States coal mining industry of using protective devices, including that of dust respirators. Clearly, dust respirators were employed before 1934, when the Bureau of Mines first established performance requirements for dust respirators under Schedule 21.[2/] 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 until perhaps very recent times. Understandably, the use of respirators has been limited in coal mines in the past. It was believed that coal dust per se did not cause pneumoconiosis; rather, silicosis was caused by a high silica content in coal dust, and few bituminous coals mined in this country exhibited high silica dust contents. Although Gough[3/] 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.[4/] Furthermore, probably many miners found respirators to be uncomfortable as well as a hindrance when working, and, consequently, their use was avoided except when discomfort from dust exceeded that from the respirator.

In more recent times, publicity about the relationship between respirable coal dust and the incidence of coal workers' pneumoconiosis has undoubtedly increased the awareness of the value of using respirators. Moreover, respirator wearing has been more actively encouraged than in the past. It should be emphasized that 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."[1/] All of this, undoubtedly, has resulted in coal miners making greater use of respirators than in the past.

This Federal Coal Mine Health and Safety Act of 1969 established for the first time in the United States respirable dust standards for coal mines. This law provided for the establishment, essentially in a step-wise arrangement, of standards of decreasing respirable dust concentrations, with all coal mines having to meet the standard of 2.0 milligrams per cubic meter no later than December of 1975. Although the act stipulates that respirable dust standards are to be met by environmental control means, it is recognized that in order to eventually meet the standard of 2.0 milligrams per cubic meter for certain underground mining operations, other means may have to be employed.

Importantly, at the time this project was started in late June of 1970, it was recognized there was little information available on the usage of respirators in coal mines, and much more importantly, what the miners -- the men who use the respirators -- felt and thought about the presently available respirators. Likewise, there was <u>no information</u>, so far as could be determined, about the effectiveness of dust respirators under actual working conditions. Therefore, it was clear much was needed to be determined about the current status of respirator usage and effectiveness in coal mining operations.

1.2 Objectives

The major objectives of this project were:

a. To determine, by means of a field survey, the current status of respirator usage with respect to duration and frequency of use, types, and training and maintenance levels.

b. To determine the acceptability among underground miners of currently used respirators.

c. To determine protection factors provided by respirators worn by working underground coal miners.

d. To make recommendations on ways to improve existing units, or on research needed to develop new types of dust respiratory protective devices for coal miners.

e. To provide recommendations to coal mine management on more effective use of dust respiratory protective devices.

During the time the work on the project was in progress, three models of single-use dust respirators were approved under existing approval schedules for use in underground coal mines. Accordingly, it was decided to determine whether these respirators would be considered acceptable by working miners for coal use and, if considered acceptable, what protection was provided by the respirators worn by working miners.

1.3 Project Organization

To accomplish the objectives set forth previously, the project was divided into two major parts, namely, an in-the-field survey on the current status of respirator usage and acceptability, etc., and an in-mine test program. The work done and results obtained are described in the remaining parts of this report. The work done covers the period from June 30, 1970 to September 30, 1973.

2. FIELD SURVEY

2.1 General

While dust respirators have been used in underground bituminous coal mines for some 40 years, little definitive information was available about the previous or current practices involving the use of respirators. In other words, little was known about such things as extent of use, duration of use, type of units in use, acceptance, or lack thereof, by the miners, training in use, and maintenance of respirators, and problems associated with currently available, approved units. Moreover, the protection provided by dust respirators under field conditions, i.e., when worn by working miners, has never been determined.

In order to obtain the needed information about use, acceptability, training, maintenance, etc., a field survey was conducted, which involved individual interviews, using the form shown in Appendix 2-1, with supervisory and safety personnel and underground miners. In addition to the interviews, the field survey also included some underground observations. Parenthetically, it should be noted the interviews would not only provide pertinent information about such things as what types of dust respirators are being used, how long the miner wears the respirator, etc., but would generate data needed to design the experimental program for determining respirator effectiveness under field conditions.

Before the actual field survey was started, however, it was necessary to determine which mines were making use of respirators in order that pertinent information would be obtained in the personal interviews. Also, it was necessary to take into account that coal mining operations varied considerably with respect to size, i.e., annual tonnage produced, and consequently, number of employees. Further, other things, such as mining conditions, geographic locations and coal seams mined were taken into consideration. It was important to keep in mind, as well, that cooperation on the part of the mining companies and the members of the United Mine Workers (UMW) would be voluntary, and would be essential if the project was to be successful.

2.2 Structuring the Survey

Prior to making any contact with individual coal mining companies, the overall project was outlined to the National Coal Association (NCA) and the UMW. As a matter of interest, an arrangement, which worked out extremely well, was made with the UMW whereby the UMW Washington office would, upon receipt of appropriate advance notice, notify local UMW officials of expected visits by Eastern personnel to particular mines. The NCA advised the member companies about the project and requested their cooperation.

At the time the survey was being planned, pertinent NCA data[5/] on mines and production were as shown in Table 2-1.

TABLE 2-1

1967 PRODUCTION (ALL MINES)

Annual Tonnage	Mines: Number	Mines: % Total	Cumulative % of Total Production
Over - 500,000	281	4.8	59.1
200,000 - 500,000	244	4.2	73.0
100,000 - 200,000	367	6.2	82.4
50,000 - 100,000	542	9.2	89.2
10,000 - 50,000	2079	35.4	98.1
Less than 10,000	2360	40.2	1.9

Of the 5,873 operating mines, 3,908 were underground, 1,507 strip mines, and 458 auger mines. Employment at these mines was 107,432, 21,439, and 2,652 for underground, strip, and auger mines, respectively. It was also reported in 1967 that over 349,000,000 tons of coal was obtained from underground mines out of the total production of about 552,000,000 tons. From these data, it was indicated that the great bulk of underground miners was employed in large producing units, i.e., over 200,000 annual tons. Moreover, other data clearly indicated that large tonnages came from a small number of mining companies.

With the foregoing in mind, a letter inquiry was sent to 178 mining companies. The purpose of this inquiry was threefold. First, to explain the project; secondly, to learn whether respirators were being used at some or all of their underground mining operations; and thirdly, to ascertain whether it would be possible to visit one or more of their operations and to interview personnel. Those companies selected to receive the initial inquiry included all companies with annual productions of more than 10,000,000 tons. Companies producing lesser tonnages were included as a result of random selection from lists prepared from state reports, or other appropriate sources, for the states of West Virginia, Pennsylvania, Kentucky, Ohio, Illinois, Alabama, Indiana, Tennessee, and Maryland. In short, all of the major coal producing states and areas in the Appalachian and Mid-Continent fields were included.

The distribution and results obtained from this inquiry are shown in Table 2-2.

TABLE 2-2

INQUIRY TO MINING COMPANIES

Mining Company Annual Production, Tons	Companies Receiving Inquiry	Response*	No Response**
Over 10,000,000	11	9 (2)	0
2,000,000 - 10,000,000	26	10 (5)	11
1,000,000 - 2,000,000	18	9 (1)	8
700,000 - 1,000,000	12	3 (1)	8
500,000 - 700,000	11	1 (1)	9
400,000 - 500,000	11	1 (2)	8
300,000 - 400,000	16	0 (1)	15
200,000 - 300,000	21	2	19
100,000 - 200,000	20	0 (2)	18
50,000 - 100,000	22	0	22
Less than 50,000	10	0	10
	178	35 (15)	128

* See footnotes on the following page.

Following this inquiry, arrangements were made with 31 different mining companies to visit 47 different mines. These 31 companies had an aggregate production in 1969 of about 225,000,000 tons of coal. In selecting individual mines for subsequent visits, efforts were made, in order to obtain a representative cross section, in so far as possible, of the coal industry, to achieve a maximum diversity as to coal seams, mining conditions, and mining methods. Data for this are shown in Table 2-3.

TABLE 2-3

SURVEY SAMPLE DATA

Number of States	8
Number of Companies	31
Number of Mines Visited	47
Total Number of Seams	27
Range of Seams, Height, in.	
Low	34
High	96
Operating Sections	
Longwall	5
Continuous	144
Conventional	95

NOTE: Further details about number of mining operations visited in each state, total miners employed, number of face miners, mining sections, and seam heights are found in Appendix 2-2.

2.3 Field Survey Interviews

The men interviewed included management, supervisory, and safety personnel, and underground workmen from all job classifications. Although the selection of those personnel interviewed at each mine was done in a

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*Those numbers shown in parentheses are for those companies also responding but who indicated they could not participate in the field survey primarily because of press of work resulting from the new Federal Coal Mine Health and Safety Act. Of these 15 companies, 14 companies reported, however, significant use of respirators.

**Included here are 15 inquiries that were returned by the post office indicating the companies had ceased operation. All were producers of small tonnages.

random manner, an effort was made to include among those interviewed all of the various job classifications found at the particular mine. A breakdown by job classification of all personnel interviewed at the 47 different mines is presented in Table 2-4.

TABLE 2-4

PERSONNEL INTERVIEWED - BY JOB CLASSIFICATION

Management and Supervisory

Job	No.
Mine Superintendent	24
Mine Manager	4
Safety Director	16
Safety Inspector	14
Engineer	6
Mine Foreman	2
Section Foreman	17
Sub-total	83

Mining Personnel

Job	No.
Shuttle Car Operator	72
Continuous Mining Machine Operator	69
Roof Bolter	54
Loading Machine Operator	31
Rock Duster	30
Shot Firer	25
Cutting Machine Operator	24
Motorman and Tram Drivers	23
Continuous Mining Machine Helper	19
Coal Drill Operator	19
Beltman	16
Longwall Operators and Jack Machine Operators	14
Brakeman	2
Service & Supply (Mechanic, Timberer, Brattice Man) (Trackman, Electrician, Bit Grinder)	30
Sub-total	428
Total	511

Generally, the interviews were conducted as the men arrived for work on the second shift. At some mines, underground observations were made, and those men observed were also interviewed. Men were interviewed singly, and except for only four instances, supervisory personnel were not present during the interview.

The field survey was carried out in the Fall of 1970 and the Spring of 1971. Approximately half of the personnel were interviewed during the first portion of the survey work and the remainder, in the Spring of 1971.

2.4 Results of the In-the-Field Survey*

2.4.1 General

During each interview, information was obtained on such things (see Interview Form, - Appendix 2-1) as miner's job classification, the type of respirator used, the duration of use, i.e., the percentage of time the respirator was worn during a working shift, the training and maintenance procedures provided. Moreover, those interviewed were asked about the acceptability of currently available units, or problems (including objections to) associated with the use of respirators now available. Also, personnel were queried about the feeling toward use of respirators in general, improvements needed or desired on existing units, need for new respiratory protective devices, and methods that could be used to improve respirator acceptability.

2.4.2 Use

2.4.2.1 Background

The Federal Coal Mine Health and Safety Act of 1969 requires that all coal mining companies furnish approved dust respirators to all miners who request such. As far as could be determined, this was being done by all mining companies -- all of the mines visited during the field survey were making respirators readily available. In actual fact, the furnishing of respirators to underground personnel at many mines is not

*Summary of Responses to questions asked of those interviewed is given in Appendix 2-3.

of recent origin*, but a matter of policy and practice for many years. It is known that respirators were in use prior to 1934.

By way of further background, the use of respirators probably has been affected by such factors as geographic or regional variations, local belief or "folklore", attitude and age of the individual miners, policy and attitude of the mining company and local mine management, and training and education in respirator use. While it was not within the scope of the present project to investigate and study past history in detail, but rather current practice, the effect of some of these factors will be discussed subsequently.

2.4.2.2 Possession and Use

Use of respirators is, essentially, on a voluntary basis throughout the industry. While the use of a respirator may be mandatory for a specific job in some locations, e.g., a bit grinder or motorman, these represent a small number of cases; moreover, enforcement of a mandatory rule is often lax. Furthermore, not only is the use voluntary, but, as will be discussed later, the individual miner usually wears the respirator on an intermittent basis, actual duration of use being a matter of individual judgment. Consequently, estimates were made on range, percentagewise, of the underground force possessing respirators and wearing (using) respirators some time during the working shift; these data are shown in Table 2-5.

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* At many locations, personnel with long periods of service reported respirators as always having been made available during their tenure. Others reported they have "always" done it. While it is not possible to quantify how long this policy has been in existence, nor how widespread it has been, it seems clear that furnishing of respirators has been practiced for a long time, predating the establishment of respirable coal dust as a cause of coal workers' pneumoconiosis.

TABLE 2-5

RANGE OF RESPIRATOR POSSESSION AND USE -- 47 MINES

Possession of a Respirator	Approximate Percent of Underground Work Force*
High	90 +
Low	40
Worn by Work Force**	
High	60
Low	20

* Includes 428 people in various job classifications, plus 17 Section Foremen, total 445.

** Sometime during shift -- see Table 2-6 for duration of use.

It is evident that a much larger percentage of miners possess a respirator than will make use of them during a shift. Nevertheless, a significant percentage of miners do use respirators.

This range in possession and actual wearing reflects a variety of things. Obviously such things as dustiness, job classification (or location in the mine), mining conditions, coal seam (or rank), and seam height have an effect. In general, men working at the face, rock dusters, roof bolters, and, in some cases, beltmen, reportedly made the greatest use of respirators. This was as to be expected in that dust levels (of visible dust) are usually highest at, or near, the working face. In certain work areas, the exposure to dust was minimal, and men working in these areas generally did not use respirators. Similarly, personnel such as foremen, safety inspectors, engineers, survey men, made little use of respirators since they usually found it to be easy to avoid exposure to heavy concentrations of dust. In the same fashion, mechanics and repairmen used respirators only when it was necessary for them to work in dust laden air, e.g., down stream from a working face.

Greater use of respirators was made in mines operating in low-volatile coal than those in high-volatile coal. Usually, more visible dust was generated when mining the more friable low-volatile coal. Similarly, there was generally more visible dust where dry conditions were found than when conditions were wet. In low-coal seams, greater use of respirators, as compared to operations in high-coal seams, was, at least in part, due to the likelihood that it is more difficult to obtain effective ventilation in low-coal. As was to be expected, more use was made of respirators in longwall and continuous mining operations than in conventional mining. Beyond these are other factors.

For example, at some mines respirators were kept in a store room and were supplied to those who asked for one, but no effort was made to encourage use. In fact, in some cases, the use of respirators was discouraged albeit subtly or indirectly, not with the objective, however, of saving money but because those in charge honestly believed respirators were of little value and not worth wearing.* In this situtation, it is understandable that there is little enthusiasm among the work force for wearing respirators. Lack of use of respirators over an extended period of time,** local "folklore," or the "manhood syndrome" undoubtedly can contribute to few miners possessing or wearing respirators.

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* Many of the Mine Foremen, Superintendents, and Safety people, often in their 50's, have come from the underground work force and have seen dustier conditions in their long years of service than exist today; moreover, a sizeable number of these persons have made little use of respirators and are still healthy. As a result, their viewpoint that respirators are of little value is understandable.

** If a pattern of non use becomes established, it is perpetuated even among new miners who will follow the habits of the existing work force. On the other hand, widespread use encourages further use.

(Training and Maintenance will be discussed subsequently; however, lack of these is certainly a factor contributing to limited possession and use.) On the other hand, there were mines at which considerable time, effort and money were spent to encourage the broadest possible use of dust respirators. New men receive instructions on how to wear and how to maintain a respirator. The benefits of using a respirator are reiterated at safety meetings. These efforts naturally result in "positive" attitudes being acquired by the work force, which, in turn, result in a higher use of dust respirators.

At most mining operations, it was found the situation was somewhere in between. While availability of respirators was mentioned -- perhaps even emphasized when a new man was hired -- training in use and maintenance was lacking. Similarly, benefits of using respirators were mentioned but not stressed. Consequently, those who wished to use respirators did; others, did not.

2.4.2.3 Duration of Use

An analysis of the data obtained in the field interviews and in the in-mine observations definitely shows that respirators are almost universally worn only on an intermittent basis. This is clearly evident in Table 2-6.

TABLE 2-6

DURATION OF RESPIRATOR USE

Hours per Shift	Percent of Underground Work Force* Interviewed
0-2	22
2-3	35
3-5	29
> 5	14
	100

* See note Table 2-5

As shown in Table 2-6, 22 percent reported using a respirator less than 2 hours per shift and 57 percent, less than 3 hours. On the other hand, only 14 percent used the respirator more than 5 hours per shift. In this last category, there were a considerable number of continuous mining machine operators, cutting machine operators, rock dusters, longwall men and shuttle car operators (also included are some men who had received medical advice to use a respirator and were doing so). However, before considering differences in use among job classifications some general comments are in order. First, the figures given for duration of use are based on the estimates provided by those interviewed. Based on observations made underground, it appeared these estimates might be somewhat high, i.e., respirators were not being worn as long a time as estimated. There was no evidence that miners were purposely over-estimating the times respirators were being worn. Rather, it is probable conditions underground, e.g., absence of daylight, for a reference point, make the judgment of time difficult. Also, the discomfort of wearing a respirator may cause the miner to feel he is wearing the respirator longer than he actually is.

As mentioned, respirator use is virtually all on an intermittent basis and the duration of use is left solely to the judgment of the individual miner who decides to use a respirator, or not, mainly on the basis of the concentration of visible dust present. As will be discussed later, difficulties associated with use of currently available, approved dust respirators influence the decision made by the individual miner. Quite obviously, since use is a matter of individual judgment, one miner will wear a respirator in a situation where another miner would not, i.e., what constitutes an unacceptable dust level to one is an acceptable level to someone else.

The criterion used by the miner to indicate the need for respirator use is probably more complex than just involving the visible dust level. While essentially all miners indicated they made use of a respirator when "it was dusty" or "when there is dust in the air", observations made underground during the survey and during the several subsequent in-mine test studies (see Section III) indicated that other criteria such as the starting of the mining machinery may be used in place of or in conjunction with the ambient air dust level. For example, men were observed using respirators when there was little visible dust present and other men observed not using respirators when visible dust was much in evidence. In the latter cases, the men were in possession of respirators, hanging around their necks. It is possible that with some men respirator use is a conditioned response to a "signal" other than the visible dust level but which will, under most circumstances, correlate with dusty conditions. That the visible dust level is used as a criterion (and perhaps the most important one) for respirator use is evidenced by the fact that many supervisory personnel reported that when additional measures were taken to reduce dust levels, the level of visible dust consequently decreased and the use of respirators also decreased.

Overall, age of the miner or length of service seemed not to be important as to how long the respirator was worn (or for that matter, whether a respirator was used or not). At some individual mines, there were reported differences between the younger and older miners.*

* In cases where more use was being made by older miners, safety personnel speculated that these older men had gotten into the habit of wearing respirators and had continued to do so; whereas the younger miners found the mines to be "not too dusty, anymore," and never acquired the habit. In other locations, where the reverse was true, it was thought the younger miners were impressed by the publicity given black lung and were aware of the handicapped older miners and therefore, were taking precautions by using a respirator. At the same time, the older miners, who never developed the habit of routinely wearing a respirator, saw no need to start to do so now. No doubt, many other interrelated factors are involved.

2.4.2.4 By Job Classification

As shown in Table 2-7 below, there were considerable variations in duration of respirator use among workmen in the same job classification. For example, 23 percent of shuttle car operators wore a respirator less than 2 hours per shift, but 28 percent used them for 5 hours or more (5 hours would constitute the great bulk of working time on a shift). Also, 45 percent of the cutting machine operators used a respirator less than 3 hours per shift, while 33 percent wore such 5 hours or more.

TABLE 2-7

DURATION OF RESPIRATOR USE BY JOB CLASSIFICATION

Job Classification	Percent Underground Work Force Interviewed* Hours per shift 0-2	2-3	3-5	>5
Shuttle Car Operator	23	30	19	28
Continuous Miner Operator	17	35	13	35
Roof Bolter	22	37	19	22
Loading Machine Operator	19	43	19	19
Rock Duster	22	38	18	22
Shot Firer	9	39	48	4
Cutting Machine Operator	12	33	22	33
Motorman and Tram Driver	18	47	24	11
Continuous Mining Machine Helper	23	31	31	15
Coal Drill Operator	32	32	36	0
Beltman	17	22	39	22
Longwall Miner Operators	13	53	7	27
Service and Supply	22	34	22	26

* See footnote Table 2-5

Undoubtedly, these variations were due, in large part, to factors such as differences in working conditions, in judgments among individuals and in miners' reactions to respirator discomfort. In addition differences in working techniques or habits among the individual miners affects the need for, and, in turn, the use of, respirators. As in many other occupations, some miners set up and execute their work so as to generate a minimum of dust, or so that they are exposed to as little dust as possible. Others are not as thorough, careful and prudent and consequently are exposed to more dust.

2.4.3 Training and Maintenance

2.4.3.1 Training Programs

Training programs provided by the mining companies in the proper use and maintenance of dust respirators were found to be largely lacking. What training existed was usually quite cursory in nature. This lack of training programs is a major weakness in the overall use of respiratory protective devices.

TABLE 2-8

TRAINING IN RESPIRATOR USE

	No. of Mines
Provided by Company*	11
None Provided by Company	36

* Includes any training when miner is first employed, or first issued a respirator, or any training provided at safety meetings.

As shown in Table 2-8, only a little over 20 percent of the mines visited had some training on the use (and maintenance) of respirators. Often this training consisted of only that given when the miner was first employed. For example, at time of employment, the miner was issued a self rescuer and a dust respirator. In so far as the latter is concerned, the miner was shown how to put on the respirator and the proper method to check the unit for leakage. He was also told where to obtain replacement filters and other spare parts, and shown how to change the filter. The need to keep the respirator clean was noted, and the miner was told to wash the respirator daily. This was the extent of training provided; in particular there were no "follow-up" programs.

A few coal mining companies had respiratory protection programs that included initial training and "follow-up." Such programs were usually a part of the overall safety effort, and include periodic meetings, outside speakers, motion pictures or slides, etc., in order to stimulate interest in respiratory protection. Foremen and Safety personnel follow-up by meeting with small groups underground, or questioning an individual miner not using his respirator. If there is a complaint about a respirator, efforts are made to correct or alleviate the difficulty. Not only is there generated a general atmosphere of genuine concern about the health of individual miners, but emphasis is placed on the benefits to be derived from using a respirator despite the discomfort involved. In this environment, the individual miner develops a positive attitude towards respirator use and, as a result, a high percentage of the miners make significant use of respirators. Although there are a few respiratory protection programs which were somewhat comprehensive and to some extent encouraged the use of respirators, none of the programs were without substantial drawbacks. There was no program found that would be considered noteworthy.

Where no training is provided, which is the situation in most instances, the new miner learns to use a respirator either by observing other miners or by reading the manufacturer's instructions; neither are adequate substitutes for good training. Most experienced miners feel sufficiently familiar with respirators that instructions are seldom consulted even on a new model unless something troublesome is encountered. Then a few may read the instructions, but most will learn by observation.*

2.4.3.2 Respirator Maintenance

Respirator maintenance, except in one company, was left to the individual miner. This, coupled with the fact that training in respirator maintenance was limited, resulted in maintenance for the most part being erratic and perfunctory. Generally, maintenance was limited to changing the filter and wiping dust from the facepiece; the major item of maintenance was that of changing filters.

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* For example, it has been reported that there were difficulties using the head harness of the new MSA 77 respirator. Attempts to secure this head harness in the same manner as that used with older MSA 66 respirators were unsuccessful. As soon as a few miners found the proper method, by reading the instructions, others learned by observation.

TABLE 2-9

FREQUENCY OF FILTER CHANGE

Frequency	Percent of Underground Work Force*
2 or more per shift	20
1 per shift	55
1 each 2 shifts	15
1 each 3 shifts	4
Longer than 1 per 3 shifts	6
	100

* See note, Table 2-5.

TABLE 2-10

FREQUENCY OF FILTER CHANGE BY JOB CLASSIFICATION

Job Classification	Percent of Workman Frequency per Shift				Longer than 1 per 3 shifts
	2 or more	1 per shift	1 per 2 shifts	1 per 3 shifts	
Shuttle Car Operator	9	65	13	6	7
Continuous Miner Oper.	36	46	9	2	7
Roof Bolter	14	60	14	4	8
Loading Machine Oper.	25	50	18	4	3
Rock Duster	18	53	7	7	15
Shot Firer	13	70	9	4	4
Cutting Machine Oper.	25	59	8	0	8
Motorman and Tram Driver	6	27	27	20	20
Continuous Mining Machine Helper	15	54	31	0	0
Coal Drill Operator	6	66	22	6	0
Beltman	12	64	12	6	6
Longwall Miner Oper.	47	40	13	0	0
Service & Supply	17	61	13	0	9

The majority of the underground mining personnel change the filter one or more times per shift -- see Tables 2-9 and 2-10 --(Usually the face-piece is wiped off at the same time; sometimes compressed air, if available, is used to blow dust off the respirator.) Instead of changing filters some miners will "recondition a used filter by blowing the accumulated dust off the outside surface using compressed air.*,**

All the mine operators provided replacement filters*** and almost all, some spare parts. (Some operators did not provide such repair parts, as valves and facepieces, feeling it was less expensive to issue an entirely new respirator rather than replace these parts). Since some repair parts are usually available, increased emphasis should be placed on training in proper maintenance procedures in order to insure that respirators in-use are functioning properly.

Inadequate maintenance is a deterrent to the use of respirators. As the respirator becomes dirtier, it becomes increasingly unattractive to wear. Coal dust, which becomes imbedded in the facepiece and head harness, causes discomfort and, in some cases, skin irritation. If the face piece becomes distorted or warped, or the exhalation valve becomes defective, the miner will notice dust collecting inside the facepiece. If the miner is unaware of the defects, he naturally has doubts about the usefulness of the respirator. When these experiences become commonplace, the miner may in time, stop using a respirator, or wear it only when the dust level is quite high. In brief, if respirators are to be used, and effectively so, proper maintenance is a must.

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* As a matter of interest, some miners even blow dust off new filters.

** Whether this practice of reconditioning filters by blowing off dust may make breathing easier (and decrease the protection) is not known; some miners think it does. When examined against a light, there appeared to be no difference in texture among used filters so reconditioned, used filters where the dust was brushed off, and new filters; however, this is not an adequate criterion for judgment.

*** In some cases, filters were freely available in the lamphouse and miners helped themselves.

Only one case was found where the respirator maintenance was performed by the operator; the procedure used by the company is outlined in Appendix 2-4. Three other mines visited had previously provided respirator maintenance but had discontinued such service. In one case, the company had used the services of an outside contractor, but the contractor had stopped doing this sort of work. In the other two instances, the servicing was done by salaried personnel -- in both cases, by partially disabled miners. However, in both situations, the union attempted to make the servicing job a part of the bargaining unit and when this occurred, the company discontinued the job and the service.

2.4.4 Acceptability of Respirators

2.4.4.1 General

In considering and evaluating the acceptability of dust respirators in underground bituminous coal mining operations, it was important to determine the miner's opinion regarding the need for respirators. This information would furnish prospectives for evaluation of the answers concerning acceptability. A workman will be more critical of a piece of equipment he feels is needless than one he feels is useful. The converse is also true, and men may be less critical of equipment they feel is valuable to them.

2.4.4.2 Need

It is evident that most coal miners feel there is a definite need for dust respirators, and such need exists regardless of the progress being made in reducing dust concentrations. This is clearly reflected in the data in Table 2-11

TABLE 2-11

NEED FOR USE OF RESPIRATORS
IN COAL MINES

Category	Percent of Underground Work Force*
Generally Needed	42
Used Whenever Dust is Present	45
Used Only When Necessary	4
Needed, but are Hard to Wear	8
Prevent Dust to Make Use Unnecessary	1
	100*

* See note, Table 2-5

Forty-two percent felt respirators were generally needed, and an additional 47 percent indicated they should be worn whenever dust is present. Only one percent thought it possible to keep dust levels sufficiently low so as to make respirators unnecessary.

Most of the miners interviewed recognized that dust at the working face might be, in the foreseeable future, maintained at acceptably low levels; however, it was felt that many other sources of dust would be difficult to control. Such operations as moving chocks on the longwall, cleaning up around conveyor belts and rock dusting were among the operations cited, wherein the dust generated would be difficult, or impossible to control by engineering means, e.g., ventilation or water sprays. It was also noted that although dust is generated for short periods of time, sometimes the concentration is high.

Some miners said they would not go underground without a respirator. Others were somewhat critical of methods being used to reduce dust levels, particularly complaining of wet conditions or excessive air. Several miners remarked, "If they use enough air to sweep all the dust away, they will either freeze us, or blow us out of the mine."

2.4.4.3 Use

As previously mentioned, miners consider dust respirators as quasi-emergency equipment to be used only when conditions require. In other words, the miners do not consider respirators as being in the same category as routinely used safety equipment such as hard hats and safety shoes. Moreover, this intermittent use is based mainly on the individual miner's judgment as to what constitutes an unacceptable level of visible dust.

2.4.4.4 Respirator Models being Used

As indicated in Table 2-12 -- most of the respirators being furnished to and used by underground bituminous coal miners are the renewable filter, half-mask type, i.e., half-mask respirators designed so that the filter may be replaced when it becomes clogged. There was some use of non-approved, single use, half-mask respirators.*

TABLE 2-12

RESPIRATORS IN USE BY UNDERGROUND MINERS

Make and Model	Percent of Total
MSA - 57 1)	7.7
MSA - 66	37.6
MSA - 77	30.0
Welsh Air Aider	3.9
Willson 45 CD 2)	2.2
Willson 600 2)	2.4
Willson Monomask	0.6
American Optical R2090	6.0
Cesco 90F	2.6
Pulmosan	2.8
Flex-A-Foam 3)	3.3
Seelig Specialties Co. Face Mask 3)	0.9
Total	100.0

(1) No longer approved and phased out by using companies
(2) Approved for pneumoconiosis producing dusts at time of survey. Not now approved under schedule 21-b
(3) Not approved for pneumoconiosis producing dusts at time of survey.

* (see p. 2-21 for this note)

Respirators manufactured by the Mine Safety Appliances Company (MSA) were those most widely used in the Appalachian and Mid-Continent coal fields. The MSA models, the Dust Foe 57, 66 and 77, accounted for about 75 percent of the respirators being used. The Dust Foe 66 represented 37.6 percent of the total, followed rather closely by the newer Dust Foe 77 with 30.0 percent. While no longer approved and being phased out by the using mining companies, the MSA 57 still accounted for 7.7 percent of respirators in use. The remaining 25 percent was divided among 9 different units, manufactured by 7 different companies.

Perhaps a bit surprising, two non-approved respirators, the Flex-A-Foam and Seelig Specialties Face Mask, were being used and being issued by some mining companies, the latter despite the provisions of the 1969 Federal Coal Mine Health and Safety Act. In some cases, the individual miner was purchasing the non-approved respirator from an outside source.

These two non-approved respirators are basically a single-use unit, i.e., to be used until dirty (filter clogged or full) and then the entire unit is disposed of. However, the miners using these were not using them on a single-use basis; rather, the miners would wash out the filter pad, a rubber or plastic foam material, each day and reuse the unit the next day. One respirator would be used in such a fashion for a period of up to a week.

Mines supplying the Flex-A-Foam or Seelig units were aware these respirators were not approved for coal mine use but continued to furnish these units because it was felt it was better for the miner to wear

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* A single-use, half-mask respirator, carrying schedule 21-b approval, became commercially available late in the fall of 1970, but this unit was not found in use at the time the field survey was made.

something than nothing. These non-approved units are lightweight and easy to breathe through thereby likely providing little, if any, protection against the inhalation of respirable dust, but the miners reportedly like these units because of these properties. It was stated that many miners (at those locations issuing the non-approved units) would wear the non-approved respirator but would not use the approved conventional half-mask unit, and that the miners using the non-approved respirators were aware such were less effective than approved respirators.* At some mines, the non-approved respirators, which had been obtained from outside sources, were confiscated from the men found wearing these units underground.

Mines issuing and using non-approved respirators had no training programs in respirator use and maintenance.

2.4.4.5 Acceptability

On the basis of intermittent, rather than continuous, use, most miners considered currently available respirators to be satisfactory, Table 2-13.

TABLE 2-13

RESPIRATOR ACCEPTABILITY
BASED ON INTERMITTENT USE

Category	Percent of Underground Work Force*
Completely	2
Generally	64
Marginally	24
Unacceptable	10
	100

* See Note: Table 2-5

It is significant however, that 24 percent of those interviewed found presently used respirators as being only marginally acceptable, and

*Time did not permit verifying these statements, nor was it possible to establish why management used the rationale presented. Importantly, project personnel in no way sanction the issuance or use of non approved units.

another 10 percent considered them as unacceptable. Clearly then, a significant number of miners have found substantive difficulties with respirators now available. Before considering problems associated with respirators and their use, it is fair to note that most miners would consider the presently available respirators as unsatisfactory for continuous use, and that most miners make the judgment as to acceptability on how troublesome respirators are to use rather than on how well dust is being removed from the air inhaled.

2.4.5 Problems Associated With Respirator Use

Problems with, or objections to, respirator use fall into two major categories and one minor category. The two major categories are breathing difficulties and physical discomfort when being worn. Of rather lesser importance is the fact that a small percentage of those interviewed reported that using a respirator interfered with work. These data are summarized in Table 2-14.

TABLE 2-14

PROBLEMS ASSOCIATED WITH RESPIRATOR USE

Category		Percent of Underground Work Force*
Cause Breathing Difficulties		37
Physical Discomfort		55
Generally Cumbersome and Uncomfortable	13	
Cause Perspiration	9	
Interfere with Tobacco Chewing	9	
Troublesome Head Harness	7	
Respirator Too Large	6	
Facepiece Troublesome	5	
Dust Inside Mask	5	
Improper Fit	1	
Interference with Work		9
Restricts Vision of Interferes with Wearing Glasses	5	
Exhalation Valve Troublesome	2	
Interferes with Communication	1	
Difficult to Carry	1	
		101**

* See Note: Table 2-5

** Total adds to 101% because of rounding.

2.4.5.1 Breathing Difficulties

The largest single complaint about respirators is that using one causes breathing difficulties; thirty-seven percent of those interviewed reported this difficulty. The severity of breathing difficulty ranged from a unit that is "hard to breathe through," to, "I just can't wear one for more than a few minutes -- it smothers me." Reportedly, breathing difficulties were accentuated when the respirator had been worn for some time and the filter had become clogged with dust or moisture.

Breathing problems were found to be particularly prevalent when miners were doing heavy manual work, such as shoveling coal or pulling cables. Many miners observed that respirators could not be worn because of breathing difficulties at the time the respirator was needed most i.e., when the miner was doing heavy work that generated dust. On the other hand, machine operators usually had no breathing problems when operating the machine, but did experience such difficulty when dismounting and pulling cables; in some cases, the operator found it necessary to remove the respirator in order to breathe properly while doing the heavier work.

Men with known respiratory impairment are seriously handicapped by using a respirator. Such persons experience breathing difficulty even when not moving around, and find it virtually impossible to wear a respirator when doing even light work. These are the same miners who reported being unable to wear a respirator more than a few minutes at one time; they are usually older men with a long history of employment underground. Where health records had been kept, it was reported there was a good correlation between the inability to wear a respirator and known respiratory impairment.

2.4.5.2 Physical Discomfort

The other major category involved physical discomfort for a variety of different reasons when respirators were used. Thirteen percent reported that the respirators were cumbersome and generally uncomfortable to wear. Included herein are such as, the respirator "hurts the face", the head harness hurts the head and sometimes causes headaches, the units are unwieldy, and the wearer bumps into other things in cramped spaces. Nine percent of those interviewed complained that wearing a respirator caused the wearer to perspire and the respirator became wet inside. Actually, the moisture found inside the respirator is that condensed from moisture in the breath; a considerable amount of such moisture can collect inside the respirator. Such condensation can make the facepiece slippery, not only making the respirator uncomfortable to wear, but making the fit around the face less effective and possibly allowing dust leakage into the respirator.

Interestingly, only nine percent noted that respirator use interfered with tobacco chewing. This would indicate that tobacco chewing is not a serious deterrent to using a respirator. However, it was observed, at most operations, that habitual tobacco chewers make little use of respirators, using a respirator only when the dust level is quite high, and often not even then. Accordingly, tobacco chewing is probably a major deterrent to using respirators, and such chewing is more of a problem than indicated by the responses received during the survey.*

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* Interestingly, there is a belief among some miners that tobacco chewing catches the coal dust.

Head harnesses were found to be a major annoyance and discomfort. Complaints included, head harness not holding the adjustment, thereby requiring several adjustments per shift; likelihood of harness breaking; difficulty of fitting on head, etc. The respirators with two head-straps posed more difficulties than units with one strap; consequently, those with two straps were usually altered to a single-strap configuration by the miner or his wife. This type of alteration affects the position and integrity of the facepiece seal. Some miners using respirators with rubber-head straps wanted elastic straps and vice versa. In summary, head harnesses are a major source of annoyance, and more comfortable head harnesses no doubt would increase respirator use.

Six percent of the underground miners reported the respirator was too large and as a result, there was also interference with vision and the problem of bumping into things (will be discussed subsequently under Interference with Work).

Five percent complained of trouble with the facepiece, and one percent with the fit of the respirator. Essentially, these are the same complaint in that poor, or at least an uncomfortable, fit is a serious shortcoming of most respirators. This, of course, is due to the fact that respirators come in only one facepiece size, whereas there are a number of different sizes of human faces. Because of the facepiece problem, often a miner finds it necessary to make an excessively tight adjustment on the head harness in order to obtain a good seal. This tight adjustment, in turn, causes facial discomfort and, perhaps, headaches. Often too, the facepiece becomes wet from perspiration or condensed moisture from the breath and the facepiece slides around the face. Unfortunately, the knitted boot furnished with some respirators to alleviate this problem is virtually of no help because it quickly becomes dirty and is, therefore, discarded by the workman.

Dust collected inside the mask was reported by 5 percent of the miners as a source of discomfort. Most of these miners felt the presence of such dust was an indication that dust was passing through the filter. Rather, the dust found inside the masks is very likely, a result of a poor seal between face and facepiece, defective exhalation valve, improper position of the filter, or damage to parts which hold the filter in position. Proper training in the use and maintenance of respirators would undoubtedly greatly minimize the problem of dust inside the mask; in addition, such training should point out the real causes of the problem, thereby correcting the erroneous impression of leakage through the filter

2.4.5.3 Interference with Work and Other Difficulties

Nine percent of the underground miners interviewed reported that the use of a respirator interfered with work; this interference was mostly restriction of vision and communications. With respeet to restriction of vision, particularly troublesome are those respirators which are large or fit high on the face; in this connection, mention was made of the MSA 77 respirator. Respirators were also reported as interfering with the use of safety glasses, or goggles, the degree of interference often depending on the shape of the miner's face, as much as on the respirator being used. All respirators interfere, to some extent, with oral communications, and the usual practice is to pull, momentarily, the respirator away from the face in order to talk to other miners. The fact that such is usual practice is probably why interference with communications was not cited as a major problem.

Some miners noted trouble with the exhalation valve becoming warped and admitting dust, while other men stated that respirators are troublesome to carry around when not being worn. While only one percent of the miners reported this as a difficulty, it probably is a more serious problem than indicated. Respirators quickly become dusty if left on a machine, and can be easily damaged if carried around strapped to the miner's belt. Similarly, many men may not recognize the danger of inhaling the dust which has been previously deposited on or in the respirator when it (the respirator) is left on the machine or is being carried around.

2.4.6 Improvements Needed in Respirators

2.4.6.1 Suggestions from Mining Personnel

As has been shown previously in this report, there are major and substantive problems associated with the use of currently available respirators in underground bituminous coal mines. Thus, as might be expected, a large majority of the miners interviewed wanted improvements to be made. Only two percent felt the presently used units could not be improved, but surprisingly, 28 percent had no suggestions for improvement. Improvements suggested are shown in Table 2-15.

TABLE 2-15

IMPROVEMENTS IN RESPIRATORS DESIRED BY MINING PERSONNEL

Improvements	Percent of Underground Work Force*	
	A	B**
Easier Breathing	19	28
Comfortable Facepiece	12	18
Smaller Unit	11	16
Comfortable Head Harness	11	16
Lighter Unit	6	9
Better Filter	5	7
Better Valves	2	4
Easier to Carry	1	2
Educate Men to Use Them	3	-
Cannot be Improved	2	-
Do Not Know	28	-
	100	100

* See Note: Table 2-5

** Percentages Recomputed from Part A by Eliminating last three Items in Part A.

Most of the miners wanted units which made breathing easier or were more comfortable to wear. Nineteen percent suggested easier breathing while 48 percent indicated increased comfort, in some way or other, was the improvement most needed. Of interest here, only three percent felt that more education on how people should use respirators would be of help.

It will be recalled that 37 percent of those interviewed cited hard breathing as a major difficulty (Table 2-14); on the other hand, only 19 percent suggested easier breathing as an improvement needed. Similarly, five percent complained about the facepiece, but 12 percent wanted a more comfortable facepiece; six percent reported that they felt existing respirators were too large, but 11 percent indicated a need for a smaller unit; and 7 percent complained about the head harness, but 11 percent wanted a more comfortable head harness.

From these data it has been concluded that while "hard" breathing is a significant problem with respirators currently in use, the discomfort associated with wearing a respirator induces an increased awareness of breathing difficulties, some of which would otherwise go unnoticed. Stated another way, we believe that in order to achieve willing routine use of respirators, the availability of a respirator(s) that is reasonably comfortable to wear will be required.

2.4.6.2 Design Improvements

From the foregoing, it is evident that comfort is a major consideration, and that the comfort factor is presently influenced substantially by facepiece fit and the head harness.

It would appear comfort might be considerably enhanced by improvements in facepiece design, particularly by providing several different sizes of facepieces for each respirator model. Such improvements would probably greatly alleviate the problem of excessive tension on the head harness. In any event, a facepiece so designed that a good seal could be achieved without excessive tension on the head harness would be a major "first" step forward and possibly could lead to increased respirator use.

Beyond this, is the need for small, lightweight units with, importantly, less resistance to breathing but no loss in dust removal efficiency. These requirements may be mutually exclusive in that decreasing the size of the respirator would probably result in a decrease in filter area and therefore, an increase in breathing resistance. This may, however, not be the case, but it is not within the scope of this project to consider advantages and disadvantages of newer respirator designs.

The use of powered air supplied respirators adapted for coal mine use seems a possible means of overcoming difficulties connected with presently used respirators. In fact, it is known that experimental work is now under way to develop such a unit for coal mine use.*

Accordingly, the possible use of an air supplied unit was discussed with all supervisory personnel and many of the underground miners interviewed. The objective was to learn, at least in a general way, the difficulties which would need to be overcome to have a workable and acceptable unit. First, it was pointed out that a viable air-powered unit should not impede the mobility of the miner. There was expressed the understandable concern that use of a hose line to feed filtered

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*At the time the field survey was made, three coal companies were working with manufacturers toward adapting supplied air respirators, used in other industries, to coal mine use. Since the survey, two models of supplied air respirators have been developed, designed for coal mine use, one under a contract from NIOSH and one under a USBM contract. NIOSH has also contracted to test underground 10 different models of supplied air respirators encompassing cryogenic units, belt carried units, as well as machine mounted units manufactured in the USA and Europe.

air would severely restrict the workman's mobility and his ability to move quickly should such be necessary. For the machine operators there was likewise the "fear" that an air-supplied unit would "tie him to the machine" even though quick disconnect hoses would be provided.

Secondly, it was noted that a suitable air-supplied respirator should add no further encumberances to the miner. In particular, mention was made of the extra weight associated with a filtering and air supply unit that could be attached to the miner's belt -- some expressed the opinion that this would represent an additional burden that would be unacceptable to most miners. Machine mounted air-supply units presumably would overcome this objection, but this would not be universally applicable.

Thirdly, it was quite evident that not only would field testing be required to determine the suitability of new units developed, but the acceptability among working miners would best be obtained by adequate and successful demonstration under actual working conditions. With many miners -- as is true for many people in other occupations -- it is often difficult to visualize what a new device will be and what it can accomplish; consequently, a successful first-hand demonstration is a necessity.

2.4.7 Attitude -- Some General Impressions and Comments

During the in-the-field survey, no attempts were made to make quantitative determinations about attitudes that influenced such things as the use and acceptability of respirators; rather, only qualitative observations were made. Some of these matters of attitude have been discussed previously in this report, but they will be reiterated here primarily for the sake of emphasis.

As might be expected, respirator use is affected by attitudes as well as by tangibles such as breathing difficulties and discomfort when the unit is worn. For example, there seems to be, in certain areas, mental attitudes for or against the using of respirators. In one area visited (West Kentucky), there seemed to be almost a tradition of non-use, while in another, it was traditional to use respirators. Interestingly, the miners in both areas seemed to recognize the need for respirators, but in the former there was not only little use, and many men did not even bother to pick up a respirator from the supply room. In addition, there were a few cases (two large mines and a small one) where the "manhood syndrome" was encountered and where the use of respirators was considered an indication of weakness. These cases seemed to be purely local conditions, i.e., for specific mines, since the mines at which this situation was found were widely separated one from the other; moreover, other mines in the immediate vicinity would not have the same condition. This "manhood syndrome" phenomenon appeared to be created (or perhaps perpetuated) by a small but "vocal" group and mostly affected the younger miner in the large mines, the older men seemingly paying little attention. At the small mine where this condition was found, hardly anyone made use of a respirator and many did not even bring the respirator to the job; likely, many of these could not even find the unit issued.

Other things connected with attitude were not only difficult to understand, but to explain. For example, why would a miner ride around on a shuttle car all day, in an area of visible dust, with a respirator hanging around his neck, but that was never worn? In the same vein, is the average miner more fatalistic or is his temporal sense different from that of the average person? Speculatively speaking, we do not feel miners are any more fatalistic than the many people who hear the National Safety Council predict 600 traffic fatalities for a holiday week-end and then promptly drive to a resort area, not even thinking about the fatality statistics that could apply to them. In other words, many miners do not think much about whether they will contact "black lung" or not. It may be the miner is less future-oriented than much of the population, his thinking being limited pretty much to the present, and is little, if any, concerned about 15 to 20 years in the future, i.e., nothing will happen that takes 20 years. As a result, the miner does not consider he will get "black lung" even though others around him have it. As mentioned, this is highly speculative, being based on limited observations. Thus, there is certainly need for further research on miner attitudes and the factors which affect such, not only on respirator use but in the broad area of health and safety practices.

Lastly, the attitude of mine management had a decided effect on the extent of the acceptance and use of respirators. A "positive" attitude, coupled with instructions on use and encouragement in safety meetings, resulted in a higher percentage of use than where the attitude was "neutral", i.e., no encouragement was given for using respirators. Needless to say, a "negative" attitude, that is, respirators are of little or no value, resulted in little use of and considerable objections to whatever units were provided.

In general, it appears that companies which are engaged in other businesses in addition to coal mining had achieved a greater acceptance and use of respirators than companies only mining coal. This may be due to the fact that the former organizations usually have comprehensive and well-integrated health and safety programs which permit the transfer of useful practices from other operations to coal mining; also, the impression was gained that these companies practice more rigid enforcement. If this impression is correct, it may be that in time these organizations have acquired a work force quite willing to accept and to practice health and safety rules; whereas, those workmen who consider the enforcement of safety and health rules restrictive have, when the opportunity presented itself, moved to companies with less enforcement.

Lastly, important as attitudes may be, in some instances, with respect to the use and acceptability of respirators, there is no doubt the fact that some of the attitudes exist is a reflection on the lack of adequate training programs in respirator use and maintenance. This, of course, is further evidence of the large need for adequate training programs in respirator use and maintenance, training programs which must be an integral part of a well-designed overall program of industrial hygiene and safety.

3. DETERMINATION OF RESPIRATOR EFFECTIVENESS UNDER FIELD CONDITIONS

3.1 General

It has been demonstrated under controlled laboratory conditions, that dust respirators provide excellent protection against the inhalation of airborne dust. However, conditions in the actual underground coal mining environment are undoubtedly quite different from those found in the laboratory. Importantly, even though respirators have been in use for many years in coal mines, so far as is known, experimental work had never been done to determine the protection provided by respirators worn by a working miner. It is, of course, this protection provided under field conditions that is of importance with respect to the health of the working miners.

The matter of determining the protection provided by respirators used under field conditions became increasingly important as results of certain findings obtained from the industry-wide, in-the-field survey of respirator usage (Section 2 of this report). First, the miners felt that there was a definite need for respirators. Second, it was found that there was a significant usage of respirators among the underground work force, particularly those at the working face. Third, the survey results indicated that training in respirator use and maintenance was inadequate, and, fourth, significant improvements were needed with respect to currently used respirators, in two areas, namely wearer comfort and breathing resistance. Thus, for example, it was apparent that work to overcome these shortcomings was of much greater consequence if the currently used units provided good protection under field conditions. Likewise, adequate training in the use and maintenance of present-day units was of increased importance if a high level of protection was found. On the other hand, if it was to be found that the present respirators provided little protection, this would be a strong impetus for investigating a new approach to providing respiratory protection to coal miners.

In order to determine the protection provided in the field by currently available dust respirators, it was necessary to measure the concentrations of respirable dust working miners would inhale with and without a respirator. To accomplish this, the best means seemed to be to sample separately, but concurrently, the ambient air and the air inside the respirator facepiece, the concentration of respirable dust being measured for both samples. Accordingly, appropriate sampling equipment and procedures were developed and two in-mine test programs were carried out. Two test programs were carried out because, as will be discussed, subsequently, it seemed appropriate to determine two different protection factors.

3.2 Protection Factors and In-Mine Testing

3.2.1 General

Results of the in-the-field survey clearly confirmed that working miners did not wear the respirator continuously but rather intermittently throughout the working shift. Moreover, while the total usage of dust respirators during the entire shift was appreciable, miners frequently put the respirator on and shortly, thereafter, took it off; miners were observed doing this as much as 10 to 15 times per hour. Of course, with intermittent wearing there are periods when miners are not wearing the respirators, thereby receiving no protection. In any event, it seemed appropriate to determine protection in such a manner that would take into account intermittent wear. This was done by determining the Effective Protection Factor (EPF), defined as the level of protection obtained by a working coal miner over the entire working shift when the respirator is worn according to the miner's training and work habits. The EPF was determined by sampling separately, but concurrently, the ambient air and the air inside the respirator facepiece over the entire working shift. The concentration of respirable dust was determined for each sample and the EPF calculated as follows:

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

where:

EPF = Effective Protection Factor
DC_A = Respirable Dust Concentration in the Mine Air
DC_M = Respirable dust concentration in the air in the respirator mask.

Since sampling was done over the entire working shift, both DC_A and DC_M are time weighted average concentrations of respirable dust.

While EPF provides very useful information about overall protection afforded the working miner, it does not reveal specifically how well the respirator protected the miner at the time the respirator is worn. Consequently, it was decided to determine True Protection Factor (TPF) which is defined as the level of protection the user receives during those periods of time he is actually wearing the respirator. TPF was calculated as follows:

$$TPF = \frac{DC_S}{DC_R}$$

where:

TPF = True Protection Factor
DC_S = Respirable Dust Concentration in the Mine air in vicinity of miner wearing the respirator.
DC_R = Respirable Dust Concentration inside respirator facepiece when miner is wearing the respirator.

3.2.2 EPF Sampling Equipment and Test Program and Procedures for In-Mine Testing

3.2.2.1 Sampling Equipment

The test equipment, which is shown in Figure 3-1, consisted of two separate mass respirable sampling systems, one for ambient air and one for in-mask, and also a time-of-wearing device for measuring the time a test subject wears a respirator. A test subject wearing the test sampling equipment is shown in Figure 3-2.

The system for sampling mine air (system on right in Figure 3-1) was the same as that presently used in many coal mines in connection with respirable dust compliance standards, and consisted of Mine Safety Appliances* (MSA) No. 456058, Monitair, Model G pump and an MSA No. 456242 Holder Assembly, which included a 10 mm AEC nylon cyclone and was equipped with an MSA No. 457193 Filter Cassette. This cassette consisted of a plastic case and filter capsule which included the ashless filter membrane, fiber backing pad and foil inlet cone. (As will be discussed later, the entire filter capsule was weighed to determine the respirable dust concentration.)

The second system, which was used to sample air in the mask and to determine the time the respirator was actually worn, was, of course, somewhat different. While the same MSA pump was used, the sampling head and filter assembly or filter cassette were not the same as those used in the system for ambient air. A special lightweight sampling head, was used for sampling in-mask air, and was mounted directly on the respirator facepiece using a Luer-Lok fitting. This sampling head consisted of the 10 mm AEC nylon cyclone, a plastic connector for connecting a tube from the pump, and a filter assembly, all of which were held together by a spring clip. This filter assembly, which was used to collect the respirable dust

* Mention of trade names or manufacturers is for identification only and does not constitute endorsement by either Eastern Associated Coal Corp. or the National Institute for Occupational Safety and Health.

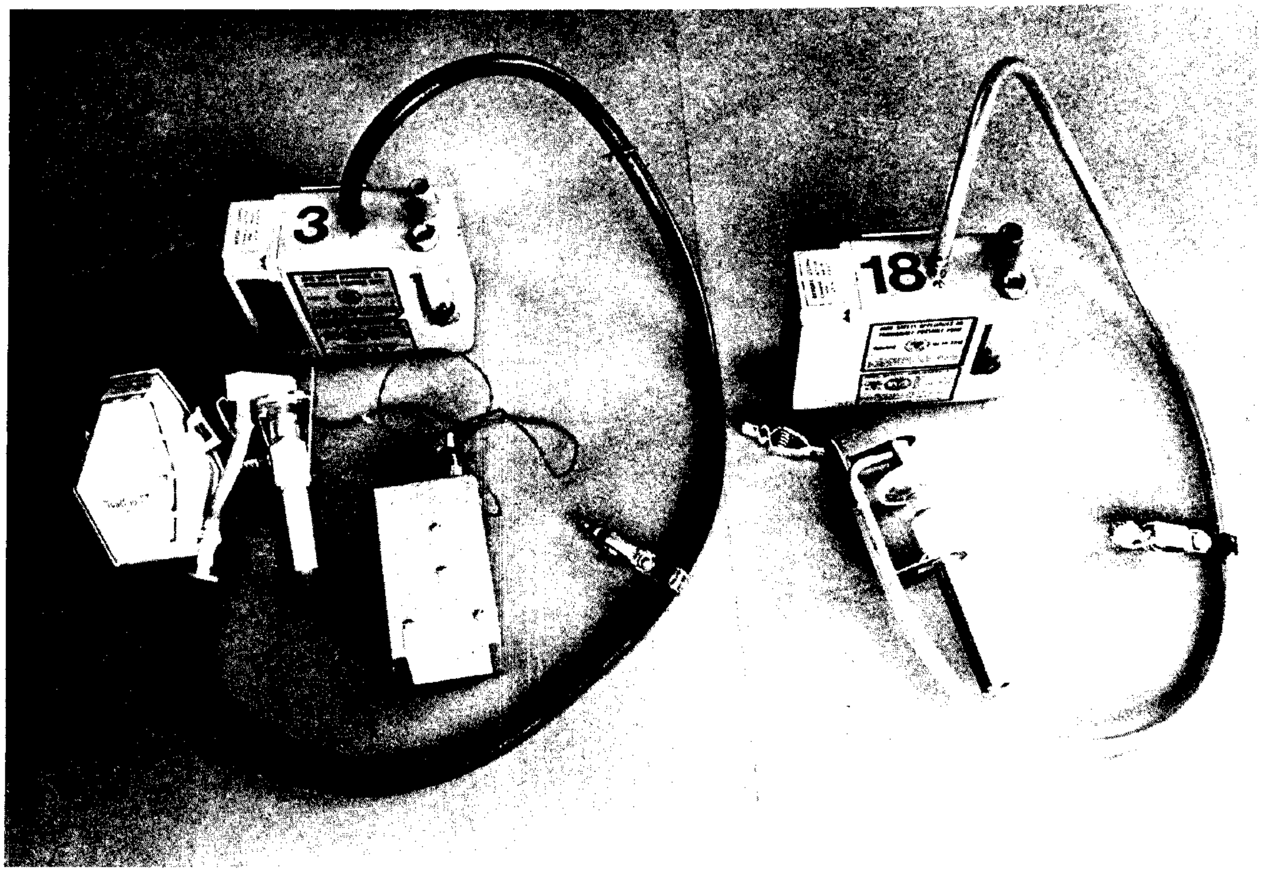


Figure 3-1. Sampling Equipment for In-Mine Testing

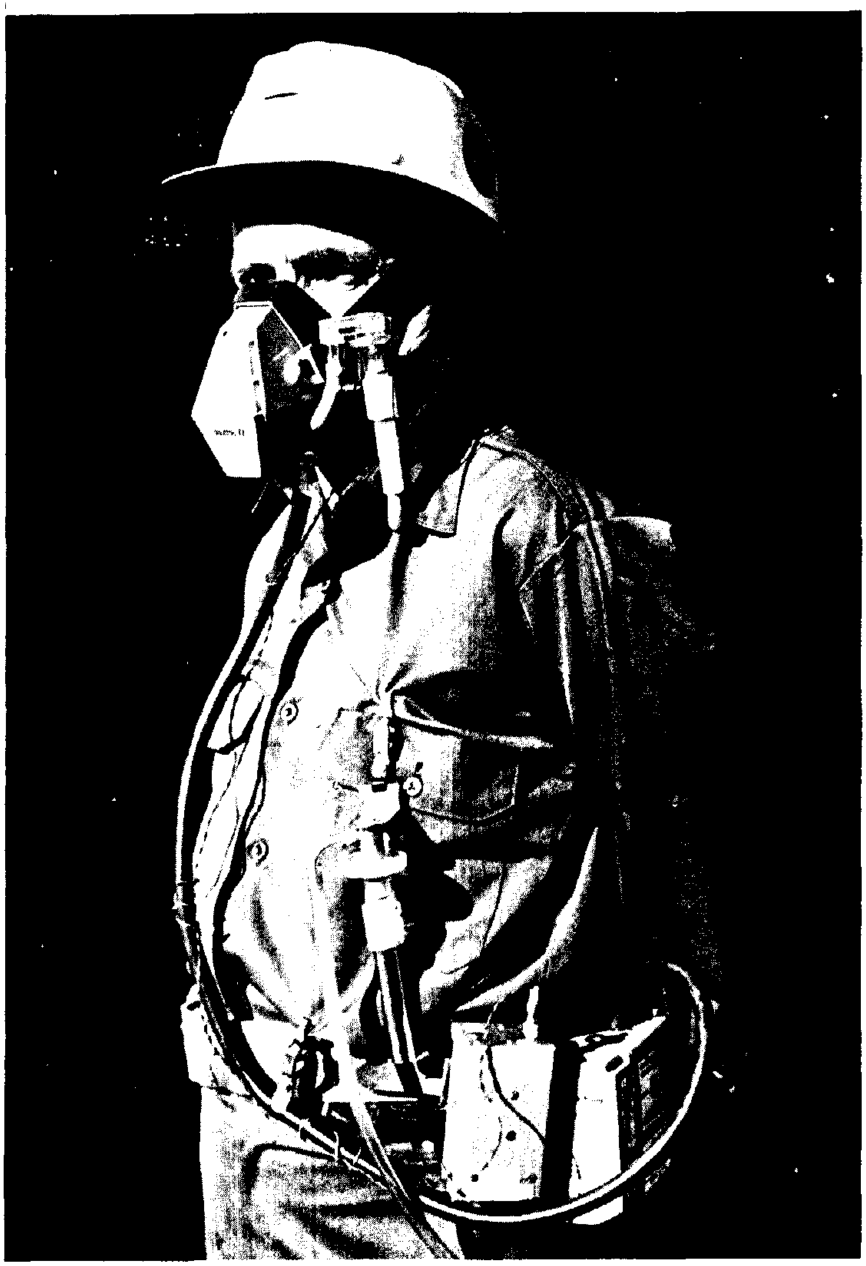


Figure 3-2. Test Subject Wearing Sampling Equipment

from the in-mask air, was made by taking the aforementioned MSA No. 457193 filter cassette and removing the filter capsule, and replacing this capsule with a MSA No. 625413 ashless membrane filter and MSA No. 456224 stainless steel support screen. (In the case of this filter assembly, only the ashless membrane filter was weighed to determine respirable dust concentrations.) These substitutions were made to improve precision with which weight of dust collected could be determined. If the conventional filter capsule had been used, variations in weight due to changes in humidity would have been more likely.

Since essentially all miners use respirators on an intermittent basis, it was important to determine the amount of protection provided by a respirator in relation to the amount of time it was worn over the working shift by the subject miner. To obtain an accurate measurement of actual wearing time, each subject miner wore a small timing device that depended on the difference in temperature between the ambient air and the miner's breath inside the respirator. A thermistor was located inside the respirator facepiece, Figure 3-3, and sensed the temperature of the miner's breath. A reference thermistor was located in the timer box worn on the miner's belt and sensed the temperature of the ambient air. The two thermistors were connected in a Wheatstone bridge circuit. A coulometric device (Curtis 150SP2), Figure 3-4, integrated the total time the bridge was unbalanced, that is, the time the mask thermistor was exposed to body temperature. The device could be read to 0.1 hour. The circuit diagram is shown in Figure 3-5.

Six different respirator models produced by three manufacturers were used in the study. Four of these respirator models, the MSA 77, MSA 66, AO R-2090 and Welsh 7100 accounted for 80 percent of all respirators found in general use during the in-the-field survey. The

Figure 3-3. Inside of Respirator Facepiece showing Thermistor

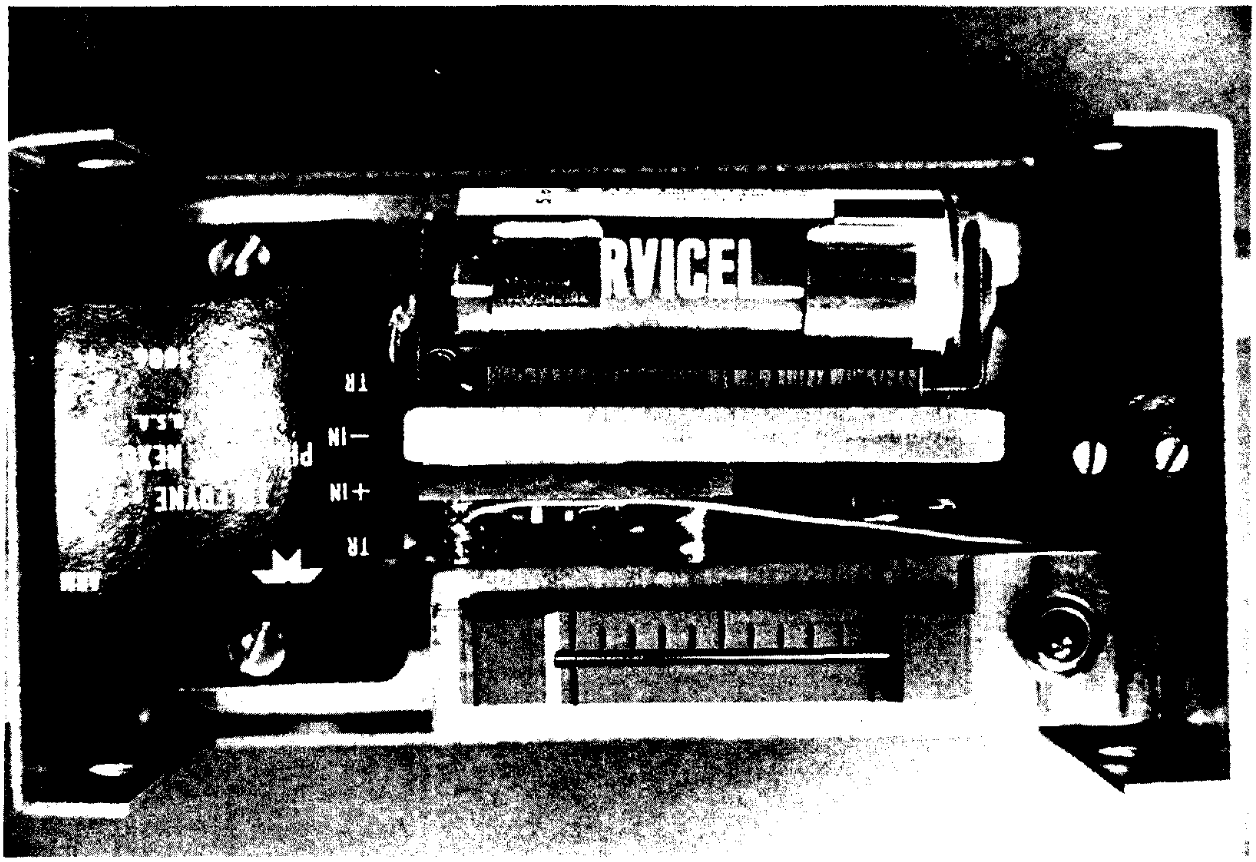
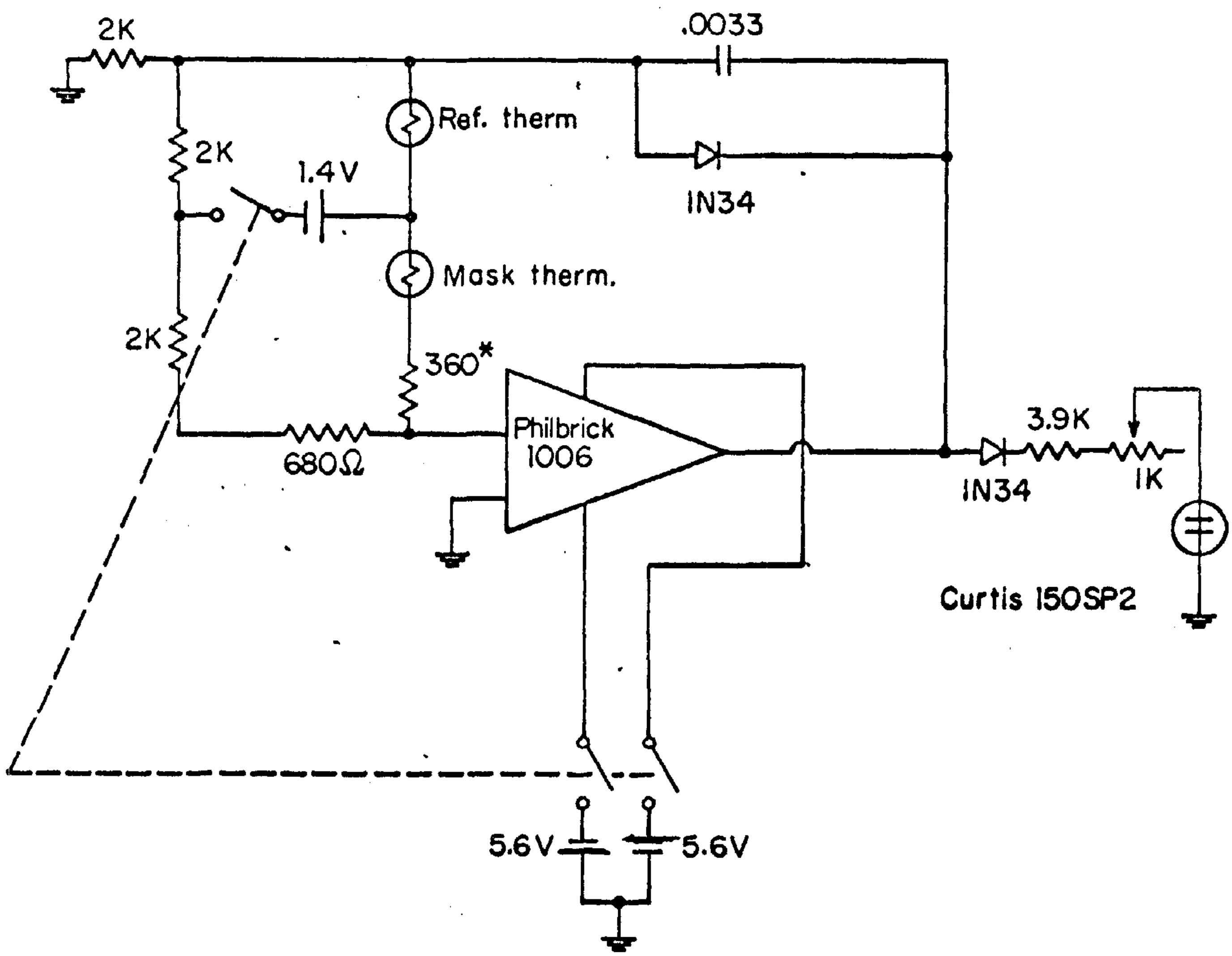


Figure 3-4. Time-of-Wearing Device
showing Coulometric Timing Device

FIGURE 3-5

CIRCUIT DIAGRAM - TIME OF WEARING DEVICE



*Selected Value

Batteries - Eveready Mercury Cell No. E 164 NEDA 1414 M   5.6 volts
- Eveready Mercury Button Cell No. E625   1.4 volts

Thermistors - Fenwall JB3 1J1

All Resistors - 1/4 Watt,

fifth respirator model, Welsh 7400, was not found during the in-the-field survey but was substituted for the Willson Monomask* when the Monomask was temporarily withdrawn from the market at the time the in-mine test program was being developed and trial runs scheduled. The Welsh 7400 was selected because it was 21-b approved and was a somewhat larger and flatter mask than the other units selected for inclusion in the study. Complaints registered during the in-the-field survey concerned poor or uncomfortable fit and interference with vision. Since the construction of the 7400 was slightly changed from the other units, it was felt that inclusion of this model might also provide some insight into fit and vision problems. The sixth respirator examined, the Welsh 7165, is a single use, or "throw away" design, to be used for one shift and then discarded. The field evaluation indicated (see Section IV of this report) it had a high degree of acceptance by working miners; consequently, it was included in the group to be evaluated for Effective Protection Factor. A detailed description of respirators used is given in Appendix 3-1.

3.2.2.2 Test Program and Procedures for In-Mine Testing

The test program for determining EPF was carried out in five different mines. In three mines, only working miners on face sections were involved; in one mine only a rock duster crew participated and at the remaining mine, miners on face sections and in rock dusting crews were involved. Pertinent

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* The Willson Monomask, which accounted for about one percent of the respirators found in general use during the field survey, was 21-b approved but was subsequently withdrawn from the market. At the time respirators were being purchased for use in the in-mine test work, the Monomask was not available. Although the withdrawal was reported temporary, a firm date for its return to availability could not be given. Under these conditions, a decision was made to substitute another model respirator. As of June, 1973, the Monomask has not yet been returned to the market as an approved respirator.

data on test mines and mining sections is given in Table 3-1. A description of the mining equipment used and conditions found on the test sections as well as rock dusting is contained in Appendix 3-2.

At each mine, except for one case (Mine A)*, where testing on face sections was involved, testing was done for five consecutive working days on two separate mining sections. Generally, on each mining section, four working miners involving different job classifications and one research investigator, designated as an observer, participated as test subjects. Each test subject wore the same respirator for the five-day period. Those miners taking part in the in-mine test work are listed by mine, section and job classification in Table 3-2. Also listed are the respirator model worn by each test subject, the age of the test subjects and years of experience as a miner. The number of test subjects wearing the different models of respirators is shown in Table 3-3.

Prior to the start of testing at each mine, project personnel, in conjunction with personnel from the safety and operating departments, briefed the test subjects on pertinent matters pertaining to the test program. At the same time, general data on the personnel and mining sections was obtained.

Briefly, the actual day-to-day testing consisted (details are set forth in Appendix 3-3) of having the test equipment transported underground to working areas where the coal was to be mined. Therefore, under the supervision of the observer, each test subject put on the test equipment, and the equipment was checked before the sampling pumps were started. In many cases, the ambient air sampling equipment was worn by the test subject;

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* The testing done at Mine A was in the nature of a pilot-program for the full-scale testing done subsequently at three other mines. Also included was some testing on 100 percent time-of-wearing of the respirator (see Appendix 3-3).

TABLE 3-1

TEST MINES AND MINING SECTIONS

Mines	Coal Seam	Mining Sections
Mine A	Pittsburgh	2 Continuous Sections 2 Rock Dusting Crews
Mine B	No. 2 Gas	3 Continuous Sections
Mine C	No. 2 Gas	1 Conventional Section 1 Longwall Section
Mine D	Pocahontas No. 3	1 Continuous Section 1 Conventional Section
Mine E	Pittsburgh	1 Rock Dusting Crew

TABLE 3-2

GENERAL INFORMATION ON TEST SUBJECT

Mine	Section	Test Subject No.	Job Classification	Age	Years as Miner	Extent of Previous Respr. Use[a,b]	Respiratory Problems[a,c]	Respirator Used During Test Series
A	Continuous Mining	1	Continuous Mining Machine Operator	53	31	Regular User	None	MSA-66
		2	Loading Machine Operator	28	10	Occasional User	None	MSA-77
		3	Roof Bolter	62	32	Regular User	None	AO-R2090
		4	Brattice Man	34	17	Occasional User	None	MSA-77
		5	Observer	49	0	Occasional User	None	Welsh 7100
	Continuous Mining	6	Continuous Mining Machine Operator	33	7	Regular User	None	AO-R2090
		7	Loading Machine Operator	55	24	Regular User	None	MSA-66
		8	Shuttle Car Opr.	62	31	Occasional User	Moderate	MSA-77
		9	Brattice Man	50	21	Occasional User	None	MSA-77
		10	Observer	36	11	Occasional User	None	Welsh 7100
B	Continuous Mining	11	Continuous Mining Machine Operator	48	25	Regular User	None	MSA-77
		12	Roof Bolter	45	19	Regular User	None	MSA-77
		13	Loading Machine Operator	53	24	Regular User	None	AO-R2090
		14	Shuttle Car Opr.	49	23	Regular User	None	MSA-66
		15	Observer	49	0	Occasional User	None	Welsh 7100
	Continuous Mining	16	Continuous Mining Machine Operator	32	6	Regular User	None	MSA-66
		17	Roof Bolter	28	3	Regular User	None	MSA-77
		18	Loading Machine Operator	48	32	Regular User	None	AO-R2090
		19	Shuttle Car Opr.	58	34	Non User	None	MSA-77
		20	Observer	28	4	Non User	None	Welsh 7100

Mine	Section	Test Subject No.	Job Classification	Age	Years as Miner	Extent of Previous Respr. Use[a,b]	Respiratory Problems[a,c]	Respirator Used During Test Series
	Continuous Mining	41	Shuttle Car Operator	42	22	Regular User	None	Welsh 7165
		42	Shuttle Car Operator	43	16	Regular User	None	Welsh 7165
		43	Shuttle Car Operator	50	24	Regular User	None	Welsh 7165
		44	Shuttle Car Operator	47	18	Regular User	None	Welsh 7165
		45	Shuttle Car Operator	52	31	Regular User	Moderate	Welsh 7165
		46	Observer	50	0	Occasional User	None	Welsh 7165
		47	Shuttle Car Operator	53	21	Regular User	None	Welsh 7165
C	Longwall Mining	21	Longwall Machine Headgate Operator	29	5	Occasional User	None	Welsh 7400
		22	Longwall Machine Tail Operator	24	4	Regular User	None	MSA-66
		23	Longwall Jack Machine Operator	26	7	Occasional User	None	AO-R2090
		24	Longwall Jack Machine Operator	23	4	Occasional User	None	MSA-66
		25	Observer	49	0	Occasional User	None	Welsh 7100
	Conventional Mining	26	Cutting Machine Opr.	46	28	Regular User	Slight	MSA-66
		27	Loading Machine Opr.	37	14	Regular User	None	AO-R2090
		28	Shuttle Car Operator	23	3	Occasional User	None	MSA-77
		29	Coal Driller Operator	43	8	Regular User	None	MSA-66
		30	Observer	23	2	Non User	None	Welsh 7400
D	Continuous Mining	31	Continuous Mining Machine Operator	49	30	Regular User	Moderate	MSA-66
		32	Shuttle Car Operator	29	7	Non User	None	MSA-77
		33	Shuttle Car Operator	48	30	Non User	Moderate	AO-R2090
		34	Continuous Mining Machine Helper	47	27	Regular User	Slight	Welsh 7400
		35	Observer	49	0	Occasional User	None	Welsh 7100
	Conventional Mining	36	Loading Machine Opr.	48	28	Occasional User	Serious	AO-R2090
		37	Cutting Machine Opr.	46	28	Occasional User	None	MSA-66
		38	Coal Driller Operator	58	33	Occasional User	None	Welsh 7400
		39	Shuttle Car Operator	48	22	Occasional User	Slight	MSA-77
		40	Observer	27	2	Non User	None	MSA-66

Mine	Section	Test Subject No.	Job Classification	Age	Years as Miner	Extent of Previous Respr. Use	Respir-atory Problems	Respirator Used During Test Series
A	Rock Dusting Crew	50	Rock Duster	32	7	Regular User	None	MSA-66
		51	Rock Duster	55	29	Regular User	None	MSA-66
		52	Rock Duster	42	7	Regular User	None	AO-R2090
		53	Rock Duster	52	36	Regular User	None	AO-R2090
E	Rock Dusting Crew	54	Rock Duster	52	25	Regular User	None	MSA-77
		55	Rock Duster	47	22	Regular User	None	MSA-77
		56	Foreman	38	21	Occasional User	None	MSA-77
		57	Foreman	41	19	Occasional User	None	MSA-77
		58	Observer	50	0	Occasional User	None	MSA-77

FOOTNOTES FOR TABLE 3-2

a. Information furnished by test subjects.

b. Regular, Occasional, and Non User are defined as follows:

   (1). Regular User - wears a respirator each day while doing his regular work

   (2). Occasional User- brings a respirator to work area but does not wear the respirator daily but wears it now and then

   (3). Non User - person who does not carry respirator and rarely, if ever, wears one.

c. None, Slight, Moderate and Serious are defined as follows:

   (1). None - so far as individual knows, no present or past chronic respiratory problems

   (2). Slight - individual thinks his breathing is not as good as it once was, but cannot necessarily show discernible signs of this

   (3). Moderate - individual reports shortness of breath after walking about 100 yards

   (4). Serious - individual reports shortness of breath after walking short distance (5-10 yards) around work area.

TABLE 3-3

RESPIRATORS TESTED BY MODEL

Respirator Model	No. of Test Subjects
Face Miners	
MSA 66	11
MSA 77	11
AO R-2090	8
Welsh 7100	6
Welsh 7400	4
Welsh 7165	7
Rock Dusting Crews	
MSA - 66	2
MSA - 77	5
AO R-2090	2

however, in some cases, local conditions indicated this sampling equipment should be located elsewhere but, of course, be nearby the test subject. Pertinent details concerning sampling locations are given in Appendix 3-4.

Once the test equipment was in place, sample pumps were turned on and the test subjects began their regular work. Pumps were run continuously, except for the lunch break, until the end of the work period, at which time the test equipment was removed and packed for transporting to the surface. During the work period, the observer recorded pertinent data on the Daily Record form, Appendix 3-5. Figures 3-6, 3-7, 3-8 and 3-9 show test subjects with testing equipment performing their regular work tasks.

After having been brought to the surface, the test equipment was taken to a field laboratory where the test respirators were carefully checked, sanitized and repaired, if necessary. Sampling pumps were inspected and put on charge so that the batteries would be at full strength for use the next day. Time-of-wearing devices were read and the time each test subject wore his respirator was recorded; these time-of-wearing devices were then reset to be ready for use the following day.

Special techniques were used when handling and processing the filter capsule and membrane filter used to collect the respirable dust sample from the ambient mine air and from the in-mask air, respectively. The need for such handling and processing was especially critical for the filter used for in-mask dust because of the small amount of dust likely to be collected, generally microgram quantities, and because of moisture, which will be discussed later.

Tare weighing of the filter capsules, which were subsequently used to measure dust in the ambient air, was accomplished by removing the filter capsule from the plastic cassette, equilibrating it for several hours and

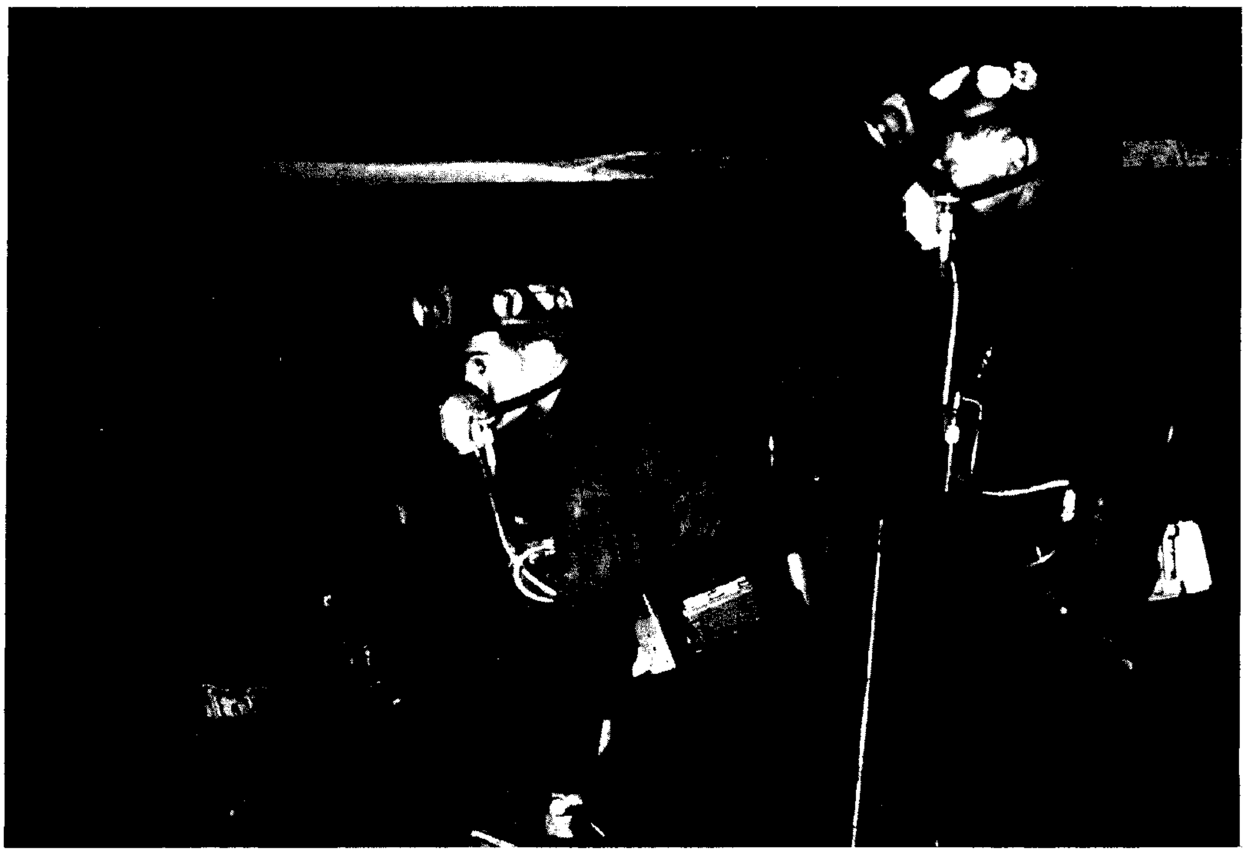


Figure 3-6. Continuous Mining Machine Operator and Roof Bolter Wearing Sampling Equipment

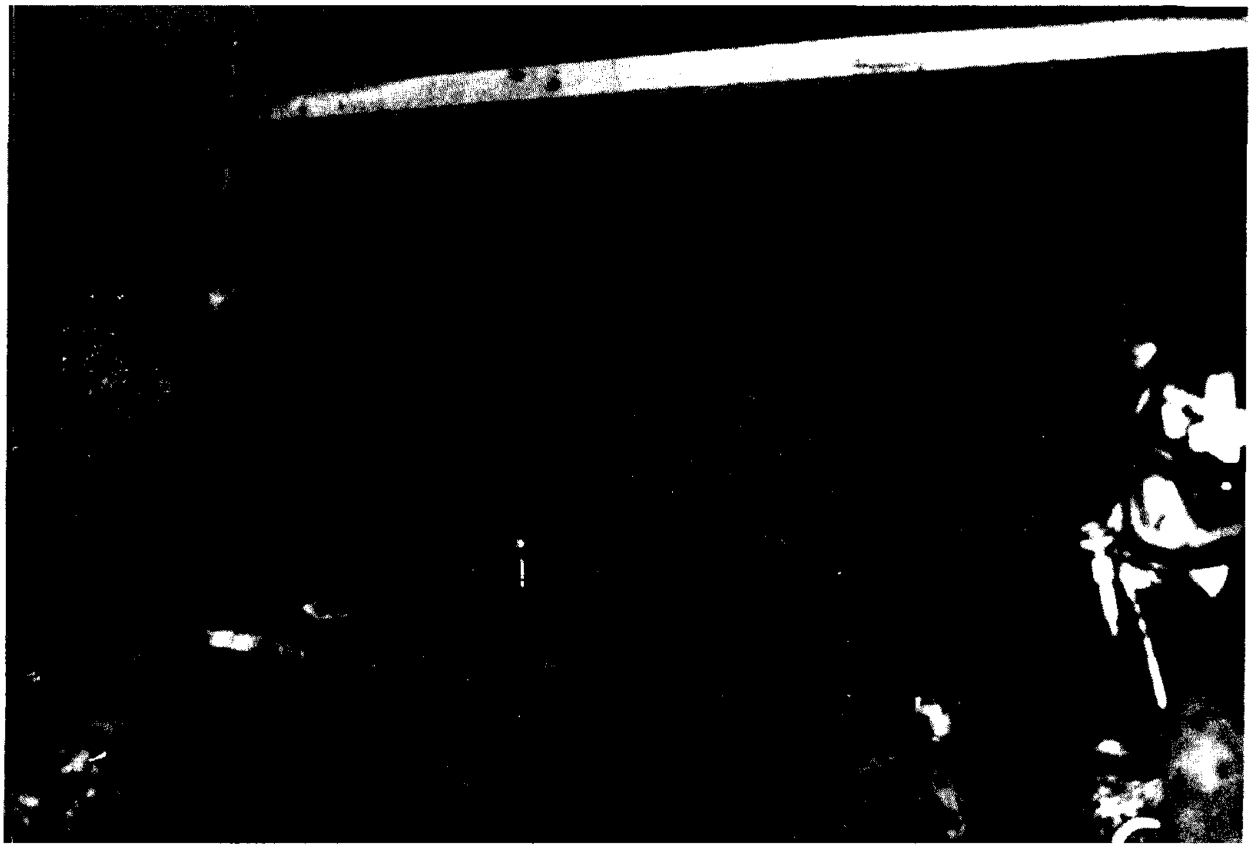


Figure 3-7. Continuous Mining Machine Operator
Wearing Sampling Equipment

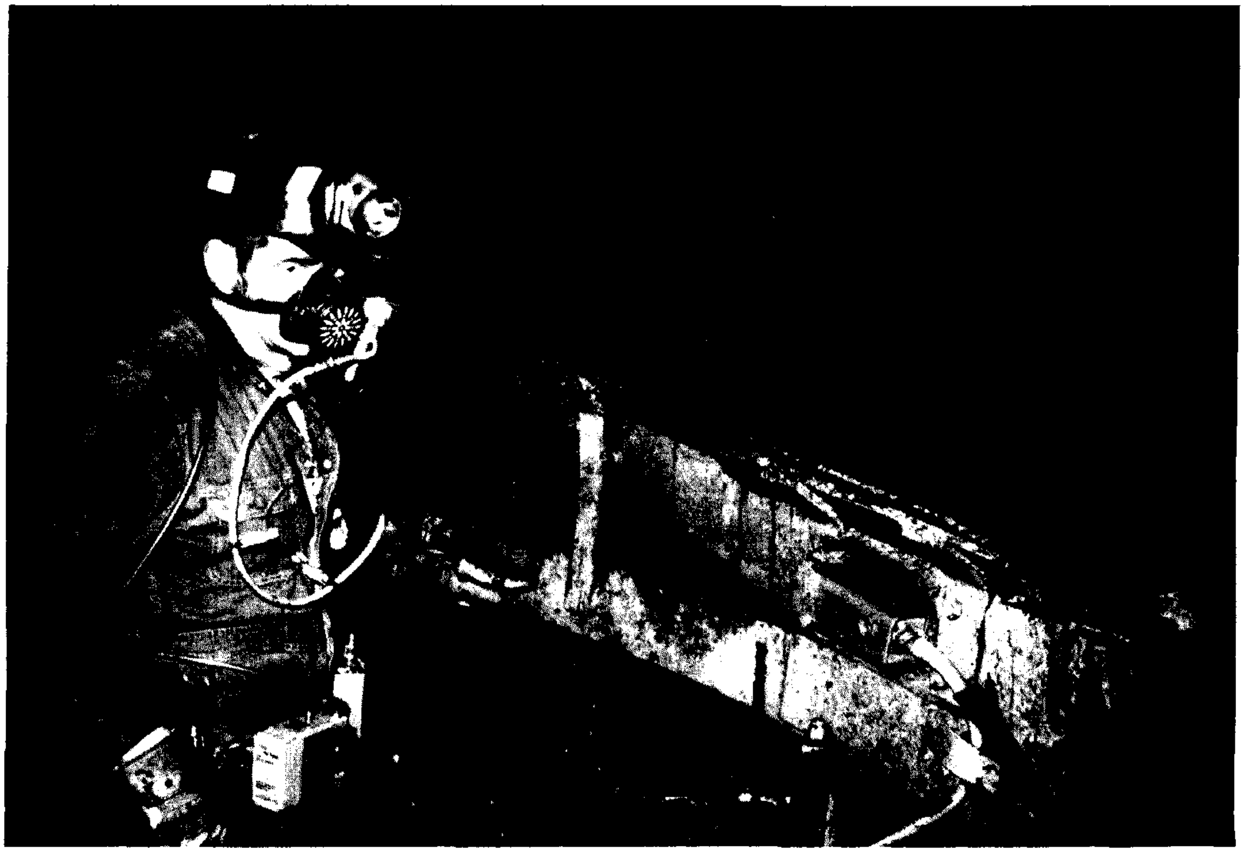


Figure 3-8. Loading Machine Operator
Wearing Sampling Equipment

Figure 3-9. Shuttle Car Operator
Wearing Sampling Equipment

weighing on a Mettler balance, accurate to 0.1 milligrams. The filter capsule was then replaced in the cassette. The filters used for the in-mask air were similarly tare weighed and handled, except that weighing was done on a Cahn MF Electrobalance with an accuracy of 1 microgram. The same equilabration and weighing procedures were followed when the filter capsule and membrane filters were reweighed after use. Aside from the normal precautions usually taken, no special treatment in the field was needed for the filter capsules used for collecting ambient air dust samples. However, it was necessary to use a special drying procedure for those filters used for in-mask dust samples.

Moisture from the miner's breath was collected in the in-mask sampling system. If the moisture were allowed to remain on the filters while these were in transit from the field to the Harvard School of Public Health laboratory for weighing, growth of fungi or other microscopic life might occur on the filter surface and thereby make an accurate determination of the dust collected impossible. Therefore, all in-mask filters were dried in the field prior to shipment for weighing. This was done by passing filtered room air through the filter assembly for a minimum of two hours at a rate of 2 liters per minute. This drying system, which is shown in Figure 3-10, successfully removed all traces of condensed moisture. After drying, the holes in the filter assembly (plastic cassette case) were stoppered and the assemblies packed and shipped.

3.2.3 TPF Sampling Equipment and Test Program and Procedures

3.2.3.1 Sampling Equipment

The sampling equipment used to determine TPF consisted of two GCA-RDM 101-4*[6] (see Appendix 3-6) Respirable Dust Monitors; one of these was used to measure the respirable dust concentration in the ambient air directly in front of the test subject's face and the other was used to

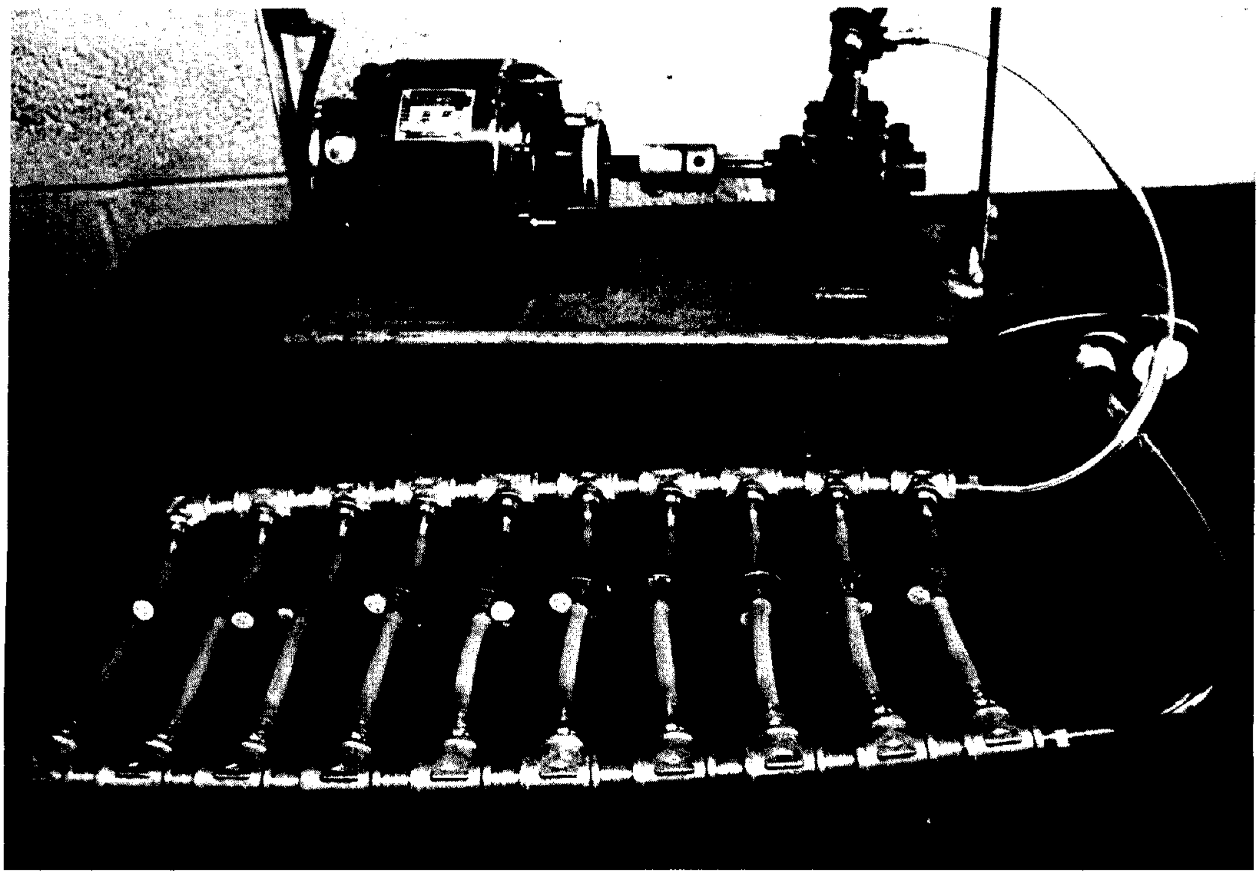


Figure 3-10. Field Drying System
for Filter Assembly

measure (at the same time) the respirable dust concentration in the air inside the respirator facepiece.

The same models of respirators employed in the EPF test work were used in TPF testing. The latter group of respirators were also modified by the insertion of a sampling port; however, the AEC 10 mm cyclone was mounted on the GCA dust monitor instead of on the respirator as in the EPF study. Figure 3-11 shows the GCA RDM-101 dust monitor and Figure 3-12 shows this equipment in use underground.

3.2.3.2 Testing Program and Procedure For In-Mine Testing

Since face shape is probably an important variable affecting the level of protection obtained by the respirator user, it was decided that the test program should involve at least one miner in each of 9 categories of face size described by Hyatt[7/] (see Appendix 3-7), Figure 3-13 and each test subject would wear all six respirators.

Accordingly, facial measurements were made on a panel of 44 miners, (see Appendix 3-7). Since no miners with face classification I, see Figure 3-13, were found, two test subjects for classification E were selected in addition to one each in the remaining seven classifications. In all, 9 men representing 8 different face size classifications participated in the underground testing.

As mentioned, each test subject wore all six respirators, each respirator being worn (intermittently, of course) for approximately one half of a working shift. During this half-shift period, four separate sampling operations were conducted; each sampling operation consisted of sampling, concurrently, for a four minute period the ambient air and air inside the facepiece of the respirator being worn by the working test subject. Care was taken to see that it was being worn in accordance with the manufacturer's recommendations; further details are contained in Appendix 3-7.

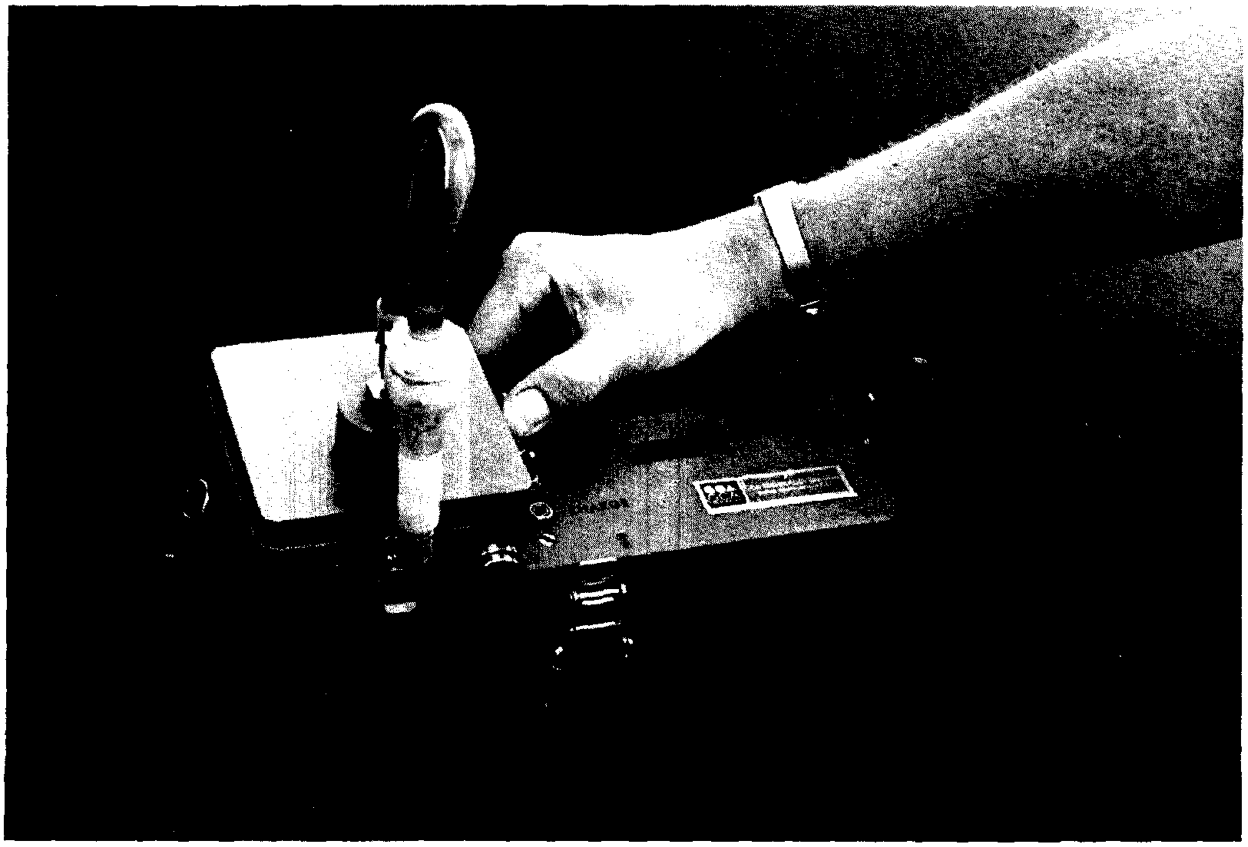


FIGURE 3-11 Picture of AEC Cyclone- GCA Monitor

FIGURE 3-12 Sampling Equipment in Use Underground

<u>FIGURE 3-13</u>

<u>FACE SIZE CLASSIFICATION DIAGRAM</u>

Face Width, mm

Face Length mm	129 - 139	140 - 145	146 - 155
136 126-	A	B	C
125 116-	D	E	F
115 105-	G	H	I

3.3 EPF - Results and Discussion

3.3.1 General - Face Miners

A summary of the scope of underground testing, excluding that involving rock dusters, for determining EPF is given in Table 3-4. Pertinent data for each test subject for each day of testing for which useful data was obtained, is shown in Appendix 3-7. Of 208 man shifts of testing done, useful data was obtained from 188. This is considered extremely good in view of the difficulties associated with conducting testing in a coal mine under actual operating conditions.

Figure 3-14 shows the distribution of EPF for all face miners and Figure 3-15 shows a similar distribution except those cases where 100 percent time of wearing of the respirator was involved. Before proceeding with the discussion of the data, a word about the test results involved with 100 percent time of wearing or continuous use of the respirator.

3.3.2 Continuous Use of the Respirator

While 10 test subjects at Mine A did wear respirators continuously for two days of testing*, such was done only with great difficulty and it must be concluded that continuous use or 100 percent time-of-wearing of the currently available, approved dust respirators is not feasible under the conditions normally encountered by miners at the working coal face.

First-hand observations of the test subjects during the two days of continuous use testing revealed that the miners became noticeably short of breath when doing heavy work or walking rapidly. This observation

* These two days of testing were not done on successive days but there was a one day interval between the two on which the test subjects wore their respirators in the normal intermittent basis.

TABLE 3-4

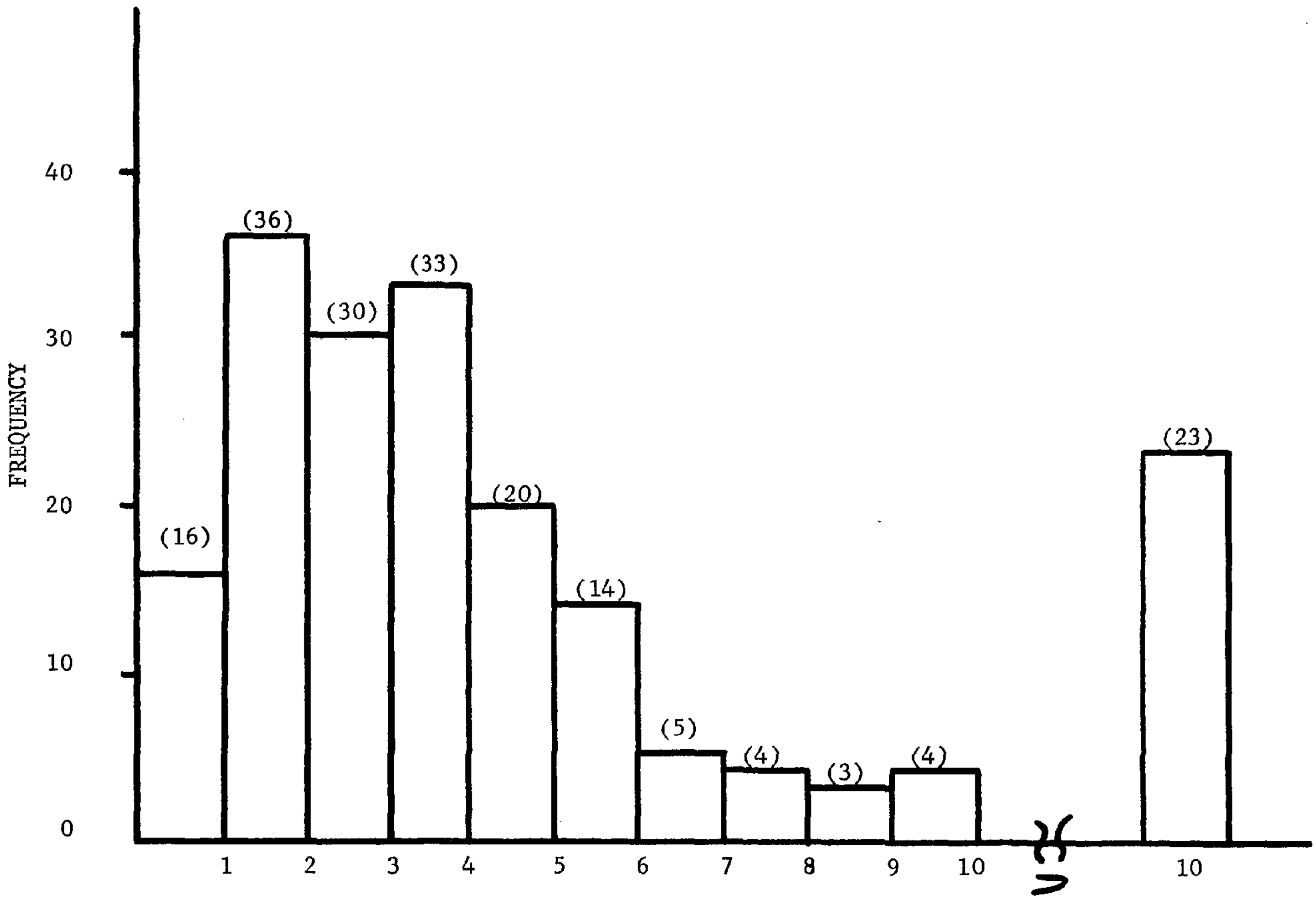
IN-MINE TEST DATA

Mines	
Number	5
Seams	3
Seam Height, In.	56, 60, 84, 120
Sections	
Continuous	7
Conventional	3
Longwall	1
Test Subjects, Job Classifications	
Continuous Mining Machine Operator	5
Continuous Mining Machine Helper	1
Loading Machine Operator	6
Shuttle Car Operators	14
Roof Bolter	3
Bratticeman	2
Cutting Machine Operator	2
Coal Driller	2
Longwall Machine Headgate Operator	1
Longwall Machine Tail Operator	1
Longwall Machine Jack Machine Operator	2
Observer	5
Days of Testing	25
Man Shifts	208
Respirator Model	6
Man Shifts of Testing per Model*	
MSA 66	53
MSA 77	48
AO R-2090	38
Welsh 7100	23
Welsh 7400	25
Welsh 7165	21

*Shifts useful data obtained

EFFECTIVE PROTECTION FACTORS - ALL MINES*

Mean Average 6.2
Median 3.3



EFFECTIVE PROTECTION FACTOR

*Includes Intermittent Use of Respirator and 100% Time-of-Wearing, or Continuous Use of Respirators.

FIGURE 3-14

EFFECTIVE PROTECTION FACTORS - ALL MINES

(Intermittent Use Only)

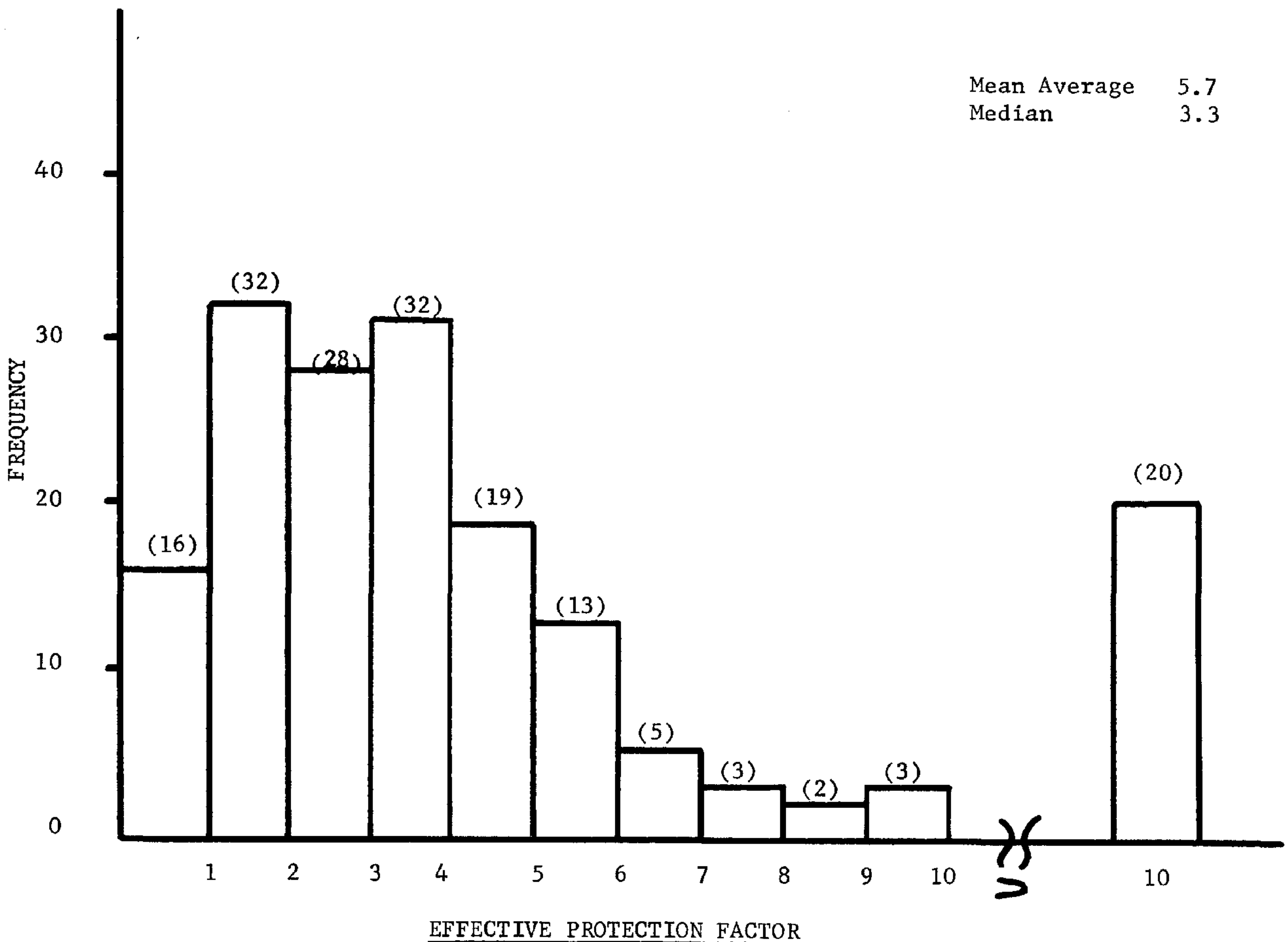


FIGURE 3-15

confirmed one of the findings of the in-the-field survey, namely that one difficulty associated with currently available respirators is that of breathing problems.

Also, it was observed that a fine cooperative spirit and attitude existed among the miner test subjects on the first day prior to the start of actual testing. However, by the time the second day of continuous use testing had been completed, this attitude had deteriorated greatly. No doubt this deterioration was a result of the annoyance and discomfort of wearing a respirator coupled with the fact that the miners were not accustomed to continuous use, nor did many miners feel the need to wear a respirator at such times as when the mine air appeared to be relatively free of dust.

The distribution of Effective Protection Factors obtained at Mine A when the respirator was worn continuously or intermittently is shown in Figures 3-16 and 3-17, respectively.

3.3.3 <u>Effective Protection Factor - All Face Miners Intermittent Use</u>

In view of the fact that it has been well demonstrated that continuous use of currently available, approved respirators throughout the work shift is not feasible, the balance of the discussion will involve only data in which there was intermittent wear of the respirators.

As shown in Figures 3-15 and Table 3-5, the EPF values obtained were distributed over a wide range and there is a skew in the distribution toward the lower EPF's, Figure 3-15. Essentially, this same pattern was found for Mines B, C and D, Figures 3-18, 3-19 and 3-20, respectively. It should be noted, however, that EPF values above 20.0 and less than 1.0 were obtained at all mines where testing was done. There was no valid reasons that these extremely high EPF values or those less than 1.0 should be considered as anomalies.

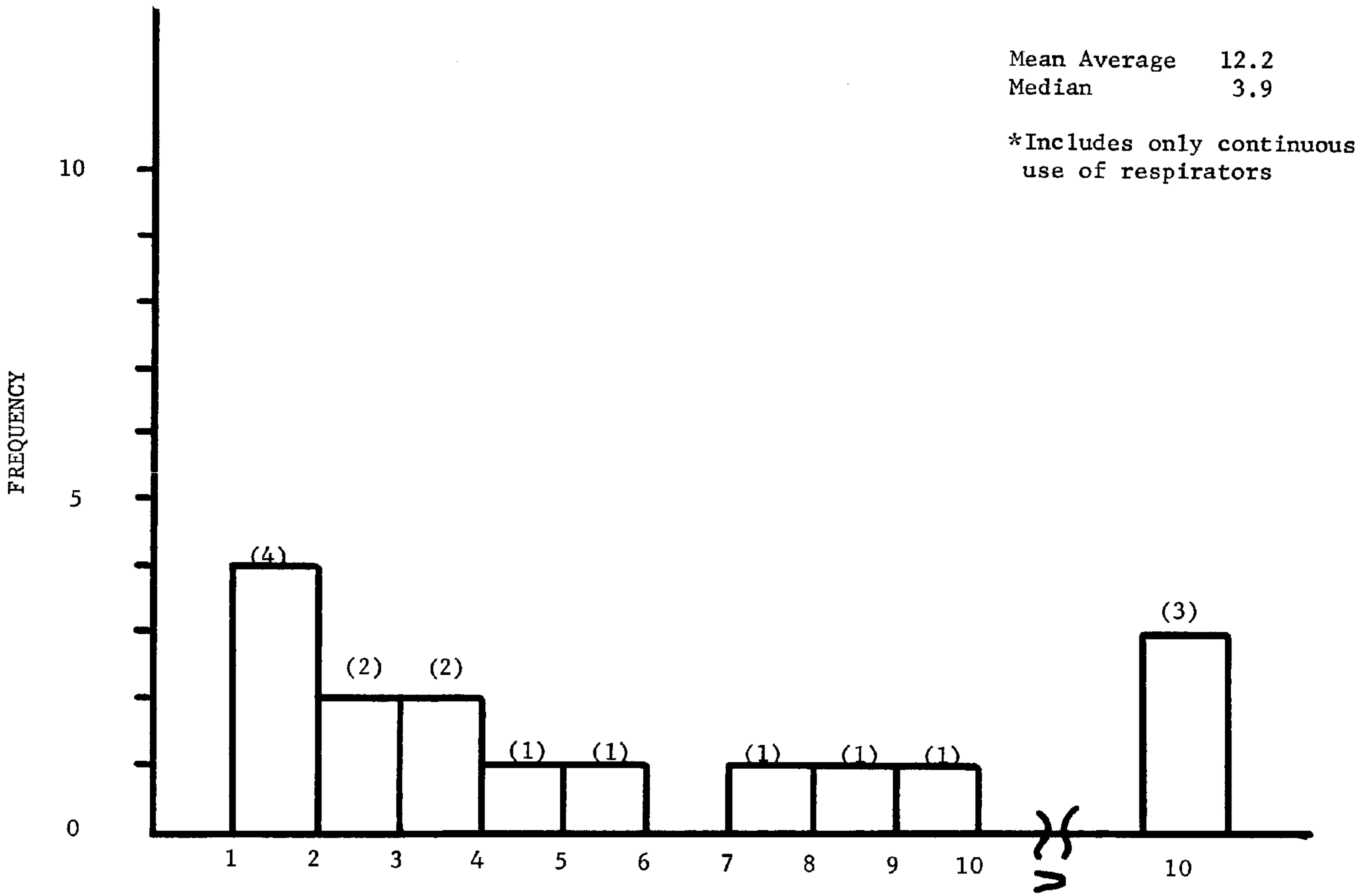
TABLE 3-5

PERCENTAGE DISTRIBUTION OF EFFECTIVE PROTECTION FACTORS

Number of Observations, Cumulative Percent

EPF	All Mines	Mine B	Mine C	Mine D
+ 10	11.6	10.6	4.1	16.7
9-10	13.3	12.1	4.1	18.7
8-9	14.4	13.6	4.1	20.8
7-8	16.2	15.1	6.1	22.9
6-7	19.1	19.7	6.1	27.1
5-6	26.6	28.8	14.3	33.3
4-5	37.6	40.9	22.4	47.9
3-4	55.5	60.6	40.8	60.4
2-3	71.7	74.2	67.3	70.8
1-2	90.8	90.9	87.8	91.7
-1	9.2	9.1	12.2	8.3
Mean Ave.	5.7	6.0	4.5	5.6
Median		3.4	2.6	3.6

EFFECTIVE PROTECTION FACTORS - MINE A*



EFFECTIVE PROTECTION FACTOR

FIGURE 3-16

EFFECTIVE PROTECTION FACTORS - MINE A*

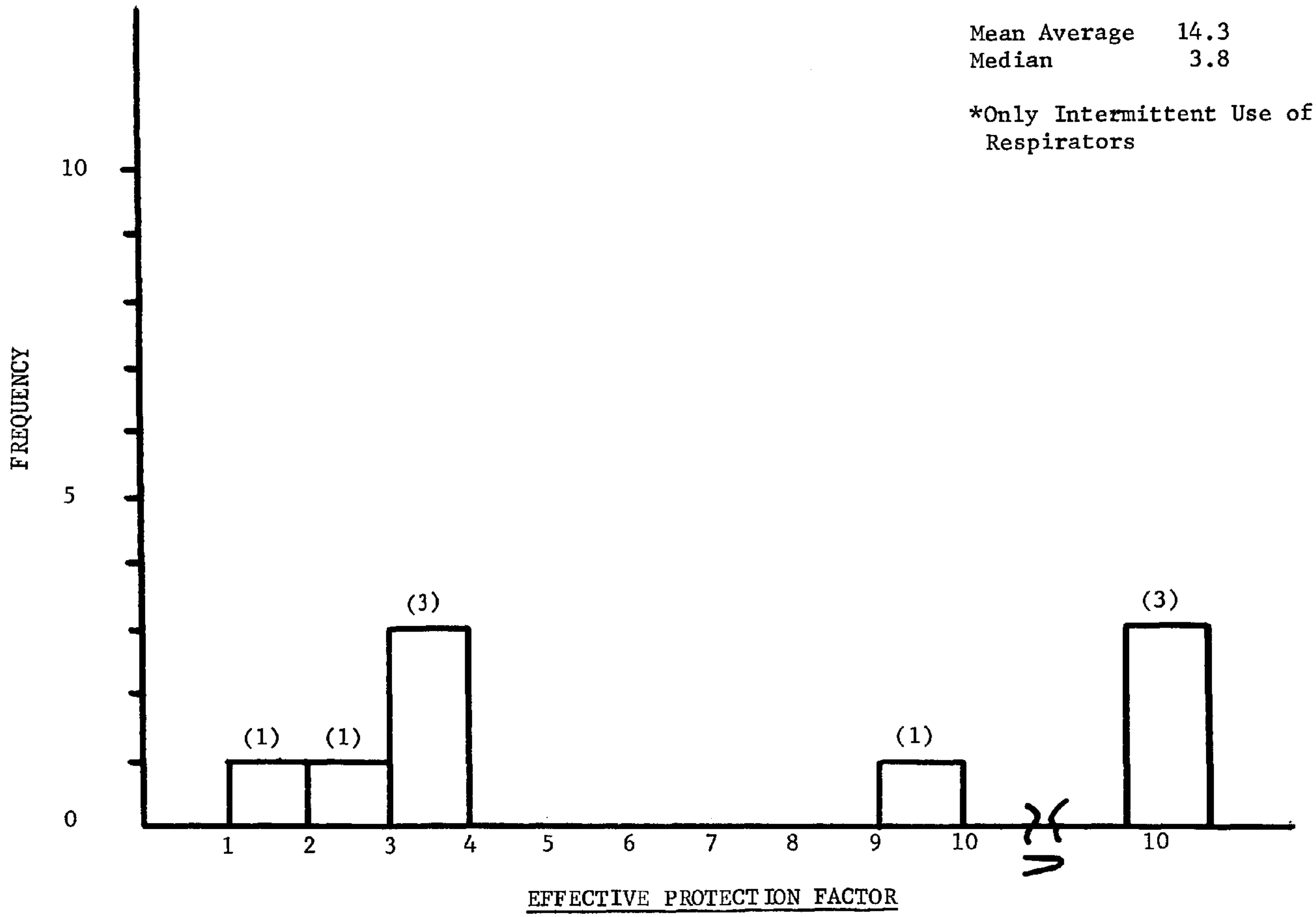


FIGURE 3-17

EFFECTIVE PROTECTION FACTORS - MINE B

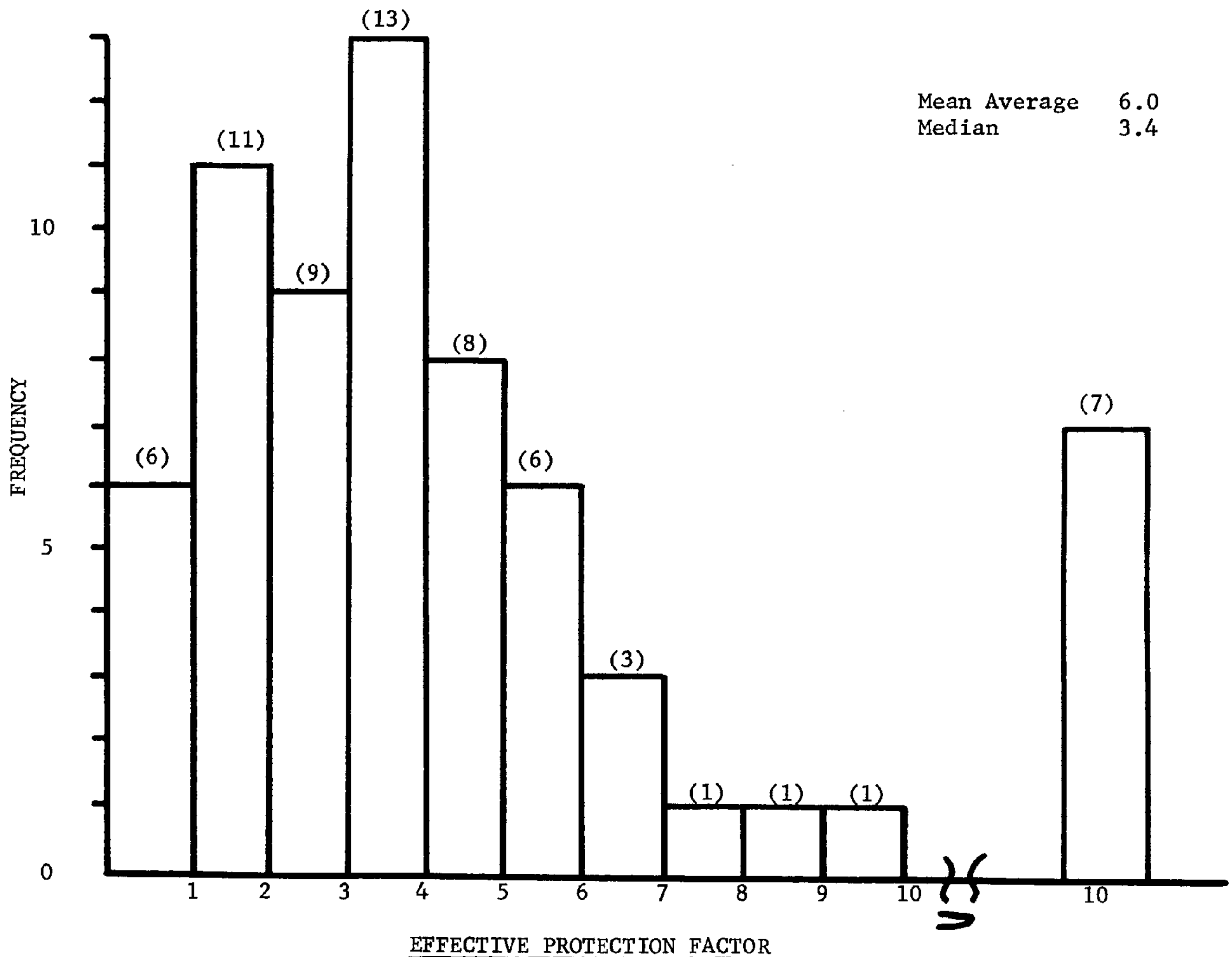
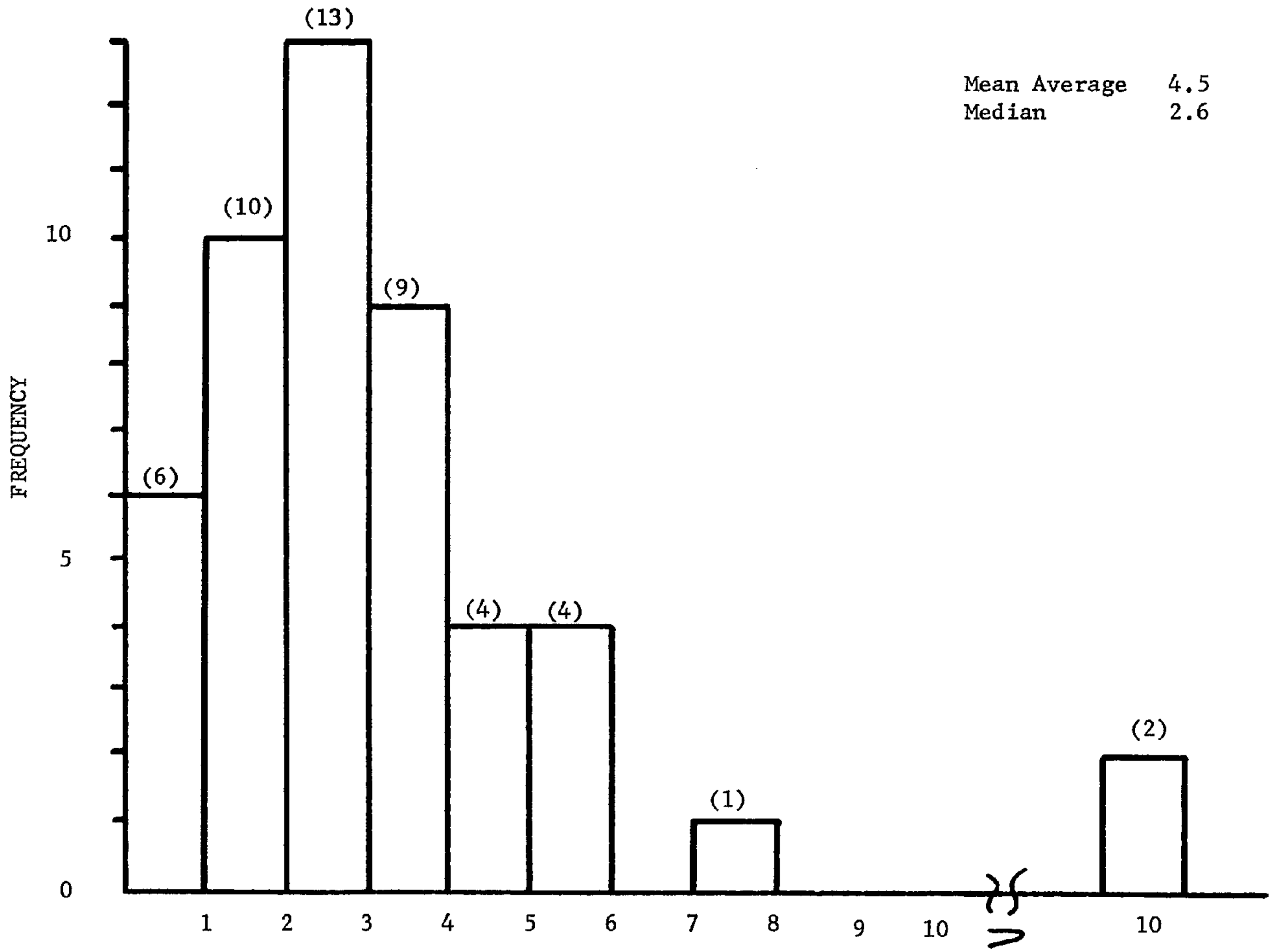


FIGURE 3-18

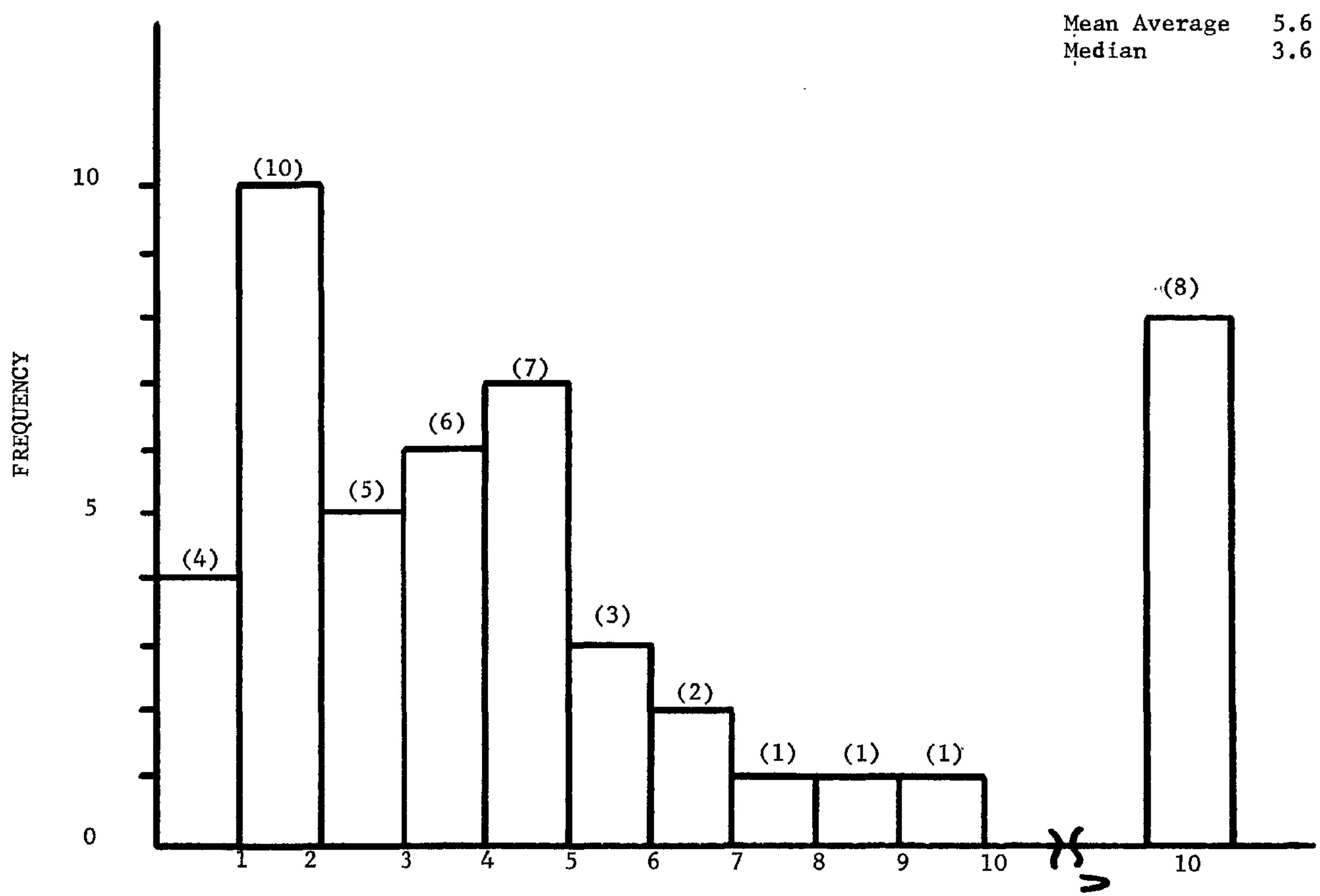
EFFECTIVE PROTECTION FACTORS - MINE C



EFFECTIVE PROTECTION FACTOR

FIGURE 3-19

EFFECTIVE PROTECTION FACTORS - MINE D



EFFECTIVE PROTECTION FACTOR
FIGURE 3-20

For example, in the case of the EPF's above 20 it was noted in most instances there was high respirable dust concentrations in the ambient air. Consequently, the filters were examined microscopically to determine whether there was contamination of the sample of respirable dust but none was found. Moreover, it was recognized in the case of values of less than 1.0, that respirable dust collected on the miner's clothes could be knocked off or brushed loose and be collected in the respirator mask when the respirator was hanging loose on the miner's chest, thereby creating the higher dust concentration in the mask than was found in the ambient air. For further comments on the EPF's above 20 and less than 1.0 see Appendix 3-8

Nevertheless, in order to make various meaningful comparisons, it appears appropriate to consider, for intermittent respirator use, EPF values between 1.0 and 20.0; the frequency distribution for these data is shown in Figure 3-21.

3.3.4 Time-of-Wearing of Respirators

As shown in Figure 3-22, the time the test subjects actually wore the respirators varied from as little as about 10 percent of the work period to about 90 percent. While the mean time-of-wearing was 46 percent, the largest frequency was in the 30-40 percent range.

There were some differences in the time-of-wearing from mine to mine, Figures 3-23, 3-24 and 3-25. For Mines B and C, the time-of-wearing seemed to follow about the pattern. Moreover, the mean averages were fairly close and the highest frequency for both mines was in the 50-60 percent range. However, for Mine D, the situation was substantially different. On the average (mean) respirators at Mine D were worn little more than a third of the time with the greatest frequency in the 30-40 percent range. On the other hand, comparing the average age of

EFFECTIVE PROTECTION FACTORS
BETWEEN 1.0 and 20.0

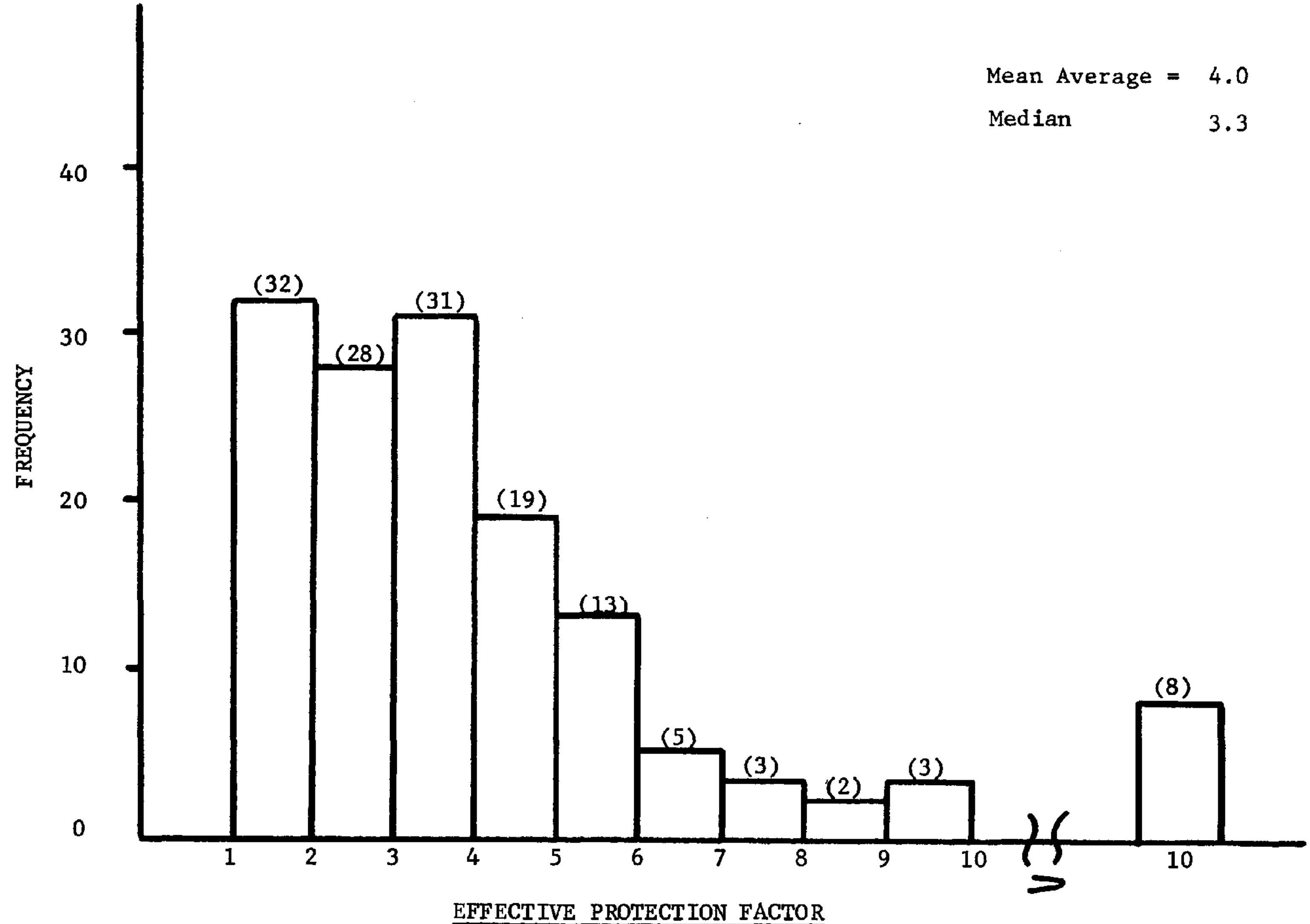
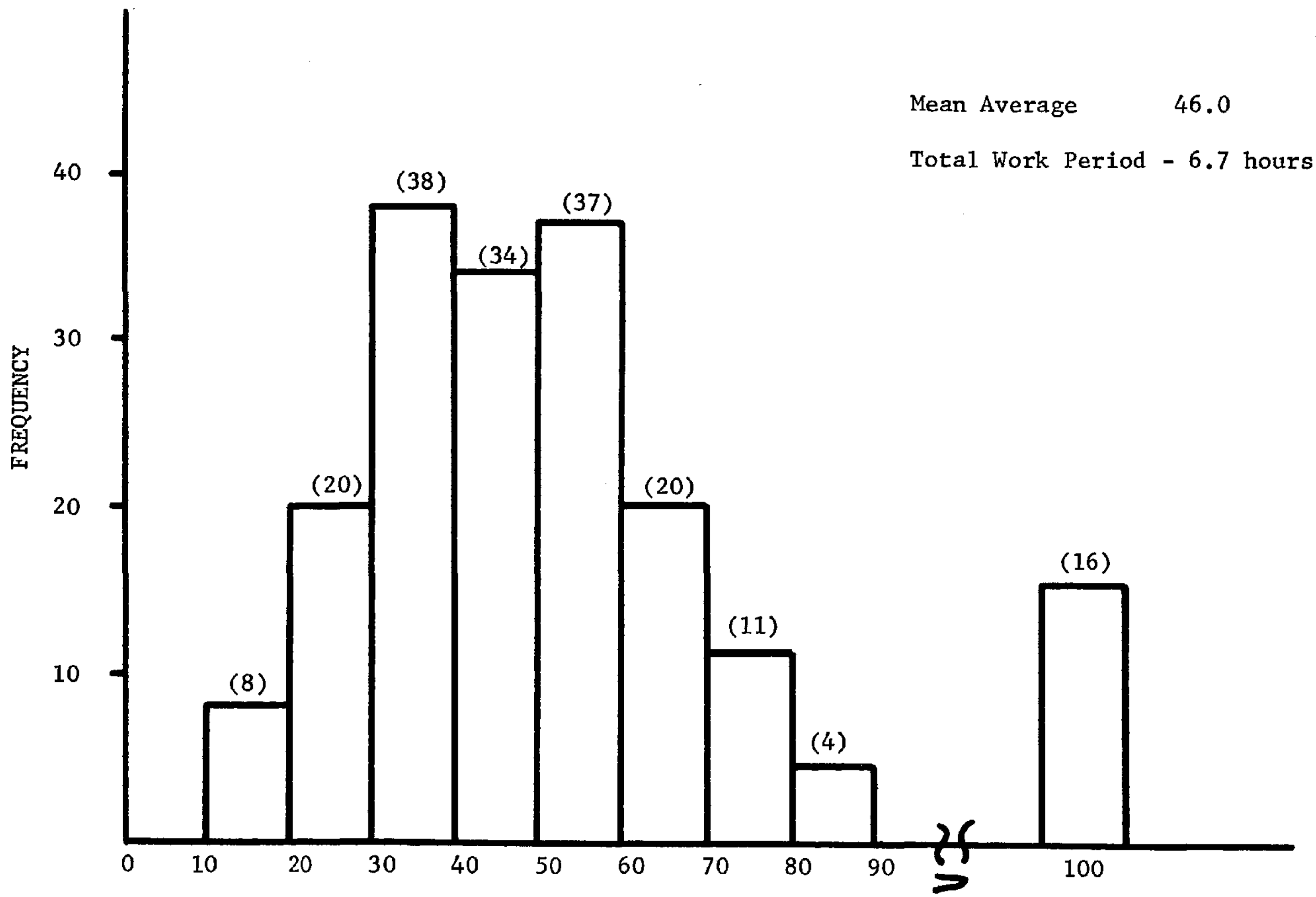


FIGURE 3-21

PORTION OF WORK PERIOD THAT RESPIRATORS WERE WORN

ALL MINES*



PERCENT OF TIME WORN

FIGURE 3-22

* Data from Mine A for continuous wearing (100% of time) of respirators omitted

PORTION OF WORK PERIOD THAT RESPIRATORS WERE WORN

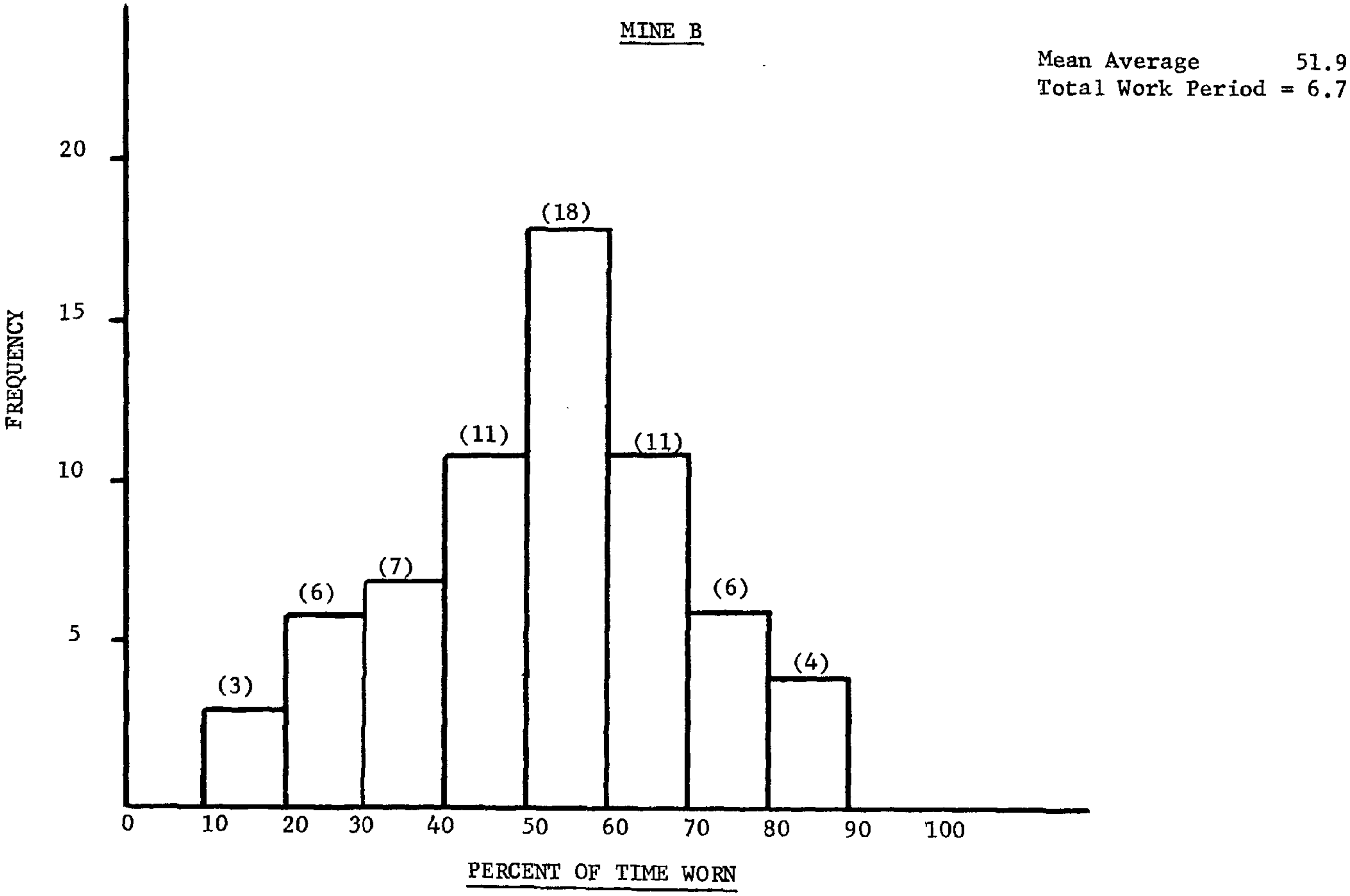
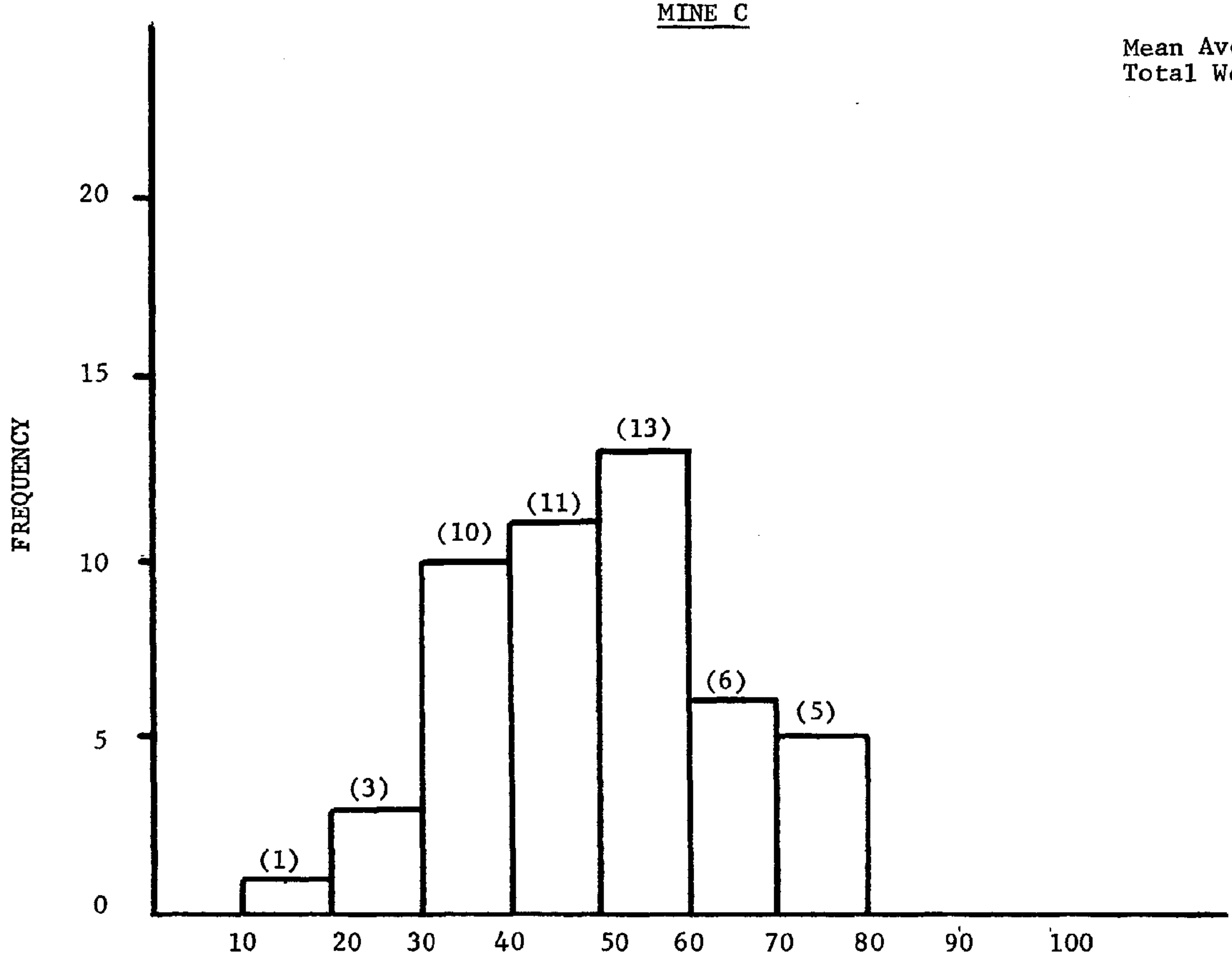


FIGURE 3-23

PORTION OF WORK PERIOD THAT RESPIRATORS WERE WORN

MINE C

Mean Average 48.4 Percent
Total Work Period = 6.7



PERCENT OF TIME WORN

FIGURE 3-24

PORTION OF WORK PERIOD THAT RESPIRATORS WERE WORN

MINE D

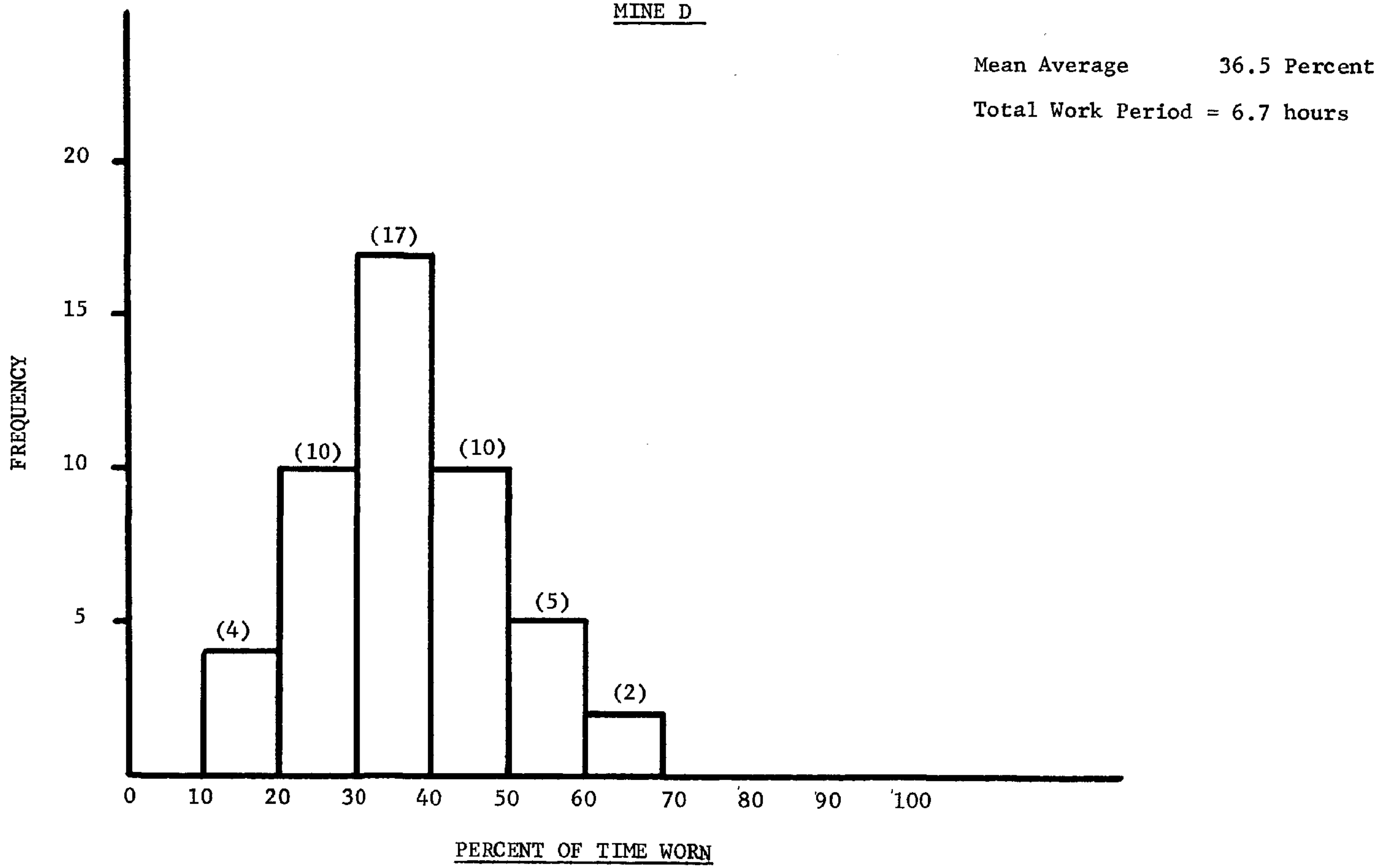


FIGURE 3-25

the test subjects, as well as the average years of experience as a miner, at these three mines, Table 3-6, it was found that average ages and experience for those at Mines B and D was virtually the same, but the average age, and like experience, at Mine C was significantly lower. Likewise, the mean averages or median EPF was the lowest at Mine C.

Thus, while it would seem the amount of time a respirator is worn should have an effect on the protection the miner obtains, it appears a variety of other factors, such as age, years of experience, dust concentration and training, which are probably interrelated, have a substantive effect on the effective protection obtained.

TABLE 3-6

COMPARISON OF THREE MINES

Mine	Mine B	Mine C	Mine D
Effective Protection Factor			
Mean Average	6.0	4.5	5.6
Mean Average*	3.9	3.3	4.7
Median	3.4	2.6	3.6
Time Respirator was Worn, %			
Mean Average	51.9	48.4	36.5
Age of Test Subjects, yr.			
Mean Average	45.6	32.3	44.9
Experience of Test Subjects, As a Miner, yr.			
Mean Average	17.8	7.5	20.7
Ambient Air Dust Concentrations mg/M3**			
Mean Average	1.82	1.82	1.58
Median	1.00	1.18	0.98

* EPF values of less than 1.0 and greater than 20.0 removed.
** As measured by Personal Sampler

3.3.5 Ambient Air Dust Concentrations

As might be expected, ambient air dust concentration exposures measured for the various test subjects varied considerably. The frequency distribution for all dust concentrations measured for all mines is shown in Figure 3-26 and for Mines B, C and D in Figures 3-27 through 3-29. The variability in these dust concentrations was fortunate in that the effective protection was determined for the different respirators under a range of dust concentrations that would be considered representative of those generally found in coal mining operations. An illustration of this day-to-day variation of dust concentration is shown in Table 3-7.

TABLE 3-7

DAILY DUST CONCENTRATIONS FOR SELECTED TEST SUBJECTS

Test Subject No.	Job Classification	Test Day	Dust Concentration Mg/M3*
16	Continuous Mining Machine Operator	1	2.40
		2	2.05
		3	3.55
		4	2.31
		5	1.92
18	Loading Machine Operator	1	1.07
		2	1.18
		3	0.95
		4	1.22
		5	0.93
31	Continuous Mining Machine Operator	1	5.21
		2	1.14
		3	0.69
		4	0.54
		5	2.70
36	Loading Machine Operator	1	2.35
		2	3.82
		3	3.29
		4	1.86
		5	1.29

* As measured by Personal Sampler

DUST CONCENTRATION IN MINE AIR*

ALL MINES

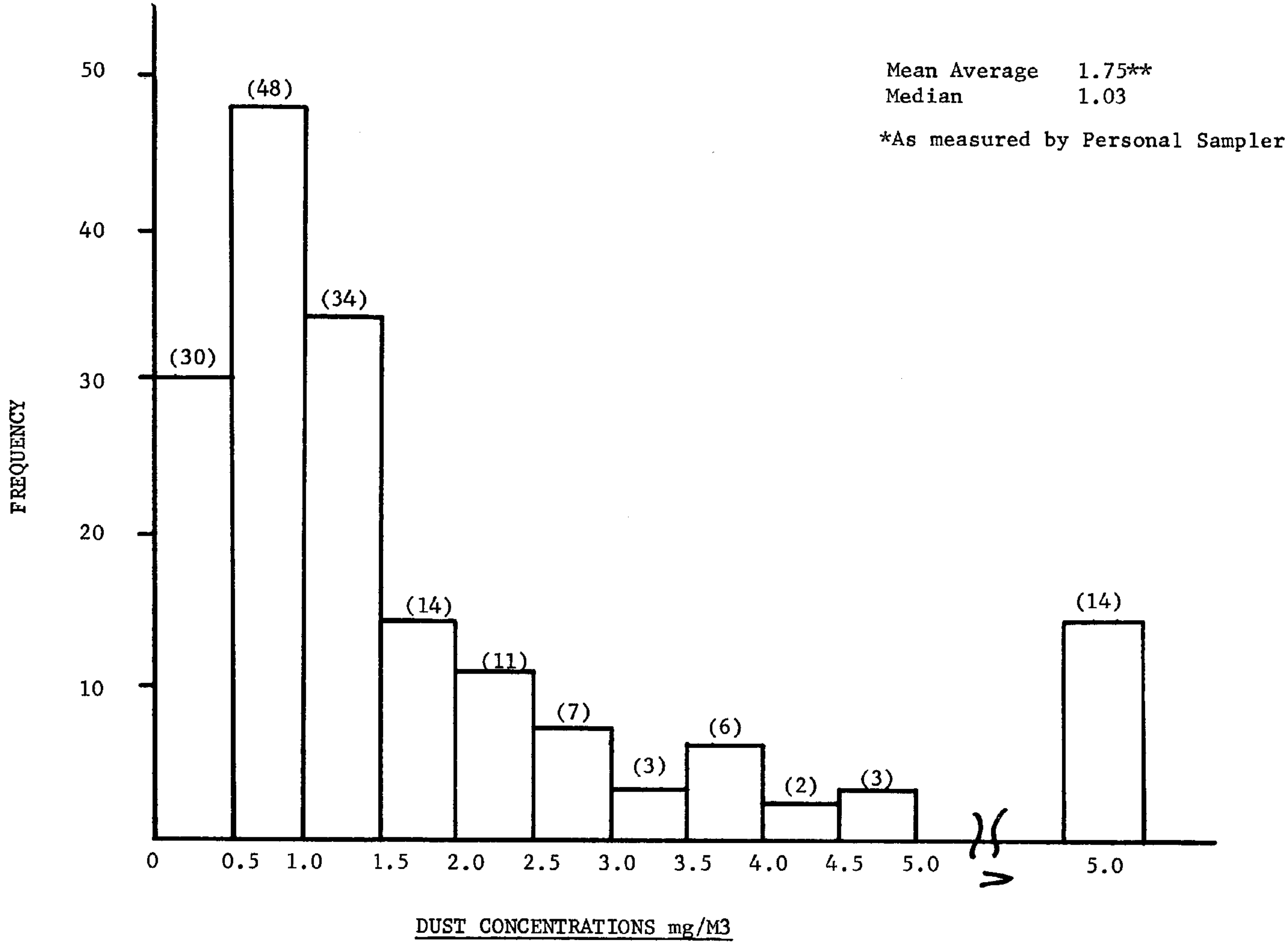


FIGURE 3-26

*Only Intermittent Wear of Respirator

**As measured by Personal Sampler

DUST CONCENTRATION IN MINE AIR*

MINE B

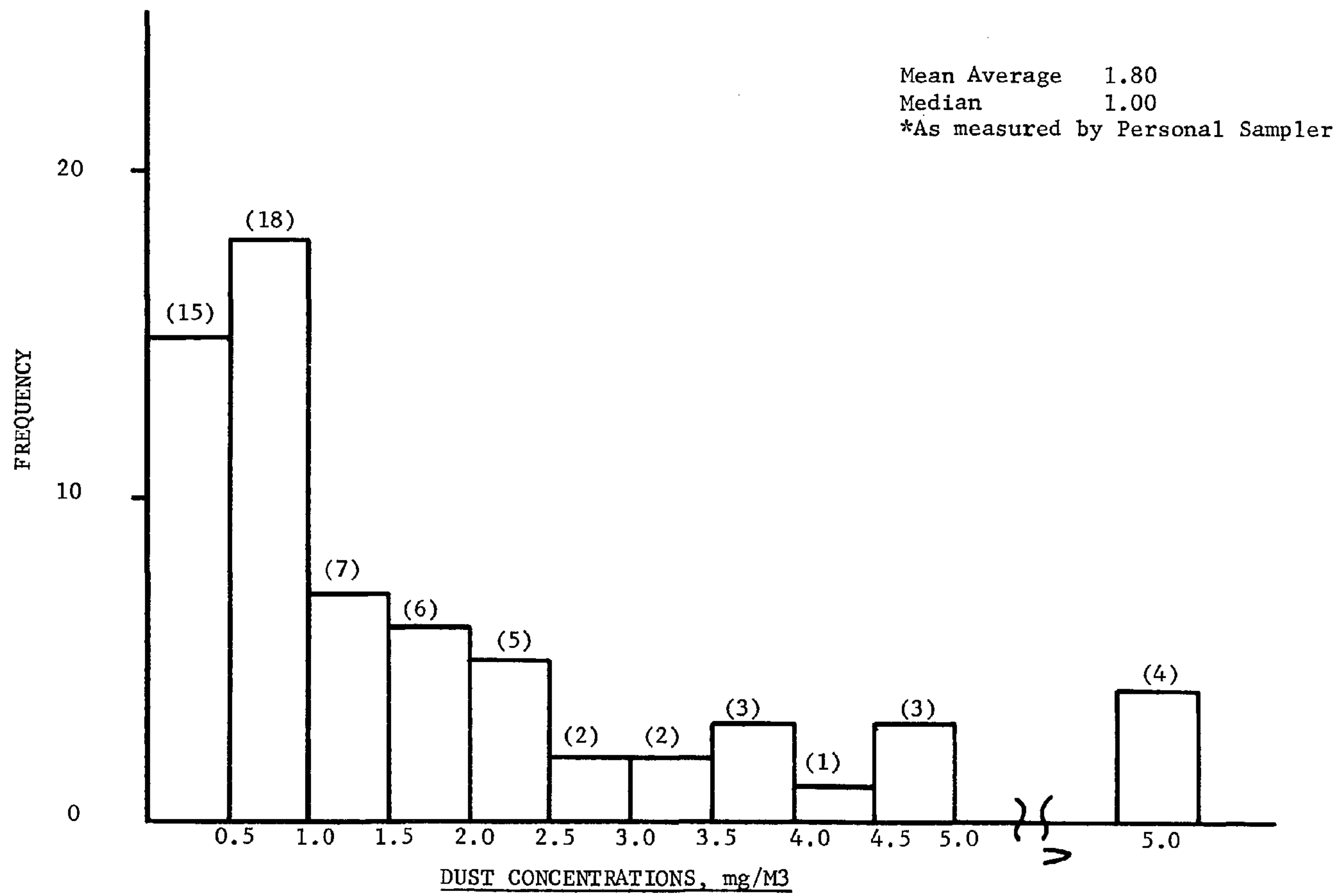
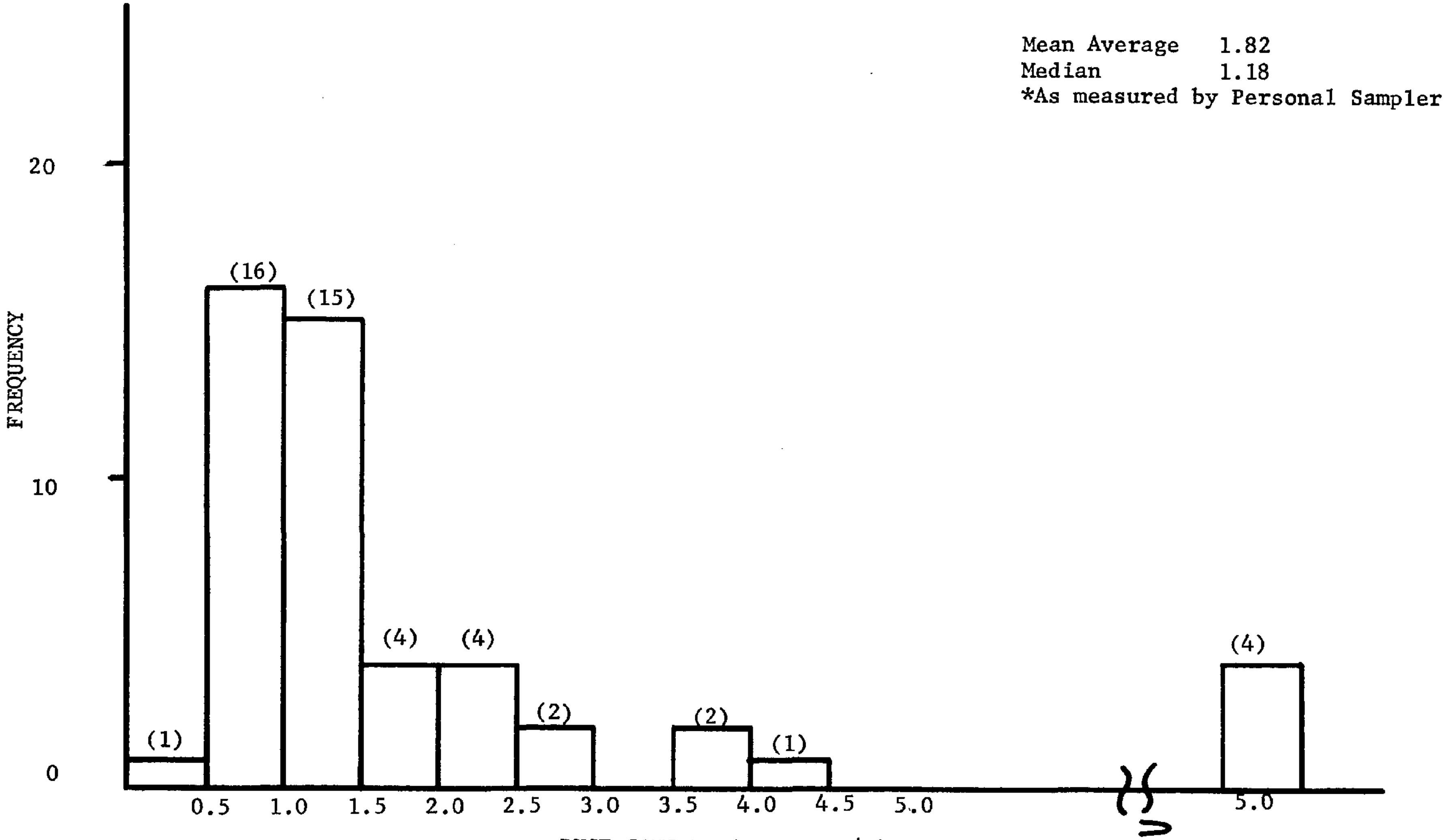


FIGURE 3-27

DUST CONCENTRATION IN MINE AIR*

MINE C



DUST CONCENTRATION, mg/M3
FIGURE 3-28

DUST CONCENTRATION IN MINE AIR*

MINE D

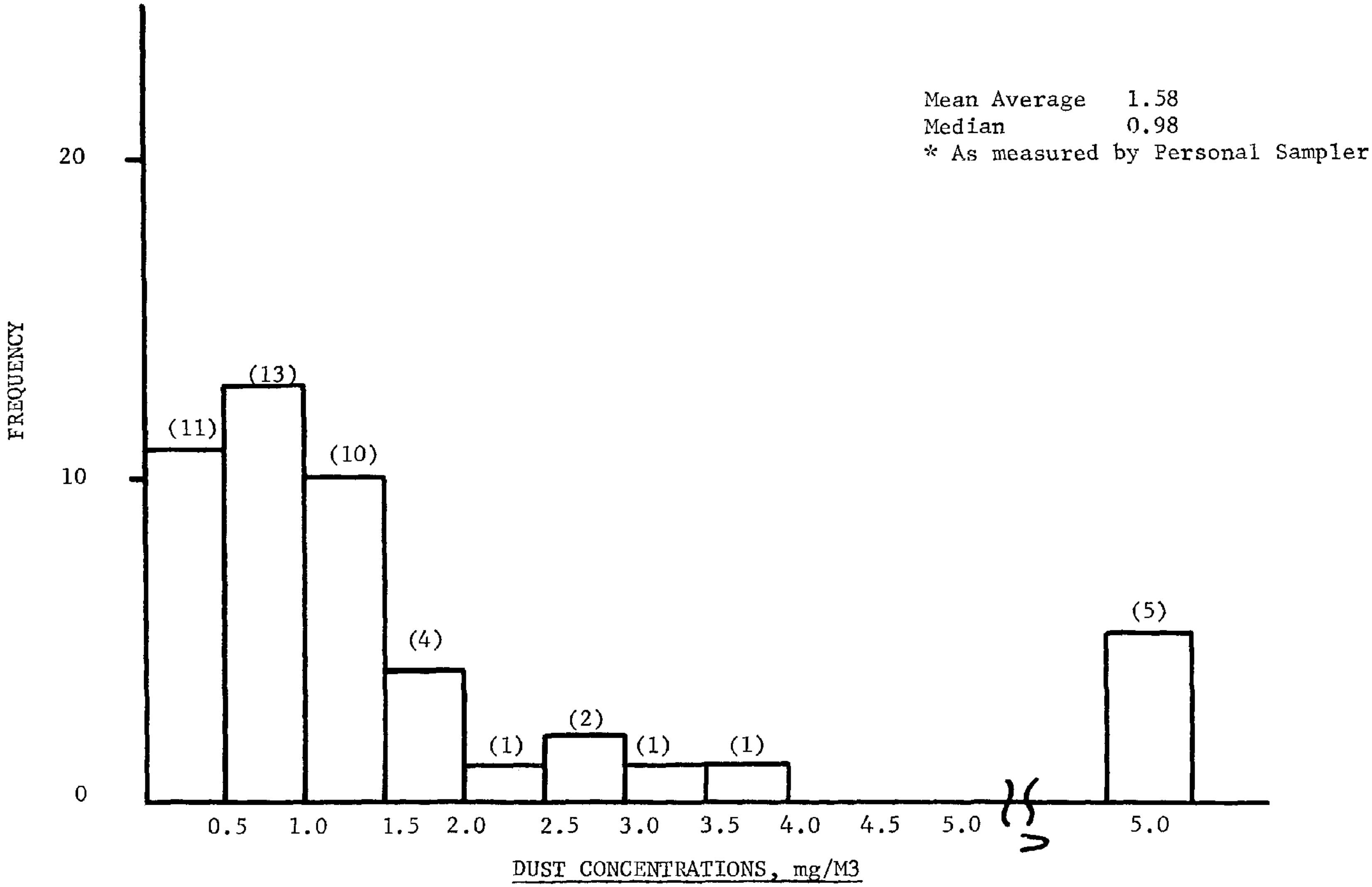


FIGURE 3-29

3.3.6 Comparison of Respirators

Six different models of respirators were included in the in-mine test program. As mentioned previously, all models had Bureau of Mines approval and four out of six were found to be in use in the bituminous coal mining industry. The two exceptions were the Welsh 7400 and the Welsh 7165; the former was included because it had a somewhat larger facepiece than those found in use and the latter, Welsh 7165, was a single-use respirator which working miners had found acceptable for underground use (see Section 4 of this report). Test results for the six respirators tested are summarized in Table 3-8.

Before comparing the different respirators, it should be pointed out that the mean average EPF value is influenced by both extremely high and low values, but particularly the former. Consequently, median values are also included for purposes of comparison. Likewise, it seemed appropriate to include for comparative purposes, indexes that were computed using only EPF's in the range of 1.0 to 20.0.

Based on median EPF values wherein all the test values are included, the Welsh 7165 was the highest followed by the Welsh 7100, MSA 77, AO R2090, MSA 66 and Welsh 7400 in that order. When the EPF's less than 1.0 and above 20.0 are excluded, the order changes slightly with the Welsh 7100 the highest followed by the MSA 77, the AO R2090 and Welsh 7165, the MSA 66 and the Welsh 7400.

In comparing mean values, it should be emphasized that testing done under conditions involving the actual mining of bituminous coal underground, while highly desirable from the standpoint of obtaining data in the "real world," e.g. measuring the protection the working miner obtains by wearing a respirator, presents formidable obstacles. In particular, it was neither feasible nor possible to test different respirators under the same set of conditions with respect to test subjects, dust concentrations and working conditions.

TABLE 3-8

COMPARISON OF DIFFERENT RESPIRATOR TYPES TESTED
(Intermittent Wear Only)

Respirator	No. of Test Subjects	No. of Test Values	Ambient Air Dust Concentrations mg/M3***		Time of Wearing, %	Effective Protection Factors (EPF)	
			Mean Avg.	Median	Mean Avg.	Mean Avg.	Median
AO R2090	8	32	2.02	1.37	42.3	5.1	3.4
		29**	2.09	1.37	42.2	4.6	3.3
MSA - 66	11	47	1.51	1.14	49.6	3.8	2.6
		39**	1.58	1.18	51.5	3.8	3.1
MSA - 77	10	37	1.70	1.01	45.8	5.8	3.5
		29**	1.59	0.92	44.3	4.0	3.5
Welsh 7100	6*	20	1.62	0.72	48.6	9.2	3.9
		17**	1.00	0.72	49.3	4.0	3.9
Welsh 7400	4	19	1.35	0.95	40.2	3.4	2.0
		17**	1.47	1.03	38.9	3.7	2.2
Welsh 7165	7	17	2.57	0.90	47.5	10.6	4.6
		13**	0.94	0.56	47.1	4.0	3.3

* Actually 3 different test subjects; one observer wore this unit for four different test periods
** All data where EPF above 20.0 and below 1.0 was excluded
*** As measured by personal sampler

And, as a matter of fact, some of the day-to-day variability in test results is due to changes in test conditions. Nevertheless, comparisons of mean values will provide some insight whether there are significant differences among respirators tested.

A comparison of mean values (wherein EPF's of less than 1.0 and more than 20.0 have not been included) using the t-test shows there were no significant differences among six respirators at the 95 percent confidence level. In other words, these data suggest that a particular miner might expect to obtain about the same protection regardless of which of the six respirators he used, see Table 3-9.

Speaking of protection, an EPF of 3.0 means that 66.7 percent of the respirable dust present has been removed from the air breathed and is not being inhaled by the miner. Similarly, an EPF of 4.0 represents 75 percent removal of the respirable dust. Based on the data shown in Table 3-8, it appears, on average, that the six different respirators as currently used remove about 70 percent of the respirable dust which otherwise, the miner would have breathed.

Several other comments are in order. First, the mean average time of wearing of the different respirator models varied little from model to model. While the Welsh 7400 was the lowest in this area, this respirator is somewhat different in design from the other models, and, perhaps, more importantly, totallyunfamiliar to the test subjects. While mean average of the dust concentrations under which the respirators were tested appears to differ, comparisons using the t-test show there are no significant differences at the 95 percent confidence level*.

* For the situation wherein EPF's less than 1.0 and more than 20 were eliminated the differences between the mean average 2.09 mg/M3 dust concentration for the AO R2090 and the 0.94 mg/M3 for the Welsh 7165 is significantly different at the 90 percent confidence level.

Interestingly, perhaps, no EPF values above 20.0 were found for the Welsh 7400.

TABLE 3-9

DIFFERENCES AMONG RESPIRATORS * **

	AO R2090	MSA 66	MSA 77	Welsh 7100	Welsh 7400	Welsh 7165
AO R2090	--	NS	NS	NS	NS	NS
MSA 66	NS	--	NS	NS	NS	NS
MSA 77	NS	NS	--	NS	NS	NS
Welsh 7100	NS	NS	NS	--	NS	NS
Welsh 7400	NS	NS	NS	NS	--	NS
Welsh 7165	NS	NS	NS	NS	NS	--

NS = Not Significant

* Using data EPF above 20.0 and less than 1.0 were eliminated

** 95% confidence level

3.3.7 Comparison of Miners by Job Classifications

In-mine testing was done on continuous, conventional and longwall sections; in all cases (except where the Welsh respirator 7165 was the only respirator being tested), one of the test subjects was the person designated as the "high-risk" man under the procedures set forth by the Bureau of Mines respirable dust sampling program. Beyond this were included other job classifications, such as loading machine operator, shuttle car operator and roof bolter, usually found in mining section crews. Before comparing the test data for different job classifications, Table 3-10, it should be mentioned that coal mining is somewhat unique. Unlike some other industries, a coal miner with a particular job

TABLE 3-10
COMPARISON OF JOB CLASSIFICATIONS

Job Classification	Number of Test Subjects	Number of Test Values	Ambient Air Dust* Concentrations mg/M³ Mean Avg.	Ambient Air Dust* Concentrations mg/M³ Median	Time of Wearing Percent Mean Avg.	Effective Protection Factors (EPF) Mean Avg.	Effective Protection Factors (EPF) Median
Continuous Min'g Machine Operator**	6	23	2.24	1.89	48.6	6.5	3.7
		19***	2.25	1.87	50.7	4.7	3.7
Loading Machine Operator	6	22	2.02	1.29	44.2	3.5	3.4
		20	2.13	1.29	44.3	3.8	3.4
Shuttle Car Operator	13	41	1.67	0.80	42.3	8.1	3.5
		31***	0.94	0.70	41.3	4.2	3.4
Roof Bolter	3	11	2.32	2.21	52.1	3.4	2.4
		9	2.76	2.78	52.0	4.0	2.8
Cutting Machine Operator	2	10	1.95	1.40	46.	4.6	3.6
		9	2.11	1.41	45.5	5.0	5.1
Coal Driller	2	10	0.75	0.92	47.1	1.7	1.7
		9	0.79	0.92	49.3	1.7	1.8
Observer	8	34	1.59	0.95	48.2	7.8	3.9
		28	1.07	0.91	47.9	4.5	3.5
Misc. Personnel	5****	21	1.40	1.17	43.7	2.9	2.6
		19	1.44	1.17	44.3	3.2	3.1

*As measured by the personal sampler.

**Includes Miner Helper

***All data where EPF above 20.0 and below 1.0 is excluded.

****Included the following: a) Bratticeman, b) Longwall Mach. Head Gate Opr., (c) Longwall Mach. Tail Opr., d)Longwall Jack Mach. Opr.

classification may do a variety of different jobs during a working shift, including a number normally associated with other job classifications; this situation can be somewhat typical in coal mining and is further described in detail in Appendix 3-9. Consequently, observed differences among job classifications could be affected or influenced to some unknown extent by this unique situation regarding performance of work tasks.

In making comparisons among different job classificationsm it seemed appropriate to eliminate data where the EPF was greater than 20.0 or less than 1.0. Turning first to the average ambient air dust concentrations, there were no significant differences (at the 95% confidence level) among the 1) continuous mining machine operators, 2) loading machine operators, 3) roof bolters, and 4) cutting machine operators. Interesting here, is the fact that although the roof bolters and loading machine operators are not the "high-risk man", the average dust concentrations to which they were exposed were not significantly different from the "high-risk" classifications, namely, continuous mining machine operator and cutting machine operator.

So far as differences with respect to EPF, the major difference among job classifications was that coal driller obtained a significantly lower EPF than other job classifications, Table 3-11. Perhaps, importantly, the coal drillers were exposed to significantly lower average ambient air dust concentrations.

Interestingly, although all of the observers were either occasional or non users of respirators, they obtained, on average, EPF's that were not significantly different from that obtained by, 1) continuous mining machine operators, 2) loading machine operators, 3) shuttle car operators, 4) roof bolters, and 5) cutting machine operators; many of the test subjects in these latter classifications were regular users of respirators.

TABLE 3-11
DIFFERENCES AMONG JOB CLASSIFICATIONS --
EFFECTIVE PROTECTION FACTOR*

	CMMO	LMO	SCO	RB	CMO	CD	O	MP
Continuous Mining Machine Operator ** (CMMO)	--	NS	NS	NS	NS	S	NS	NS
Loading Machine Operator (LMO)	NS	--	NS	NS	NS	S	NS	NS
Shuttle Car Operator (SCO)	NS	NS	--	NS	NS	S	NS	NS
Roof Bolter (RB)	NS	NS	NS	--	NS	S	NS	NS
Cutting Machine Operator (CMO)	NS	NS	NS	NS	--	S	NS	NS
Coal Driller (CD)	S	S	S	S	S	--	S	S
Observer (O)	NS	NS	NS	NS	NS	S	--	S
Misc. Personnel (MP)***	NS	NS	NS	NS	S	S	S	--

* All data where EPF above 20.0 and less than 1.0 excluded.

** Includes Continuous Mining Machine Helper.

*** Includes Bratticeman, Longwall Machine Head Gate Operator, Longwall Machine Tail Gate Operator, Longwall Jack Machine Operator

NS = Not Significant

S = Significant

3.3.8 Factors Affecting EPF Obtained by Face Miners

As shown previously in Figure 3-21, an average EPF of 4.0 was obtained by face miners when EPF's of less than 1.0 and greater than 20.0 were eliminated from the data analyses. Stated another way, an EPF of 4.0 means that 75 percent of the respirable dust present in the ambient air was removed and was not breathed by the miner, Table 3-12.

TABLE 3-12

EFFECTIVE PROTECTION FACTOR RESPIRATOR EFFICIENCY

Effective Protection Factor	Efficiency (% of Respirable Dust Removed)	Protection Factor	Efficiency (% of Respirable Dust Removed)
1	0.0	11	90.9
2	50.0	12	91.7
3	66.7	13	92.3
4	75.0	14	92.8
5	80.0	15	93.3
6	83.3	20	95.0
7	85.7	25	96.0
8	87.5	30	96.7
9	88.9	40	97.5
10	90.0	50	98.0

While this may be considered a reasonably good level of protection, several things should be emphasized. First, in many instances EPF's were significantly lower and, as shown in Table 3-12, an EPF of 2.0 means the miner is still inhaling 50 percent of the respirable dust present. Secondly, the mean average dust concentrations for all test values, where only intermittent wear respirators was involved, Figure 3-26, was 1.75 mg/M3 (as measured by the personal sampler) and 1.55 mg/M3 (as measured by the personal sampler) when EPF values of less than 1.0 and more than 20.0 were eliminated from the data base. Translated in MRE equivalent dust concentrations, these values become 2.80 and 2.48 mg/M3, respectively; both values are above 2.0 mg/M3 limit. Thirdly, an EPF of 4.0 is certainly well below what is considered possible based on laboratory measurements.

It might be expected that the EPF would be higher the longer the respirator was worn, i.e., less dust is inhaled the more the respirator is worn. Similarly, since miners reported that respirators are worn "when it's dusty", it might seem the higher the dust concentration the more the respirator would be worn and the more protection would be obtained; of course, in this situation, it is presumed there is some general relationship between the concentrations of visible and respirable dust present and this may not be the case.

As shown in Figure 3-30, there was no significant relationship between the TOW (Time-of-Wearing of the Respirator) and EPF obtained. This may seem surprising because even though dust concentrations are not comparatively uniform but vary widely during the shift, it would be expected that increasing the time a respirator is worn would increase the protection level at least to some extent. Clearly, this was not found and very probably because other factors had a more pronounced effect on the protection. For example, quite likely the fact that each model of respirator has only one face size makes it difficult for different miners to get uniformly good seals between face and facepiece. Moreover, most of the presently available models of respirators have a two-strap head harness which are simply not feasible to wear in the manner recommended by the manufacturers. Coal miners wear respirators not only intermittently but with variable frequency. Sometimes a respirator is put on and removed many times during the period of an hour; other times it is worn for comparatively lengthy periods or not worn at all for equally lengthy periods. When not in use, the respirator is worn around the user's neck resting loosely on his chest. Virtually always, it would be

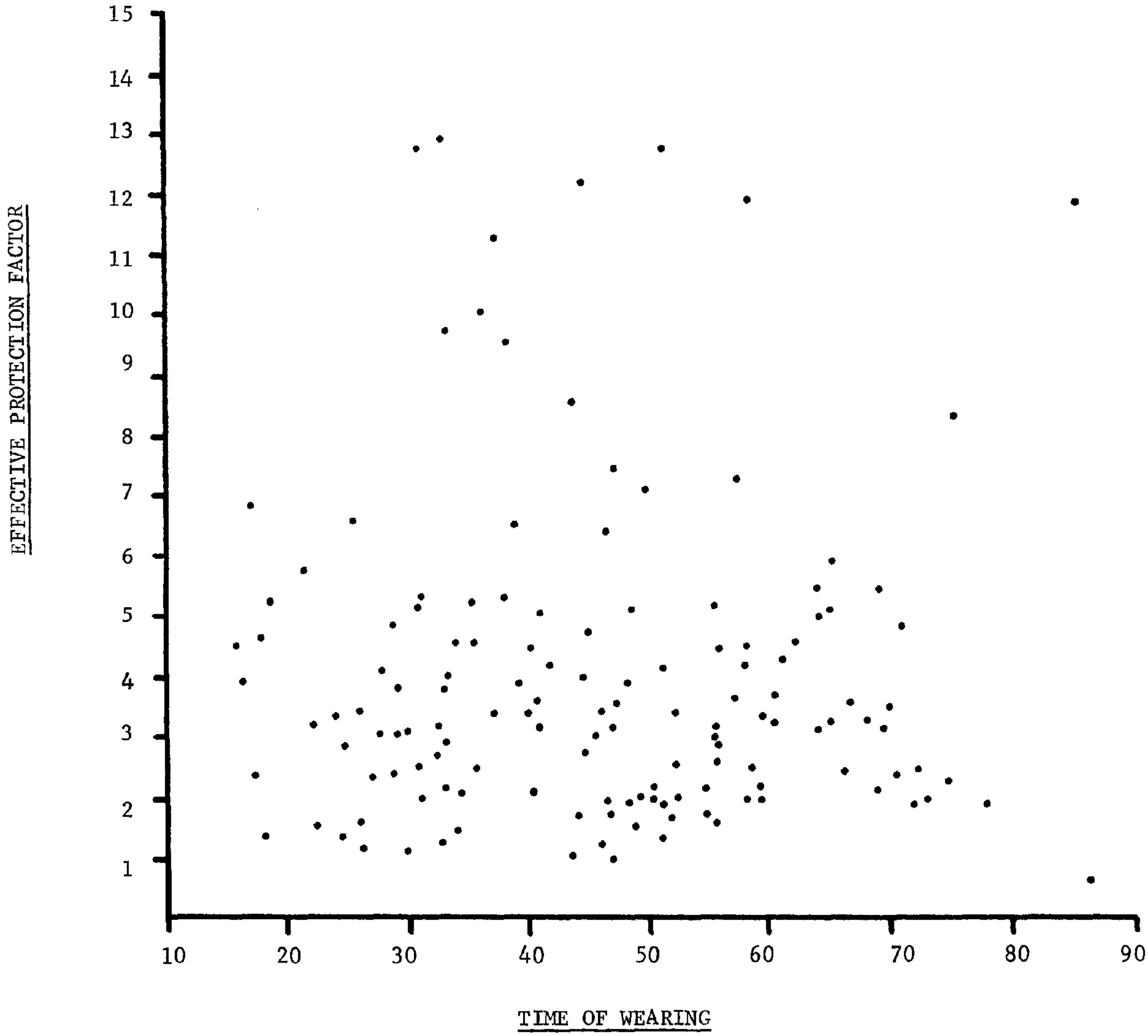

EFFECTIVE PROTECTION FACTOR
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
10
20
30
40
50
60
70
80
90
TIME OF WEARING

FIGURE 3-30

inconvenient and impossible where conditions are cramped, for the miner to properly position the head straps across the back of the head because this would require removal and repositioning of both hard hat and cap lamp. Consequently, miners convert the double strap harness to a single strap configuration that is worn around the neck and below the ears.

As a matter of fact, research should be undertaken to develop better head harness, or equivalent, for respirators used in coal mines. Such research should be undertaken in the context of a systems approach wherein there is integration of needs for such as head protection, illumination, respiratory protection, eye protection and noise protection.

There was no relationship between the TOW and the average ambient air concentration of respirable dust, Figure 3-31. This, too, may seem a bit surprising, particularly when many miners say they wear respirators "when it's dusty," i.e., the visible dust level is above that which the miner considers acceptable. Nevertheless, there appear to be valid reasons why no relationship was found. For one thing, some miners were observed to be relating the wearing or not of a respirator to whether the mining machine was running or not. Moreover, the dust level is undoubtedly highly cyclical with respect to time and location. Dust levels are affected by a variety of things such as coal production per unit time, changes in ventilation as mining penetrates deeper into a room and effectiveness, or lack thereof, of dust suppression methods. In fact, dust concentrations measured using the GCA RDM 101 Respirable Dust Monitor showed at one mining face, dust levels of several milligrams per cubic meter while actually mining was in progress to almost zero when the continuous mining machine was not running. However, the dust measured by the mass respirable personal sampler is a time weighed average over the entire shift of the high and low concentrations. Therefore, depending on the high and low concentrations, it is quite possible

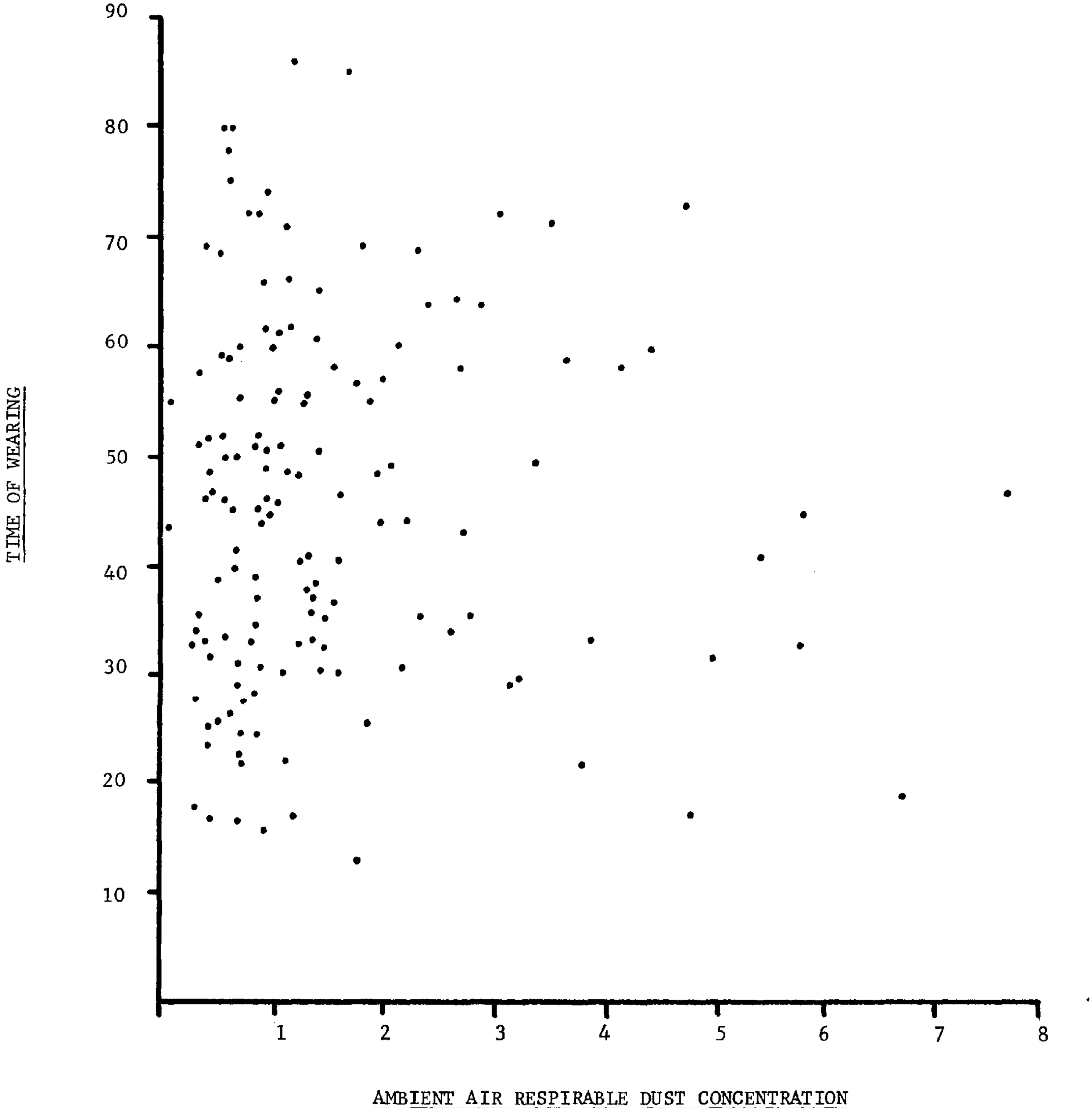

TIME OF WEARING
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
AMBIENT AIR RESPIRABLE DUST CONCENTRATION

FIGURE 3-31

for two miners to have worn their respirators the same total elapsed time but be exposed to different average ambient air dust concentrations or vice versa.

As shown in Figure 3-32, there is a poor, but nevertheless, significant correlation between ambient air dust concentration (DC_A) and Effective Protection Factor (EPF); there is a 99.9 percent probability this correlation did not occur by chance. Although many factors, such as intermittent use, differences in facial shapes, cyclical nature of dust concentrations with respect to time and space and individual miner attitudes affect the EPF obtained, it is felt there is valid explanation why a general relationship between DC_A and EPF could exist. It has been frequently observed that as the visible dust level, or more properly the opacity of the mine air, increases miners tend to take more care, or make further adjustments, to insure a better fit of the respirators. Assuming that, on average, such actions on the part of the miners result in better fits and that there is direct, although general, proportional relationship between visible and respirable dusts, it is likely miners are obtaining increased levels of protection as dust levels increase.

There is further substantiation, as will be discussed in detail subsequently, for this concept in that the True Protection Factors, which were determined using the best fit of respirator possible, obtained were significantly higher than EPF's.

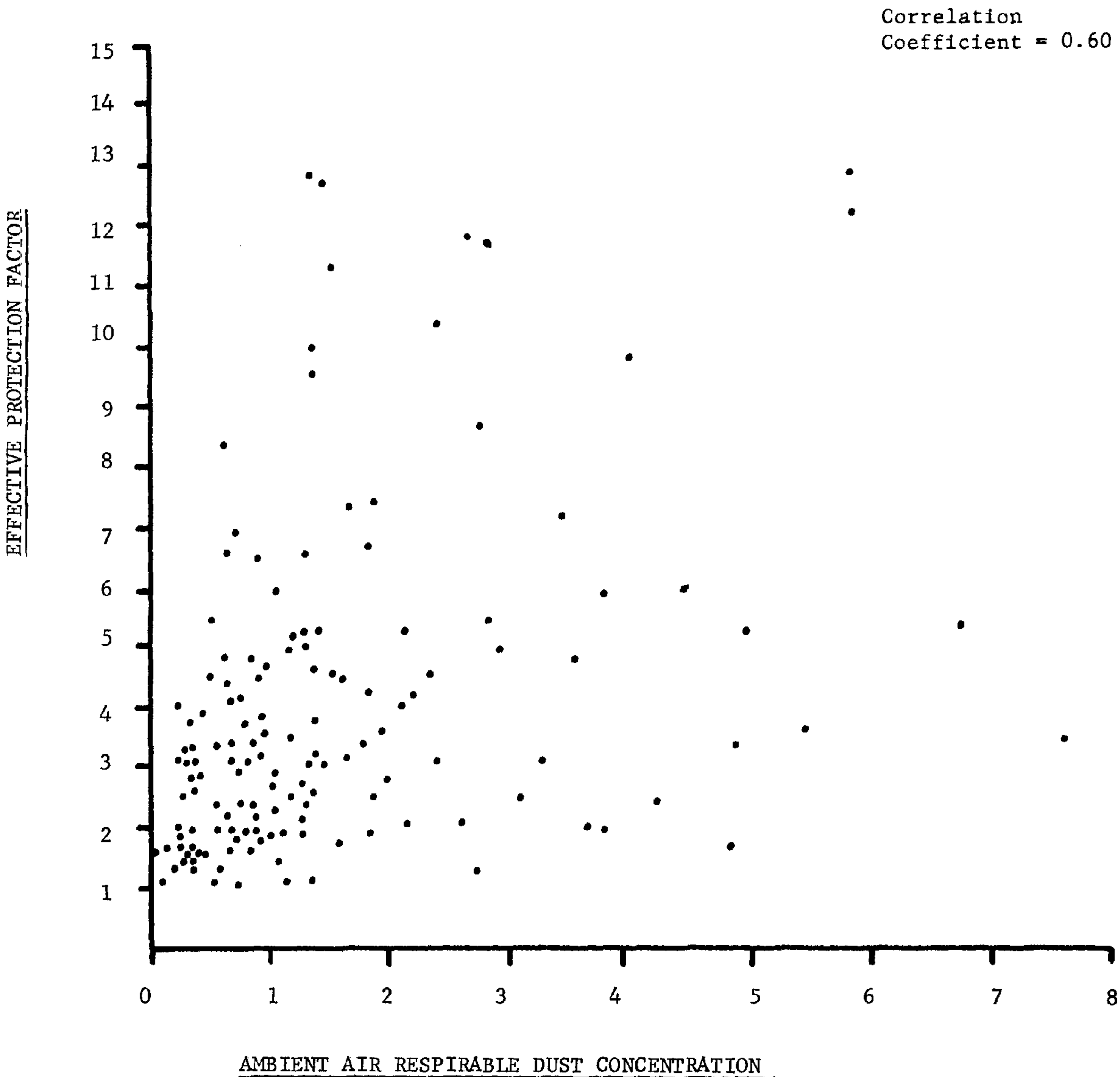

Correlation
Coefficient = 0.60
EFFECTIVE PROTECTION FACTOR
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
AMBIENT AIR RESPIRABLE DUST CONCENTRATION

FIGURE 3-32

3.3.9 EPF - Rock Dusting Crews

Three rock dusting crews involving 8 different test subjects participated in 20 man shifts of testing. Three different respirators were used, MSA 66, MSA 77, and AO R2090; no attempt was made to compare performance of these three different respirators. Test results are summarized in Table 3-13. As a matter of interest, there were no EPF values less than 1.0 and only two EPF's greater than 20; test results wherein the EPF's above 20 are omitted from data are summarized in Table 3-14.

TABLE 3-13

SUMMARY OF TEST RESULTS FOR ROCK DUSTING CREWS

Test Subjects	8
Man Shifts of Testing	20
Ambient Air Dust Concentrations, mg/M^3	
Mean Average	3.33
Median	2.60
Time of Wearing of Respirator, %	
Mean Average	29.1
Median	29.5
Effective Protection Factor	
Mean Average	10.2
Median	7.2

TABLE 3-14

SUMMARY OF TEST RESULTS FOR ROCK DUSTING (EPF's less than 1.0 and greater than 20.0 eliminated)

Ambient Air Dust Concentration mg/M^3	
Mean Average	2.56
Median	2.50
Time of Wearing of Respirator, %	
Mean Average	29.5
Median	29.5
Effective Protection Factor	
Mean Average	7.9
Median	6.3

Before comparing results obtained with rock dusters, it should be noted that miners engaged in mechanical rock dusting are involved in a different work environment compared to face miners, and, in particular, where wearing of respirators is concerned. Usually the mechanical rock dusters are working at some distance from the area where the coal is actually being mined. Consequently, the mine air around the rock dusters contains little respirable dust except when the rock dust is actually being applied (blown on) to exposed surfaces. In this latter situation, however, a rather heavy cloud of dust is generated and most rock dusters find it necessary to wear a respirator for the entire period of actual dusting. Thus, while rock dusters like face miners wear respirators intermittently the frequency of on-off-on of the respirator is substantially less for the former.

There were several significant differences with respect to those miners working at the face and those engaged in mechanical rock dusting, Table 3-15. The average ambient air concentration of respirable dust for all face miners was somewhat lower than for those doing rock dusting; however, with the exception of shuttle car operators, the dust concentrations for those other classifications of face miners was not significantly higher than that for rock dusters. Secondly, the percent of working time the respirators were actually worn was much less for the rock dusters than for the face miners. Despite this, the EPF obtained by rock dusters was significantly higher than that obtained for all job classifications of face miners, except the Cutting Maching Operator.

Face operations represent a different set of conditions compared to those found in machine rock dusting. Likely these differences effect such things as the proportion of time respirators are worn and the Effective Protection Factors obtained by face miners and rock dusters. Men working

TABLE 3-15

COMPARISON* OF FACE MINERS AND MINERS DOING MECHANICAL ROCK DUSTING

		Ambient Air Dust Concentration mg/M3 Mean Avg.	Time of Wearing %, Mean Avg.	Effective Protection Factor, Mean Avg.
A.	Face Miners	1.55	46.0	4.0
B.	Face Miners by Job Classifications			
	Continuous Mining Machine Operator	2.25	50.7	4.7
	Loading Machine Operator	2.13	44.3	3.8
	Shuttle Car Operator	0.94	41.3	4.2
	Roof Bolter	2.76	52.0	4.0
	Cutting Machine Operator	2.11	45.5	5.0
C.	Mechanical Rock Dusters	2.56	29.5	7.9

* Data for EPF less than 1.0 and greater than 20.0 eliminated.

at the face are subjected to dust concentrations which vary almost continuously throughout the shift, the concentration being effected by such as rate of extraction of coal, position of mining equipment, ventilation and dust suppression methods. Dust concentrations for the most part are comparatively low with occasional high levels. This varying nature of concentration results in most face miners doing two things. They put on and take off a respirator many times during a shift and the period of actual wear will vary from a very few minutes to somewhat longer periods. On the other hand, the rock duster spends about two-thirds of his time setting up equipment and about one-third in actual rock dusting. During the "set-up" period, the rock duster is working in almost dust free air, but during actual rock dusting, dust concentrations are quite high. Consequently, the rock duster makes essentially no use of a respirator during the "set-up" time but wears the respirator continuously during the actual rock dusting which may last an hour or more.

Probably the facts that the rock duster is exposed, at certain times, to obviously high concentrations of dust which in turn require the respirator to be worn and that he wears his respirator continuously during such exposure, explains, in part, why rock dusters obtain the higher EPF.

3.4 TPF - Results and Discussion

3.4.1 General

As indicated previously, the determinations of EPF's provided not only an excellent overview but specific information of the protection working miners obtained by wearing respirators in the usual intermittent manner. However, because wearing of a respirator was intermittent during the work period, measuring EPF did not provide information about protection obtained during the time the respirator was actually worn. Stated a bit more precisely, determining EPF did not provide data on what protection could be obtained during the period a respirator is worn and worn in the manner prescribed by the manufacturer.

Equally important, it was recognized that differences in human facial size and shape could be an important variable affecting the protection obtained by wearing the currently-approved, presently available half mask respirator. Consequently, it seemed appropriate to obtain some insight about such effects with respect to coal miners.

Thus, as mentioned, an in-mine test program was carried out during which each of the nine (9) test subjects wore six (6) different models of respirators and TPF's were determined; test results are summarized in Tables 3-16, 3-17 and 3-18.

Before making any comparisons or discussing these results, several things should be emphasized. TPF measurements were made, as previously indicated, under conditions where the test subject was wearing the respirator in as close conformance as possible to the manufacturer's recommendations. Normally, respirators are not worn according to the manufacturer's instruction, particularly with respect to head harness. Secondly, each TPF value for a given respirator for a specific test subject was obtained by averaging four test determinations of dust concentrations inside and outside the mask,

TABLE 3-16

SUMMARY OF TPF RESULTS

Test Subject Job Classifications	Facial Size* Classifications	TPF MSA 77	MSA 66	AOR2090	Welsh 7100	Welsh 7400	Welsh 7165
Roof Bolter	A	10.8	10.9	15.4	9.1	7.2	7.8
Cutting Machine Operator	B	12.3	9.7	10.5	6.6	9.6	7.9
Continuous Mining Machine Operator	C	10.7	10.4	11.4	8.2	10.2	9.2
Bratticeman	D	11.7	9.5	19.5	12.4	9.0	8.3
Timberman	E	14.2	9.6	11.2	7.1	4.0	6.0
Loading Machine Operator	E	9.7	9.9	10.1	11.6	11.9	9.6
Roof Bolter	F	10.2	7.5	8.6	6.6	8.9	9.0
Research Engineer	G	9.7	9.5	10.0	8.5	5.7	9.8
Loading Machine Operator	H	12.6	6.9	5.8	8.4	11.6	13.5

Mean Average for all Test Subjects = 9.7

* See Figure 3-13

TABLE 3-17

SUMMARY OF TEST RESULTS

Respirator Model	DC_A, mg/M3* Mean Avg.	TPF Mean Avg.
MSA 77	2.61	11.3
MSA 66	2.71	9.2
AOR2090	2.41	11.4
Welsh 7100	2.84	8.7
Welsh 7400	2.06	8.7
Welsh 7165	2.99	9.0

* As measured by GCA RDM 101 Respirable Dust Concentrations.

TABLE 3-18

SUMMARY OF TEST RESULTS

Job Classifications	Facial Size* Classification	DC_A, mg/M^3** Mean Avg.	TPF Mean Avg.
Roof Bolter	A	2.53	10.2
Cutting Machine Operator	B	2.42	9.4
Continuous Mining Machine Operator	C	4.85	10.0
Bratticeman	D	2.24	11.7
Timberman	E	1.91	8.7
Loading Machine Operator	E	2.33	10.5
Roof Bolter	F	3.92	8.4
Research Engineer	G	1.59	8.9
Loading Machine Operator	H	1.68	9.7

* See Figure 3-13

** As measured by GCA RDM 101 Respirable Dust Monitor.

each determination being made over a four minute period while actual mining of coal was in progress. This being the case, dust was being generated and concentrations were higher than the overall shift average; therefore, it can be suggested that TPF's were determined under conditions representing (or tending to represent the worst possible case). Thirdly, except for two (2) people, the test subjects participating in the TPF work were different than those who took part in the EPF program. Consequently, some differences observed could be a result of different test subjects involved.

While the nine (9) test subjects who participated in the TPF work represented 8 different facial sizes, it should be emphasized that these 8 facial shapes, i.e., test subjects, are not necessarily a cross-section of the population of underground miners.

Perhaps, even more importantly, it must be recognized that it is virtually impossible to maintain the same conditions from test to test when conducting the experimental testing when actual mining is in progress. While some uniformity of test conditions can be maintained, e.g., the same test subjects can be used, there is no feasible way of maintaining control over all conditions. For example, in Figure 3-18, is shown the mean average ambient air respirable dust concentration (DC_A) to which each of the test subjects was exposed during the testing periods. There were significant differences as shown in Table 3-19. When differences in dust concentrations with respect to respirators is considered, Table 3-20, there are less significant differences.

In any event, recognizing the aforementioned difficulties with lack of uniform testing conditions, a small panel of test subjects and other things, it should be emphasized that the following discussion is, by and large, projected in terms of providing useful indicators and valuable insights rather than conclusions. It should be noted, so far as is known, this is the first time such experimental work has been done, i.e., determining TPF while actual

TABLE 3-19

DIFFERENCES* IN AMBIENT AIR DUST CONCENTRATIONS - TEST SUBJECTS

Test Subjects	A	B	C	D	E	E	F	G	H
A	--	NS	S	NS	NS	NS	S	S	S
B	NS	--	S	NS	NS	NS	S	S	S
C	S	S	--	S	S	S	NS	S	S
D	NS	NS	S	--	NS	NS	S	NS	NS
E_1	NS	NS	S	NS	--	NS	S	NS	NS
E_2	NS	NS	S	NS	NS	--	S	S	S
F	S	S	NS	S	S	S	--	S	S
G	S	S	S	NS	NS	S	S	--	NS
H	S	S	S	NS	NS	S	S	NS	--

----

* 95% Confidence Level using t test

NS=Not Significant

S=Significant

TABLE 3-20

DIFFERENCES* IN AMBIENT AIR DUST CONCENTRATIONS - TEST RESPIRATOR

	MSA 77	MSA 66	AOR2090	Welsh 7100	Welsh 7400	Welsh 7165
MSA 77	--	NS	NS	NS	NS	NS
MSA 66	NS	--	NS	NS	S	NS
AOR2090	NS	NS	--	NS	NS	NS
Welsh 7100	NS	NS	NS	--	NS	NS
Welsh 7400	NS	S	NS	NS	--	S
Welsh 7165	NS	NS	NS	NS	S	--

----

* At 95% Confidence Level using t test

NS= Not Significant

S= Significant

coal mining is in progress.

3.4.2 Comparison of TPF and EPF

As shown in Table 3-21, there was a significant and substantial difference between the TPF and EPF values. Not surprisingly, the mean average TPF was over nine (9) compared to a mean average EPF of 5.7. Likewise, there seemed to be a more normal distribution of the TPF values (Figure 3-33) compared to the EPF values (Figures 3-14 and 3-15).

TABLE 3-21

COMPARISON OF TPF AND EPF

	TPF Mean Avg.	EPF Mean Avg.
All Data*	9.7	5.7
Selected Data**	9.3	4.0

* For EPF Intermittent Wear Only

** For TPF, all values outside of 3 standard deviations of the grand mean average were removed (3 out of 72 were removed). For EPF all values with EPF less than 1.0 and greater than 20.0 removed.

3.4.3 Comparison of Respirators

As was expected, the mean average TPF value for each respirator model was significantly higher than the corresponding EPF value, Table 3-22.

TABLE 3-22

COMPARISON OF RESPIRATORS

EPF & TPF

Respirators	EPF Mean Average	TPF Mean Average
MSA 66	3.8	9.2
MSA 77	4.0	11.3
AOR2090	4.6	11.4
Welsh 7100	4.0	8.7
Welsh 7400	3.7	8.7
Welsh 7165	4.0	9.0

TRUE PROTECTION FACTOR

Mean Average: 9.7
Median: 9.6

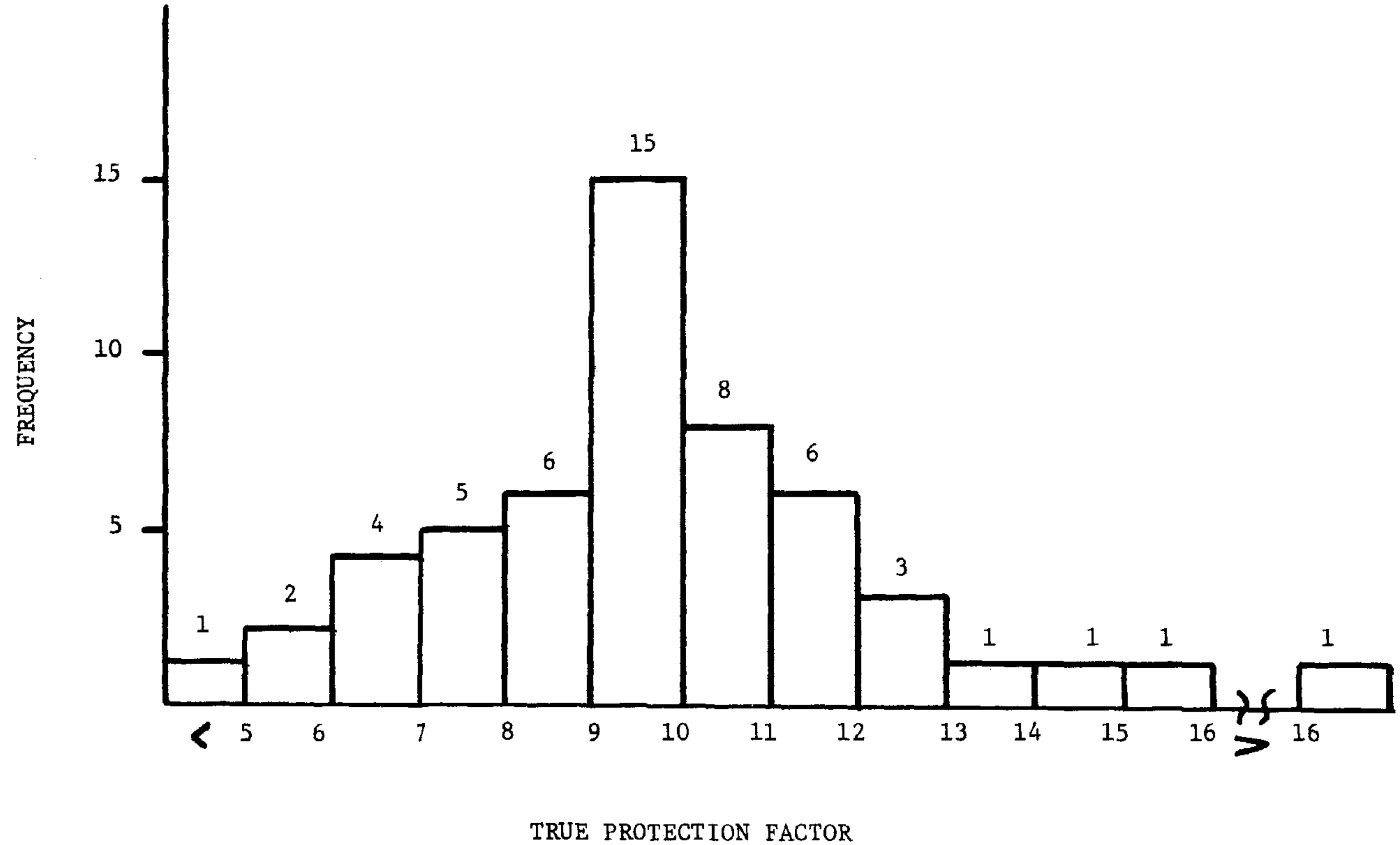


FIGURE 3-33

It will be recalled, using mean average EPF values, that there were no significant differences among the six different respirators tested, see Table 3-9. Not quite the same situation was found using the mean average TPF values, Table 3-23. While there was no significant difference between the AOR2090 and the MSA 77, each of these models had significantly higher mean average TPF values than the remaining four respirators tested. However, the existence of the indicated differences should be considered with considerable caution and not necessarily widely applicable, for several cogent reasons, principally that the test panel consisted of only nine subjects. Although there were 8 of 9 different facial classifications represented, the test panel is not necessarily representative of the population of working miners. We would certainly encourage the repeating of TPF measurements covering a larger group of tests subjects and for a longer period of time.

3.4.4 Comparison of Job Classifications and Facial Shapes

As shown in Table 3-24, there were some significant differences among the mean average TPF values for different job classifications. In some cases, but certainly not all, there were significant differences in the ambient air dust concentrations, compare Table 3-24 and Table 3-19. The fact that some test subjects with different facial shapes obtained significantly higher or lower TPF values, we believe, strenghtened the viewpoints that 1) facial shape has an effect on protection obtained, 2) respirators should be made in more than one facial size and 3) research should be undertaken to determine how many facial sizes should be provided.

Some additional indications of the effect on facial size on TPF can be obtained from a careful analyses of the data shown in Table 3-16, particularly as pertains to each respirator model. For example, in the case of the MSA 77 unit, it can be shown that there were significant (statistically) differences among certain mean average TPF values for certain different test subjects,

TABLE 3-23

DIFFERENCES AMONG THE RESPIRATORS* - TPF

	AO R2090	MSA 66	MSA 77	Welsh 7100	Welsh 7400	Welsh 7165
AOR2090	--	S	NS	S	S	S
MSA 66	S	--	S	NS	NS	NS
MSA 77	NS	S	--	S	S	S
Welsh 7100	S	NS	S	--	NS	NS
Welsh 7400	S	NS	S	NS	--	NS
Welsh 7165	S	NS	S	NS	NS	--

---

* 95% Confidence Level

S= Significant

NS= Not Significant

TABLE 3-24

COMPARISON OF JOB CLASSIFICATIONS

Test Subject* **	A	B	C	D	E	E	F	G	H
A	--	NS***	NS	NS	NS	NS	S	NS	NS
B	NS	--	NS	NS	NS	NS	NS	NS	NS
C	NS	NS	--	NS	NS	NS	S	S	NS
D	NS	NS	NS	--	S	NS	S	S	NS
E	NS	NS	NS	S	--	NS	NS	NS	NS
E	NS	NS	NS	NS	NS	--	S	S	NS
F	S	NS	S	S	NS	S	--	NS	NS
G	NS	NS	S	S	NS	S	NS	--	NS
H	NS	NS	NS	NS	NS	NS	NS	NS	--

----

* Letter designations also refer to facial shape, see Figure 3-13

** Job Classifications of test subjects as follows:

A= Roof Bolter

B= Cutting Machine Operator

C= Continuous Mining Machine Operator

D= Bratticeman

E= Timberman

E= Loading Machine Operator

F= Roof Bolter

G= Research Engineer

H= Loading Machine Operator

*** At 95% Confidence Level

thereby indicating that facial shape may be a factor affecting protection. However, it should be recognized that except for one category only one face size in each facial category was a test subject. Therefore, apparent differences or lack thereof, may have been maximized or minimized, respectively. Nevertheless, it seems the differences in TPF values obtained for each respirator model indicates that differences in face shapes have an effect on protection obtained and, more importantly, here is an area where further research is needed.

4. FIELD EVALUATION OF SINGLE-USE RESPIRATORS

4.1 Background and Objectives

4.1.1 Background

As has been previously mentioned, respirators found in use in the coal industry were the half mask, renewable filter type. At the time the field survey was done, no approved single-use respirators were in use, and understandably so. While single-use respirators have been available for some years for protection against nuisance dusts, only recently have three different models of single-use respirators received Bureau of Mines approval under Schedule 21-b* for use in underground coal mines.

While these units were approved on the basis of required laboratory testing done under Schedule 21-b*, there was essentially no information, or experience, available on how effective these respirators would be under conditions found in operating underground coal mines. Moreover, although these newly approved respirators potentially might have advantages over the currently used renewable filter types, there was likewise no direct information on whether the ultimate user -- the working coal miner -- found these respirators acceptable or not. Consequently, a field evaluation program was designed and executed.

4.1.2 Objectives

The field evaluation program had the following objectives:

(a) to determine if the three approved single-use respirators were acceptable to working coal miners for routine use

(b) to determine for each respirator which characteristics enhanced acceptability; similarly, to determine which characteristics were undesirable, and what, if any, corrective action was indicated

* One unit 21-c approved.

(c) to determine for each respirator judged unacceptable what, if any, corrective measures should be taken to make the unit acceptable

(d) to determine for each respirator which characteristics, if any, would make the unit unsuitable (or impractical) for use in underground coal mining, and, if such characteristics were found what, if any, corrective action was indicated.

4.2 Experimental Program

In order to accomplish the aforementioned objectives, a test program was carried out at five different mines of Eastern Associated Coal Corp.; two of the mines were located in Northern West Virginia, and the latter three, in the Southern part of West Virginia.

Briefly, this test program, which is described in Appendix 4-1 consisted of selecting, at each mine, a group of test subjects who represented supervisory personnel and various job classifications for face miners and who were regular users of dust respirators. Involved in the test program were 97 different test subjects representing first-line supervisory personnel and 20 different underground mining job classifications, Table 4-1.

After receiving appropriate instructions, these test subjects wore one of the three single-use respirators being tested in place of their regular respirator for a period of up to three working days; a new respirator unit was given the test subject each day and the used unit retained for subsequent examination at the conclusion of the test period; each test subject was interviewed individually on an unstructured basis by a project staff member to determine whether or not the test subject considers the test respirator acceptable and his reasons therefor. By using an unstructured interview technique it was also possible to learn what different test subjects felt about the desirable and undesirable characteristics of the test respirator and about what, if any, improvements might be needed.

The three single-use respirators, Figures 4-1, 4-2, and 4-3, tested were:

a. 3M Model 8710
b. American Optical Model R1040
c. Welsh Model 7165

A detailed description of these units is given in Appendix

At each of the mines (or during each test period) two single-use respirators were evaluated. Consequently, 76 of the 97 test subjects wore two different models of respirators. A "wildcat" strike and other local conditions precluded all test subjects from wearing two units.

TABLE 4-1

VOLUNTEER TEST SUBJECT - BY JOB CLASSIFICATION

Job Classification	No. of Subjects
Roof Bolter	19
Continuous Mining Machine Operator	16
Shuttle Car Operator	11
Section Foreman	6
Longwall Jack Machine Operator	6
Timberman	5
Loading Machine Operator	5
Cutting Machine Operator	4
Motorman - Brakeman	4
Coal Driller	3
Beltman	3
Bratticeman	2
Boom Operator	2
Rock Dust Crewman	2
Longwall Machine Headgate Operator	2
Trainee	2
Tipple Attendant	1
Trackman	1
Utility Man	1
Wireman	1
Safety Technician	1
	97

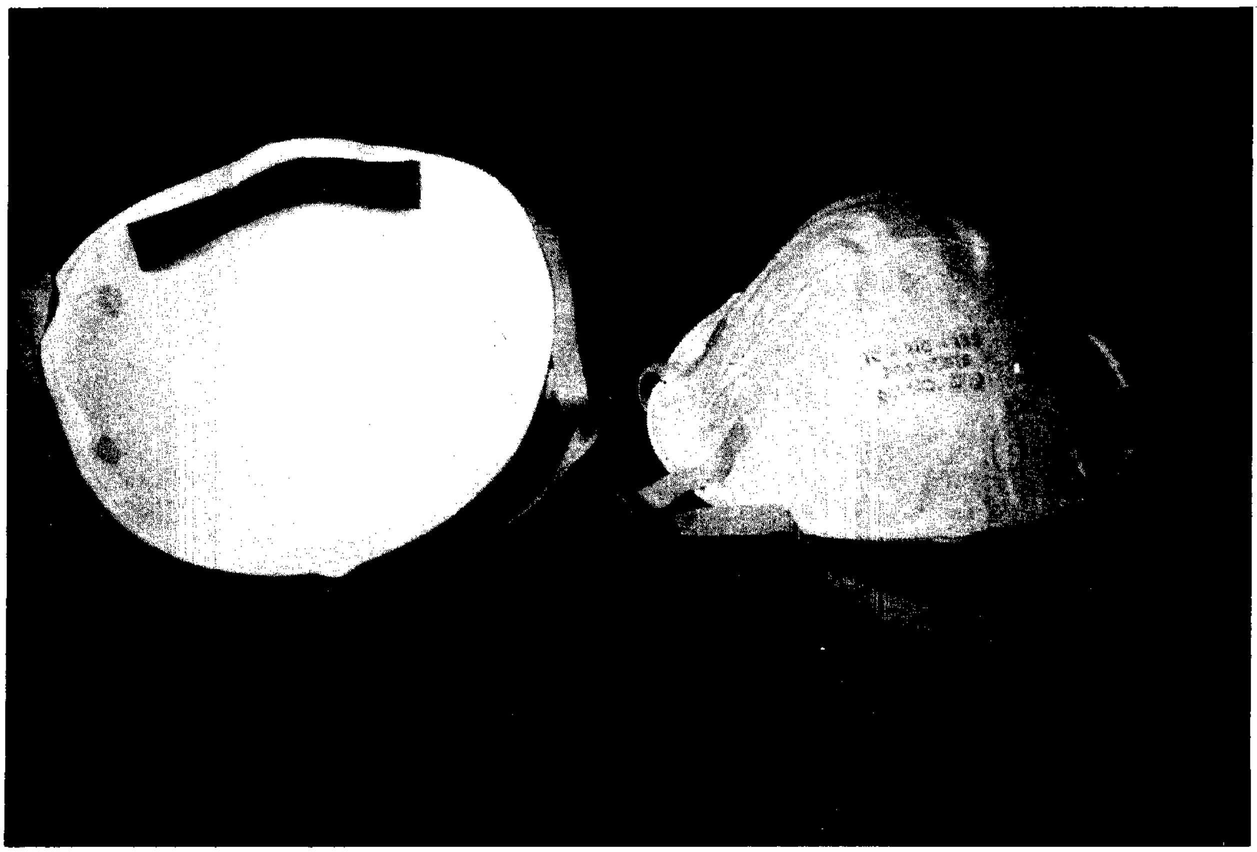


Figure 4-1. 3M Model 8710

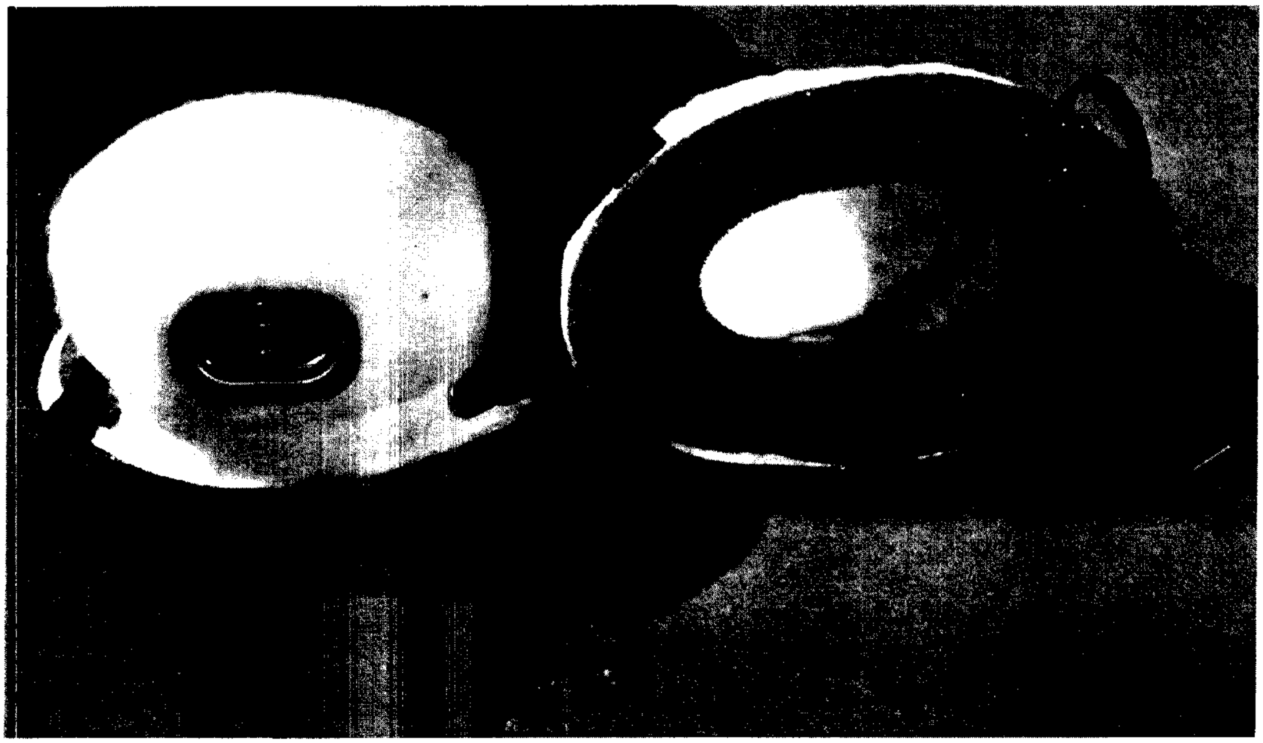


Figure 4-2. American Optical Model R1040

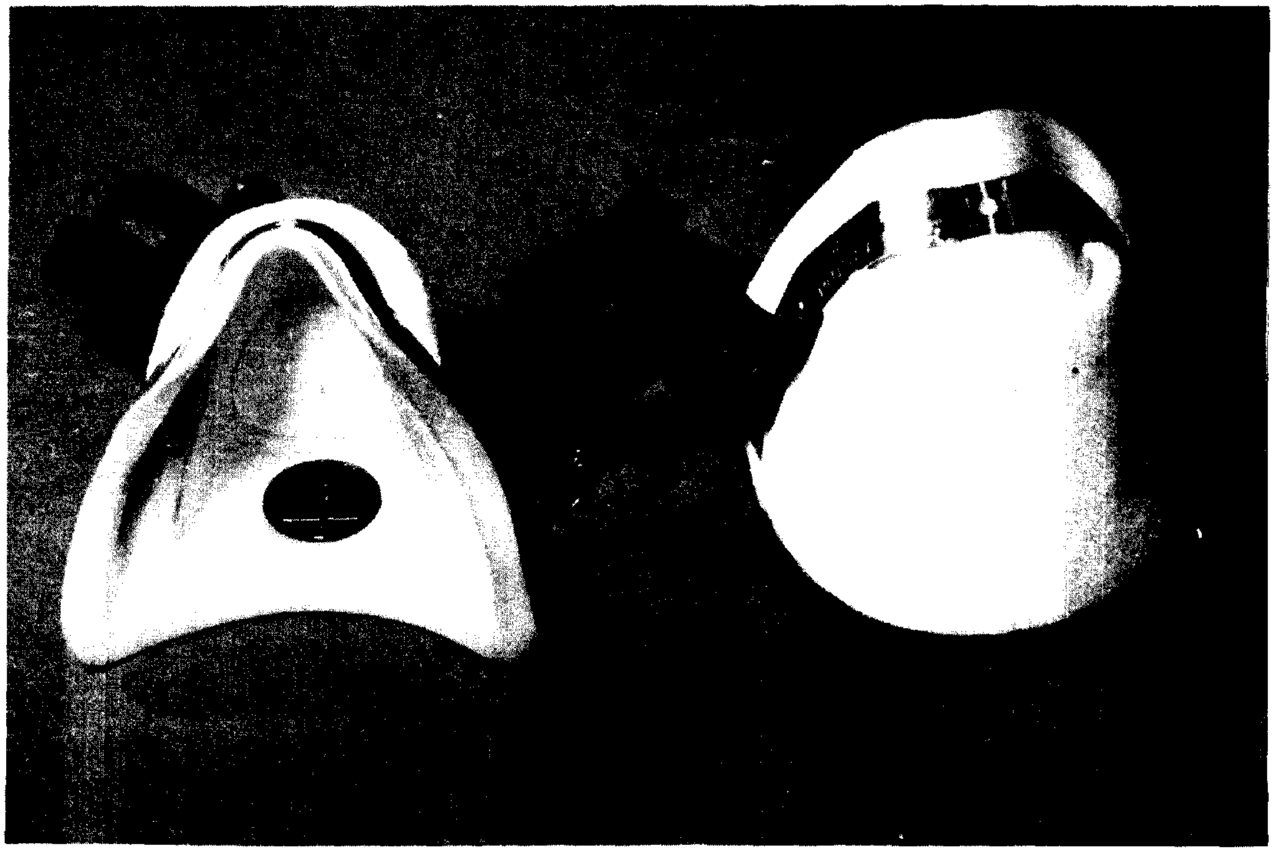


Figure 4-3. Welsh Model 7165

4.3 Results and Discussion

4.3.1 General

As mentioned three models of single-use respirators were worn by different test subjects; pertinent data on number of test subjects and man shifts of wear is shown in Table 4-2.

Based on his experience of actually wearing the single-use respirator, each test subject was asked among other things during the interview period to classify the respirator as acceptable, marginally acceptable, or unacceptable; these terms being defined as follows:

Acceptable - miner is willing to use the single-use respirator in the same fashion that he used respirator presently issued to him by the mining company; the miner considers the single-use respirator as good as, or better than the renewable filter unit(s) he is wearing, or has worn.

Marginally Acceptable - miner would use the single-use respirator but prefer not to do so; he considers the single-use respirator not quite as good as renewable filter unit(s) he is wearing or has worn.

Unacceptable - miner is not willing to use, or finds he cannot physically use, the single-use respirator; he considers the single-use respirator definitely inferior to the renewable filter unit(s) he is wearing, or has worn.

As shown in Table 4-3, the test subjects considered two of the three

TABLE 4-2

SUBJECTS AND MAN SHIFTS

Respirator Model	No. of Test Subjects	Man Shifts of Wear
3M - Model 8710	76	82
American Optical Model R1040	13	14
Welsh Model 7165	84	153

TABLE 4-3

ACCEPTABILITY OF SINGLE-USE RESPIRATORS

	Number of Test Subjects		
Respirator Model	American Optical R1040	3M-8710	Welsh 7165
Acceptable	0	7	73
Marginally Acceptable	0	2	3
Unacceptable	13	67	8

single-use respirators as unacceptable but one was found to be acceptable.

4.3.2 3M - Model 8710

Seventy-Six test subjects wore this respirator; 7 found it acceptable, 2 marginally acceptable and 67 unacceptable. As shown in Table 4-4, 38 subjects complained that wearing the respirator caused "it to get too hot" against the face, 14 subjects noted breathing problems, 7 subjects noted that the mask became wet inside and stuck to the face, and 7 subjects felt they were breathing "stale air" i.e., air which just had been exhaled. We think these difficulties are, to a large extent, due to the fact this respirator has no exhalation valve and therefore all air, particularly that being exhaled, passes through the filter.

Interestingly, forty-seven miners considered this respirator too fragile for use in underground coal mines. Moreover, it was observed that the head harness is such that the respirator cannot lie loosely around the miner's neck when not being worn but rather is easily crushed when placed there. Similarly, the fragility of the mask precludes the miner storing or carrying it in his shirt pocket where currently used renewable filter units are often carried or stored. The condition of this respirator before and after use is illustrated in Figure 4-4.

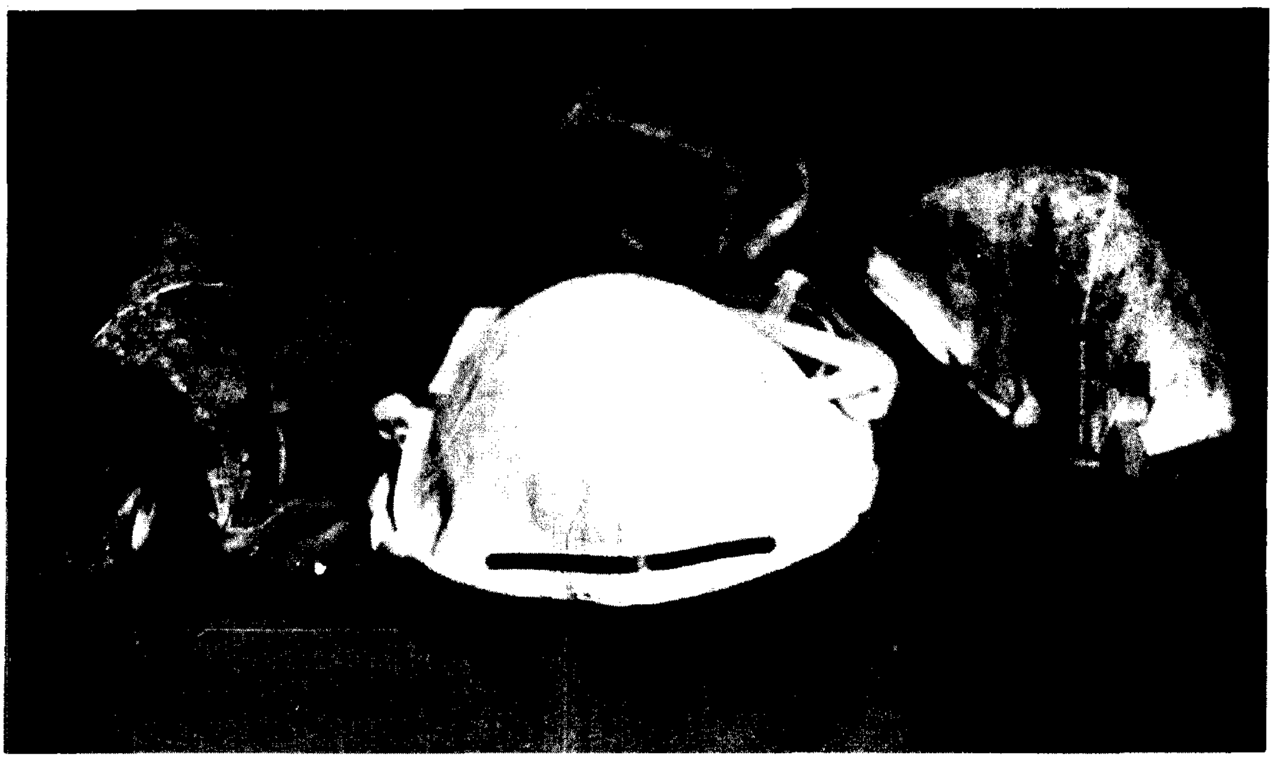
TABLE 4-4

MINER EVALUATION OF SINGLE-USE RESPIRATORS

Respirator	3M - No. 8710
No. of Test Subjects	76
Total Number of Man Shifts	82
Classification, Number of Test Subjects	
Acceptable	7
Marginally Acceptable	2
Unacceptable	67
Reasons Given by Test Subjects	
Too Hot	38
Too Fragile	47
Hard to Breathe Through	14
Inhale the Air you just Exhaled	7
Gets Wet Inside - Sticks to Face	7
Easy to Breathe Through	6
Removes the Dust Well	3
Additional Remarks by Test Subjects	
May Be Useful for Brakeman	1
Can't Wear Around Neck	4
Hurts Nose	1
Easy to Speak Through	1
Fits Well	1

FIGURE 4-4

CONDITION OF RESPIRATOR BEFORE AND AFTER USE
3M MODEL 8710



4.3.3 American Optical Model R1040

This respirator was worn by 13 test subjects all of whom considered it unacceptable. In fact, only one test subject was willing to wear a unit a second day. The reasons for this respirator being classified by the test subjects as unacceptable were mainly concerned with comfort; breathing resistance apparently was not a problem, Table 4-5. The major objections were that wearing the respirator caused a rapid build-up of heat against the face and that the head harness anchorage tends to "bite" into the face and cheek bones. Although this respirator has an exhalation valve, it seems that the operation of the valve is such that coupled with low filter resistance much of the exhaled breath passes through the filter rather than valve; this may account for the rapid build-up of heat against the face.

Examination of used respirators revealed that most of them were crumpled and crushed and, therefore, this unit is probably not sufficiently rugged to be suitable for use in underground coal mining operations. Figure 4-6 shows conditions of the respirator before and after use.

4.3.4 Welsh Model 7165

Of the 84 test subjects who wore this single-use respirator, 73 considered it acceptable, 3 marginally acceptable, and eight unacceptable. As shown in Table 4-6, the major reasons for acceptance were comfort and easy breathing. Sixty-three miners commented it was "easy to breathe through" and 37 men noted it was light and comfortable on the face. In addition, the miners liked the light weight and the small size and the fact that this respirator could be carried conveniently in their shirt pockets when not in use. The condition before and after use is shown in

TABLE 4-5

MINER EVALUATION OF SINGLE-USE RESPIRATOR

Respirator	American Optical R1040
No. of Test Subjects	13
Total Number of Man Shifts Used	14

Classification, Number of Test Subjects	
Acceptable	0
Marginally Acceptable	0
Unacceptable	13

Reasons Given by Test Subjects	Number of Test Subjects
Gets too hot on face	13
Hurts the Face	11
Rubs Neck and Makes it Sore	6
Gets Wet Inside	3
Head Harness Troublesome	2

Additional Remarks by Test Subjects	Number of Test Subjects
Can't Stand it on Me	2
Just No Good	2
Very Hot	1
Uncomfortable	1

FIGURE 4-5

CONDITION OF RESPIRATOR BEFORE AND AFTER USE
AMERICAN OPTICAL MODEL R1040

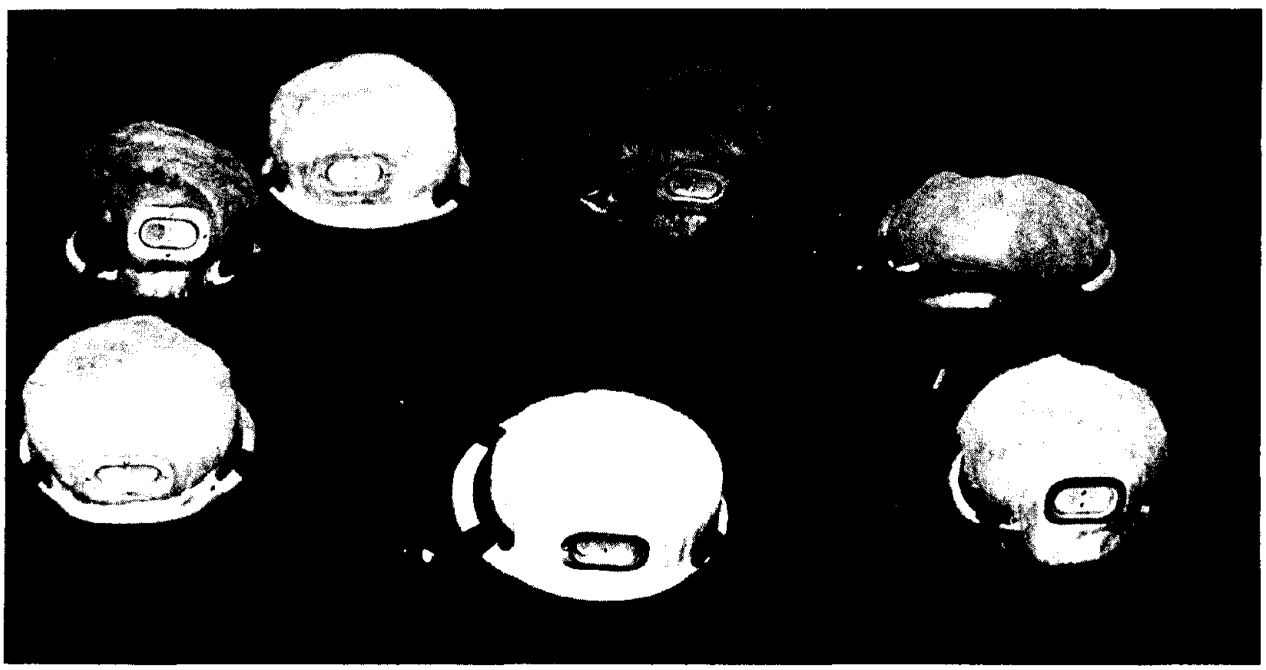


TABLE 4-6

MINER EVALUATION OF SINGLE-USE RESPIRATORS

Respirator	Welsh 7165
No. of Test Subjects	84
Total Number of Man Shifts	153

Classification, Number of Test Subjects	
Acceptable	73
Marginally Acceptable	3
Unacceptable	8

Reasons Given by Test Subject	Number of Test Subjects
Easy to Breathe Through	63
Light and Comfortable	37
Easy on the Face	6
Small	5
Does Not Interfere with Vision	2
Plastic Digs into Face	13
Fits Poorly	7
Head Harness Troublesome	17
Metal Nose Band Bends	2
Interferes with Safety Glasses	2
Hurts Face	2

Additional Remarks by Test Subjects	Number of Test Subjects
Better than any other Respirator	3
Good, But not as good as MSA-77	10
Better than MSA-77	12
Good Progress toward better Respirator	3
In the way around your Neck	1

Figure 4-6.

Despite the fact that a large majority of the test subjects found the Welsh Model 7165 respirator to be acceptable, there are some troublesome areas wherein it is indicated that improvement is needed. About 15 percent (13 out of 84) test subjects, reported that the plastic facepiece tended to dig into the face, particularly, under the eyes; and a little over 8 percent (7 out of 84) of the miners felt the respirator "could fit better". Seventeen men complained of problems with the head harness. The first two comments suggest that a facepiece of different material may be needed, or several different facial shapes may be needed to fit different face sizes, or a combination of both. The third comment about head harness problems is further evidence that the double strap head harness commonly found on respirators available for coal mine use are not feasible. In other words, a better head harness is needed.

Generally speaking, this Welsh respirator seemed sufficiently rugged to stand up in the rigorous environment of coal mining operations.

4.3.5 Conclusions

A field evaluation of three models of single-use respirators was made. The data obtained to date can be summarized as follows:

a. of the three models of single-use respirators evaluated, only the Welsh Model 7165 was considered acceptable by the miners who wore test units

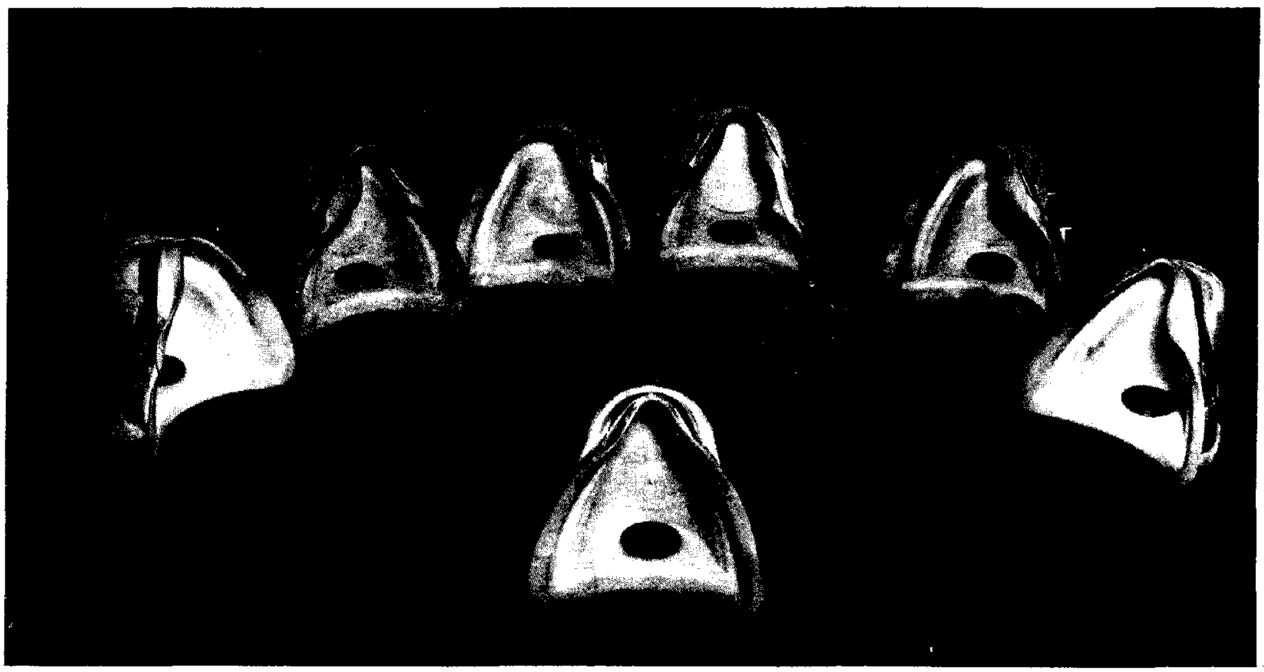
b. the degree of comfort afforded the wearer was cited by test subjects as the principle reason for acceptance or not of the single-use respirators

c. breathing resistance was not noted as a significant problem with any of the three single-use respirators, albeit some breathing difficulties were reported for the 3M Model 8710.

FIGURE 4-6

CONDITION OF RESPIRATOR BEFORE AND AFTER USE

WELSH MODEL 7165



5. CONCLUSIONS

As a result of the work reported herein, the following conclusions can be drawn:

1. Half-mask dust respirators are in general use throughout the bituminous underground coal mining industry.

2. Most respirators being used had the required Bureau of Mines (now NIOSH--BofM) approval; about 5 percent of the units being used were not approved.

3. Most miners feel there is a definite need for respiratory protective devices.

4. Use of respirators is, essentially, voluntary on the part of the miner, and in most mines use of respirators is generally limited to miners working in the vicinity of the face, rock dusters, roof bolters and, in some cases, beltmen.

5. Respirators are worn only on an intermittent basis; the amount of use, i.e., total time the respirator is worn, varies considerably and is affected by a number of factors, especially the level of visible dust and time the mining equipment is running.

6. Most miners feel that the presently available, approved respirators are acceptable for intermittent use but over a third of the miners feel the current units are unacceptable or marginally acceptable.

7. Wearing discomfort and breathing resistance are cited by miners as the major disadvantages of the present-day half-mask respirators. Another major problem is that the two-strap head harness is not suitable for coal mine use.

8. Training in the use of respirators, including the benefits to be derived from use and in the maintenance of respirators is inadequate.

Less than 25 percent of the mines visited during the in-the-field survey had any type of training program, and often these programs were more cursory than thorough. In addition to lack of training programs, at some mines there was a "negative" attitude toward respiratory protection against respirable dust which appeared to decrease the use of respirators.

9. Improvements in dust respirators wanted by miners are easier breathing, smaller and lighter-weight units, and a more comfortable facepiece and head harness.

10. As used under actual working conditions, presently available respirators provide face miners a reasonable level of protection against the inhalation of respirable dust. The mean average Effective Protection Factor (EPF) obtained was 5.7, thereby indicating an average of about 70 percent of the respirable dust present was not inhaled as a result of wearing a respirator.

11. Effective Protection Factors varied considerably from miner to miner and from day to day for each test subject.

12. Perhaps surprisingly, in-mine test results showed that the length of time the respirator was worn during the working shift did not affect the level of protection obtained.

13. Similarly, the length of time that the respirator is worn is not related to the ambient air average respirable dust concentration.

14. There was a poor but nevertheless significant correlation between the ambient air average concentration of respirable dust and the overall level of protection, Effective Protection Factor (EPF), obtained; the higher the dust concentration, the higher the EPF. It appears as the dust concentration increases that the miners, on average, endeavor to obtain a better fit between facepiece and face

when wearing the respirator.

15. Among the six models of respirators tested, i.e., the AOR2090, MSA 66, MSA 77, Welsh 7100, Welsh 7400, and Welsh 7165, there were no significant differences as to the level of overall protection, EPF, provided.

16. Rock dusters obtained significantly higher EPF's than did face miners. Among the various job classifications of face miners there were no significant differences in levels of protection obtained except for the coal driller who had a lower EPF than the others.

17. Determination of True Protection Factor (TPF), i.e., protection obtained when the respirator is actually being worn and in accordance with the manufacturer's instructions, indicated the respirator can provide significantly higher protection under such "ideal" field conditions (the mean average TPF was 9.7) than can be obtained under normal working conditions (see conclusion #10). Difficulty in maintaining proper seal between facepiece and face appears to be the major reason for reduced protection level under normal working conditions.

18. TPF determinations indicated facial size and shape can affect the level of protection provided; likewise it was indicated there might be some difference among respirators tested. In both cases, more confirmatory testing is needed.

19. Among the three approved single use, half mask respirators, the AOR1040, 3M 8710 and Welsh 7165, only the Welsh 7165 was found to be acceptable to working miners and suitable for use in coal mines.

20. As far as coal miners are concerned, there is a definite need for more comfortable respirators with reduced resistance to breathing. Similarly, for half mask respirators with reduced resistance to breathing. Similarly, for half mask respirators there is need for better designs so that a good fit between facepiece and the wearer's face can be secured.

6. RECOMMENDATIONS

6.1 Use of Respirators

Despite the need for improvement of the currently available, presently approved dust respirators, it has been clearly shown that these respirators provide a significant level of protection to the working coal miner exposed to respirable dust. Therefore, it is recommended that coal mine management, including top and middle management and first-line supervisors and mine safety personnel actively encourage the use of respirators. Such use should be definitely limited to those respirators having the required NIOSH--BofM approval.

6.2 Training in Use and Maintenance of Respirators

Clearly, there is need for working miners to be trained properly in the use of respirators; likewise, there is an evident need that respirators be properly maintained. Consequently, it is recommended that an appropriate training program for mining personnel be developed showing how dust respirators are properly used. This program should be developed under sponsorship of NIOSH, assisted by other appropriate government agencies; importantly, this training program should be developed in close consultation with representatives from the coal industry and United Mine Workers. One of the objectives of the program development would be the determination of frequencies of training and refresher training.

Similarly, a program for respirator maintenance should be developed; this, too, should be a cooperative effort involving government, the coal industry and the United Mine Workers.

6.3 Improved Dust Respiratory Protective Devices

There is a definite need for improved dust respirators or respiratory protective devices suitable for use in coal mines, and it is recommended that NIOSH undertake or sponsor research to achieve such.

It has been shown that the presently-available approved respirators cannot be worn for long periods, particularly if heavy work is involved; likewise, there is a comfort problem, and the present two-strap head harness is not suitable for coal mine use. In developing improved respiratory protective devices or respirators, it is recommended that a systems approach be considered in order, also, to take into account the need of the miner for head protection, noise protection, illumination, etc.

As far as improved half-mask respirators, or equivalent, are concerned, it is recommended that more than one facial size and shape be developed and produced. In order to determine the proper number of different sized face pieces and the configurations thereof, it will probably be necessary to carry out studies on the facial size and characteristics of coal miners. Once it has been determined what size face pieces are needed, it is well worth considering requiring manufacturers to produce like sized units.

6.4 Field Evaluation for Respirator Approval

The field evaluation work reported herein on three approved single-use respirators clearly showed two of the units were not suitable for coal mine use. Consequently, in so far as respirators used in coal mines are concerned, it is recommended that government approval schedules be revised to include a field evaluation program, or a laboratory simulated equivalent, in order to insure an approved respirator is feasible to the user and will be able to withstand the rigors of the coal mining environment.

7. REFERENCES

1. Federal Coal Mine Health and Safety Act of 1969 (Public Law 91-173)

2. Schutz, R. H., "The Dust Respirator Problem", Proceedings of Symposium on Respirable Dust, Washington, D. C. Nov. 3-4, 1969.

3. Gough, J., "Pneumoconiosis in Coal Trimmers," J. Patch Bact 51, 277 (1940)

4. Morgan, W. K. C., "Coal Workers Pnemoconiosis" AIHA Journal, Vol 32, No. 1, January 1971.

5. NCA Coal Data -- 1967

6. Lilienfeld, P. and J. Dulchinos, "Portable Instantaneous Mass Monitor for Coal Mine Dust," AIHA Journal, Vol 33, No. 3 pp 136-145 (1972)

7. Hack, A. L., Hyatt, E.C., Held, B. J., Moore, T. O., Richards, C. P., McConville, J. T., "Selection of Respirator Test Panels Representative of U. S. Adult Facial Sizes", LA-5488, Los Alamos Scientific Laboratories, March 1974. (LA-5488 was unpublished at the time of preparation of this report.)

8. ACKNOWLEDGEMENTS

The work carried out under this project could not have been successfully completed without the excellent cooperation and splendid assistance of many organizations and individuals.

Special thanks are due to both the individual mining companies and United Mine Workers for participation and assistance with the field survey. The fact that all the visits scheduled by project personnel were carried out as planned demonstrates that both mine management and UMW personnel played a vital role in insuring the success of this operation.

Especially noteworthy was the cooperation and assistance from the Operating and Safety Departments of Eastern Associated Coal Corp. which did so much to insure the successful execution of the in-mine testing work. In particular, the many underground miners who served as test subjects are to be commended.

During the course of the work, Mr. J. R. Lynch and Mr. A. K. Gudeman from NIOSH served as project officers. Throughout, these men provided wise counsel and encouragement for which the project staff is most grateful.

Form Approved
Budget Bureau No. 85-S70013

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
Environmental Health Service
Environmental Control Administration
Bureau of Occupational Safety and Health
1014 Broadway, Cincinnati, Ohio 45202

COAL MINE RESPIRATOR SURVEY

Survey No. _____ Date _________

Identification

Name and address of company ____________________

____

____

Name of person interviewed ____________________

Name of interviewer ____________________

Mine Description

Mine name ____________________

County ____________ State ____________ BM Code ____________

Type of mining ____________________

Total number of miners ____________________

Number of face miners ____________________

Number of working sections ____________________

Seam height ____________________

ECA-119 (Cin)

Respirator Use

For each specific respirator application provide the following information:

1. For what operation is the respirator being used? ______________________________

____

2. What air contaminant is present? ____

____

3. What type of respirator is used? ____

____

4. Job title of miner using respirator ____

____

5. Are air contaminant concentrations measured in this environment - if so, what are the concentrations?

____

____

6. How long does the miner use the respirator? ____________________________________

____

7. Is use of the respirator by the miner voluntary or required? _____________________

____

8. Is the miner trained in the use of the respirator? _______________________________

____

9. How, and by whom, is the respirator cleaned and maintained? _____________________

____

If respirators are used for more than one application in this mine, use additional copies of page two of this form.

General Comments

In general, do the miners find the types of respirators they use acceptable - if not, what are their objections?

What do you think is the appropriate use of respirators in mines?

What methods can be used to improve respirator acceptability?

What types of respirators should be developed for mine use?

Other comments:

ECA-119 (Cin)
(6-70)

APPENDIX 2-2

Data on Mining Operations Visited

During the field survey, 40 mining operations (representing 47 different mines) were visited in eight different states. Distribution of these operations by state is shown in Table 2-2-1.

TABLE 2-2-1

Operations Visited - By State

State	No. of Operations
Alabama	3
Illinois	2
Indiana	1
Kentucky	7
Ohio	3
Pennsylvania	10
Virginia	4
West Virginia	10
Total	40

Pertinent data for each of 40 mining operations with respect to number of miners at the face and total number of miners, mining sections, and seam height are shown in Table 2-2-2.

TABLE 2-2-2

Miners, Mining Sections, & Seam Heights

Operation Identification Number	Miners, No. Face	Miners, No. Total	Mining Sections, No. Conventional	Mining Sections, No. Continuous	Mining Sections, No. Longwall	Mining Sections, No. Total	Seam Height In.[(a)]
1	290	543	3	9	1	13	56
2	320	357	2	6	-	8	96
3	193	410	-	12	1	13	80
4	146	286	6	2	-	8	54
5	65	88	2	-	-	2	48
6	276	490	-	9	1	10	54
7 (b)	37	72	3	1	-	4	36
8	120	185	-	7	-	7	42
9	100	138	4	2	-	6	40-42
10	45	95	-	3	-	3	50-66
11	126	239	-	6	-	6	54
12	300	500	-	12	-	12	66-72
13	150	448	-	8	-	8	68
14	50	310	-	3	-	3	78
15	100	171	-	5	-	5	78
16	105	180	-	5	-	5	58
17	96	208	-	8	-	8	57
18 (c)	58	64	2	-	-	2	54
19	54	98	3	-	-	3	55
20	120	193	-	6	-	6	84
21	70	169	-	5	-	5	72
22 (d)	107	224	5	1	-	6	72 (56-93)
23	420	659	10	-	-	10	60-120
24	156	325	13	-	-	13	60-120
25	90	320	6	1	-	7	45-50
26	50	108	2	-	-	2	60
27	132	227	6	-	-	6	54
28 (c)	145	225	4	3	-	7	45 (65-80)
29	124	340	1	7	-	8	48-60
30	100	141	5	-	-	5	44
31	81	127	4	-	-	4	58-72
32	180	360	-	7	2	9	54
33	104	230	-	6	-	6	84
34	36	80	-	3	-	3	32-36
35	6	11	1	-	-	1	31-54
36	95	185	2	3	-	5	35-55
37	111	165	5	-	-	5	42
38 (e)	70	127	2	2	-	4	34
39	45	93	2	-	-	2	47-55
40	75	140	2	2	-	4	48-54
Total	4948	9331	95	144	5	244	-

(a) As reported by the Mining Company
(b) Includes 4 mines
~~(c) Includes 2 mines~~
(d) Mining Operations in 2 seams,
~~(e) Includes 3 mines~~

APPENDIX 2-3

SUMMARY OF SURVEY RESPONSES

(See Appendix 2-1 for Survey Form)

A. Survey Sample Data

Number of States		8
Number of Companies		31
Number of Mines		47
Number of Seams		27
Range of Seam Height, in.,	Low	34
	High	96

Mining Sections	
Longwall	5
Continuous	144
Conventional	95

B. Responses to Questions --

1 and 4. For What Operation (and Job Title) is Respirator Being Worn?

Management and Supervisory

Job	No.
Mine Superintendent	24
Mine Manager	4
Safety Director	16
Safety Inspector	14
Engineer	6
Mine Foreman	2
Section Foreman	17
Sub-total	83

Mining Personnel

Shuttle Car Operator	72
Continuous Mining Machine Operator	69
Roof Bolter	54
Loading Machine Operator	31
Rock Duster	30
Shot Firer	25
Cutting Machine Operator	24
Motorman and Tram Drivers	23
Continuous Mining Machine Helper	19
Coal Drill Operator	19
Beltman	16
Longwall Operators and Jack Machine Operators	14
Brakeman	2
Service & Supply (Mechanic, Timberer, Brattice Man) (Trackman, Electrician, Bit Grinder)	30
Sub-total	428
Total	511

2. What Air Contaminant is Present?

	No.
Coal	386
Rock Dust	118
Drill Stone	243
Sand	25
Pyrite Bales	1
Emery and Steel Dusts	2
Shot Hole Smoke	4
Cable Fire Smoke	1
Total	780*

*Total is more than 511 because many of those interviewed responded that the respirator is being used to protect against more than one contaminant.

3. What Type of Respirator is Used?

RESPIRATORS IN USE BY UNDERGROUND MINERS*

Make and Model	Percent of Total
MSA - 57 1)	7.7
MSA - 66	37.6
MSA - 77	30.0
Welsh Air Aider	3.9
Willson 45 CD 2)	2.2
Willson 600 2)	2.4
Willson Monomask	0.6
American Optical R2090	6.0
Cesco 90F	2.6
Pulmosan	2.8
Flex-A-Foam 3)	3.3
Seelig Specialties Co. Face Mask 3)	0.9
Total	100.0

(1) No longer approved and phased out by using companies
(2) Approved for pneumoconiosis producing dusts at time of survey. Not now approved under schedule 21- b
(3) Not approved for pneumoconiosis producing dusts at time of survey

*Includes 428 people in various job classifications, plus 17 section foremen; total 445.

5. Are air contaminant concentrations measured in this environment -- if so, what are concentrations?

		Numer of Mines
Respirable dust	Yes	47
	No	0

Concentrations were being measured in accordance with required Bureau of Mines sampling program. Reportedly, concentrations varied from less than 2.0 to over 4.0 mg/M_3.

6. How long does miner use the respirator?

DURATION OF RESPIRATOR USE

Hours per Shift	Percent of Underground Work Force* Interviewed
0-2	22
2-3	35
3-5	29
>5	14
	100

*See note, question 3.

DURATION OF RESPIRATOR USE BY JOB CLASSIFICATION

Job Classification	Percent Underground Work Force Interviewed*			
	Hours per Shift			
	0-2	2-3	3-5	>5
Shuttle Car Operator	23	30	19	28
Continuous Miner Operator	17	35	13	35
Roof Bolter	22	37	19	22
Loading Machine Operator	19	43	19	19
Rock Duster	22	38	18	22
Shot Firer	9	39	48	4
Cutting Machine Operator	12	33	22	33
Motorman and Tram Driver	18	47	24	11
Continuous Mining Machine Helper	23	31	31	15
Coal Drill Operator	32	32	36	0
Beltman	17	22	39	22
Longwall Miner Operators	13	53	7	27
Service and Supply	22	34	22	26

*See note, question 3.

7. Is Use of Respirator Voluntary?

	Number of Mines
Yes	0*
No	47

*One mine required respirators to be used when drilling or cutting coal.

8. Is the Miner Trained in Use of the Respirator?

TRAINING IN RESPIRATOR USE

	Number of Mines
Provided by Company*	11
None Provided by Company	36

*Includes any training when miner is first employed, or first issued a respirator, or any training provided at safety meetings.

9. How, and By Whom, is Respirator Cleaned and Maintained?

	Number of Mines
By Individual	46
By Company	1

C. General Comments

1. NEED FOR USE OF RESPIRATORS IN COAL MINES

Category	Percent of Underground Work Force*
Generally Needed	42
Used Whenever Dust is Present	45
Used Only When Necessary	4
Needed, but are Hard to Wear	8
Prevent Dust to Make Use Unnecessary	1
	100*

*See note, question 3.

2. RESPIRATOR ACCEPTABILITY BASED ON INTERMITTENT USE

Category	Percent of Underground Work Force*
Completely	2
Generally	64
Marginally	24
Unacceptable	10
	100

*See note, question 3.

3. PROBLEMS ASSOCIATED WITH RESPIRATOR USE

Category		Percent of Underground Work Force*
Cause Breathing Difficulties		37
Physical Discomfort		55
Generally Cumbersome and Uncomfortable	13	
Cause Perspiration	9	
Interfere with Tobacco Chewing	9	
Troublesome Head Harness	7	
Respirator Too Large	6	
Facepiece Troublesome	5	
Dust Inside Mask	5	
Improper Fit	1	
Interference with Work		9
Restricts Vision or Interferes with Wearing Glasses	5	
Exhalation Valve Troublesome	2	
Interferes with Communication	1	
Difficult to Carry	1	
		101**

*See Note, question 3.
**Total adds to 101% because of rounding

APPENDIX 2-4

Respirator Maintenance Program

During the field survey, it was found that one mining company provides for the maintenance of dust respirators to be done by the company. This program, which the miners may use on a voluntary basis, is essentially as follows:

1. The company issues MSA 77 respirators and each respirator issued has identifying marks placed on the respirator body under the filter cover. This provides a means of insuring that the miner receives back his own unit after the respirator has been serviced.

2. At the end of the shift, the miner removes the filter cover and dirty filter, and puts the respirator body in a designated basket. The miner retains the filter cover and washes it before the next use.

3. The bath house man washes and sanitizes each respirator body; subsequently, it is inspected for defects and either the defects are repaired or a new unit is provided. Then, the respirator body is hung on a peg board, and is available for the miner to pick up the next day.

4. The miner picks up the serviced respirator, installs a clean filter and the filter cover, and is ready to start work with a clean and properly working respirator.

As mentioned, use of this maintenance service is voluntary (and also need not be used daily) but the miners are strongly urged to use such. Most of the miners make use of the service every day or too, but a few never use it and apparently these few do little respirator maintenance on their own. There are also a few of the work force who still take their respirators home to wash. There was no explanation as to why these latter two groups did not use the service available.

The operator felt that the time and money spent for this maintenance was more than offset by the savings in respirator use annually. Moreover, the fact that most men had clean, repaired respirators most of the time has resulted in a high acceptance and use of respirators, and high morale. The company has not been able to estimate monetarily the value of these respirators, but feels there is an additional "pay off" in less absence from work, etc.

APPENDIX 3-1

Respirators Used in EPF In-Mine Testing Program

1. Mine Safety Appliances Company Dustfoe No. 77

The No. 77 is a fairly large mask 4.5 inches (114 mm) in over-all height, 3.25 inches (82 mm) in width, and 4.0 inches (102 mm) in depth; it weighs 4.6 oz (130 g). The body is plastic fitted with a replaceable rubber facepiece. A double strap elastic head harness is used, Figure 3-1-1. This unit accounted for 30 percent of all respirators found in use during the field survey.

2. Mine Safety Appliances Company Dustfoe No. 66

The No. 66 is somewhat smaller, height 3.5 inches (89 mm), width 3.0 inches (76 mm), depth 3.5 inches (89 mm), and lighter than the No. 77, 3.4 oz (95 g). The body of the respirator is metal with a replaceable rubber facepiece and a replaceable filter holder, Figure 3-1-2. A single strap elastic head harness is used. The No. 66 accounted for 37 percent of all respirators found in general use during the field survey.

3. American Optical Corporation - R2090

The R-2090, Figure 3-1-3, is a relatively small, height 4.0 inches (102 mm), width 3.5 inches (89 mm), depth 3.0 inches (76 mm) though not particularly lightweight unit, 4.6 oz (130 g). The respirator body and facepiece are one integral unit made from relatively hard rubber. A double strap rubber head harness is used. This unit accounted for approximately 9 percent of all respirators found in general use during the field survey.

4. Welsh Manufacturing Company No. 7100

The 7100 is a small, height 3.5 inches (89 mm), width 3.5 inches (89 mm), depth 3.25 inches (83 mm), lightweight, 2.6 oz (75 g), unit,

Figure 3-1-4. The facepiece and respirator body are one integral unit made from flexible plastic, a two strap, elastic head harness is used. This unit accounted for approximately 4 percent of all respirators found in general use during the field survey.

5. Welsh Manufacturing Company - No. 7400

The 7400 is a rather wide flat unit, height 6.0 inches (152 mm), width 4.25 inches (108 mm), depth 3.0 inches (76 mm) with filter attached. The body of the respirator is only 2.0 inches (50 mm) in depth. The unit is fairly heavy, 4.9 oz (140 g). The body and facepiece are a single integral unit made from flexible plastic. A two-strap rubber head harness is used, Figure 3-1-5.

6. Welsh Manufacturing Company - No. 7165

The 7165 is essentially a single-use version of the Welsh Model 7100. The facepiece is formed from a lightweight plastic to which a filter is attached using cement and staples. On the exterior edge is a metal band that can be bent to adjust the seal around the bridge of the nose of the wearer. The metal band is used to stiffen the sealing edges and serves as an anchor point for the 2-strap head harness. The head harness is adjustable. The respirator, Figure 3-1-6, is 3.5 inches (89 mm) wide, 4.0 inches (100 mm) high, 3.0 inches (76 mm) in depth, and weighs 3.18 oz (90 g).

3-1.2 EPF Testing of Respirators with 100% Time-of-Wearing

While it was recognized, as a result of the in-the-field survey that underground miners wear respirators only on an intermittent basis, i.e., part of the time, and furthermore, it was recognized substantive difficulties might be encountered by miners trying to wear respirators continuously, i.e., 100 percent of the time, it was decided some in-mine testing involving respirators worn continuously should be undertaken. Accordingly, at Mine A, the test subjects on both test sections wore their respirator continuously except for the lunch-break. Except for this continuous wearing of the respirator, the daily testing procedure was the same as that described above.

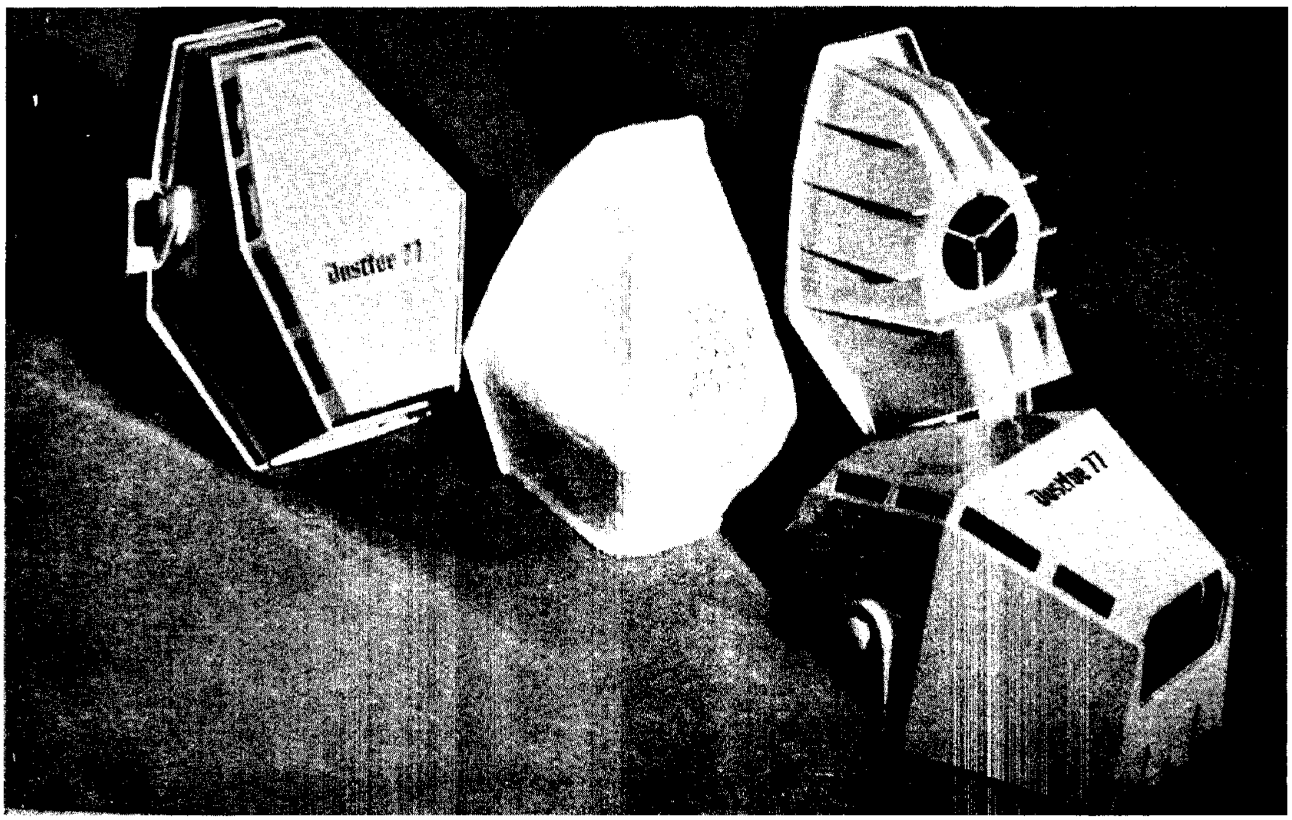


FIGURE 3-1-1

Mine Safety Appliances Company

"Dustfoe" No. 77

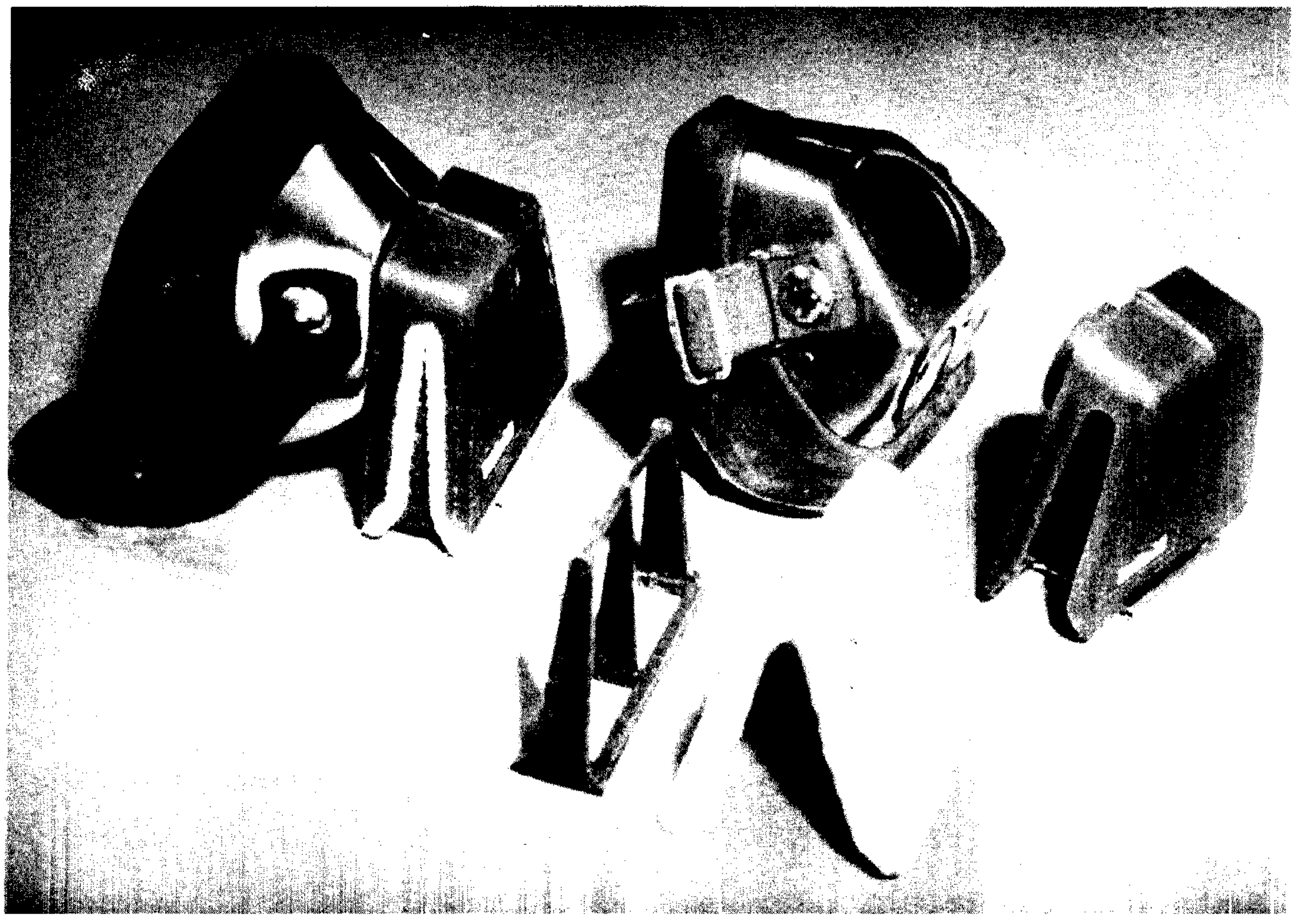


FIGURE 3-1-2

Mine Safety Appliances Company

"Dustfoe" No. 66

FIGURE 3-1-3

American Optical Corporation

R-2090

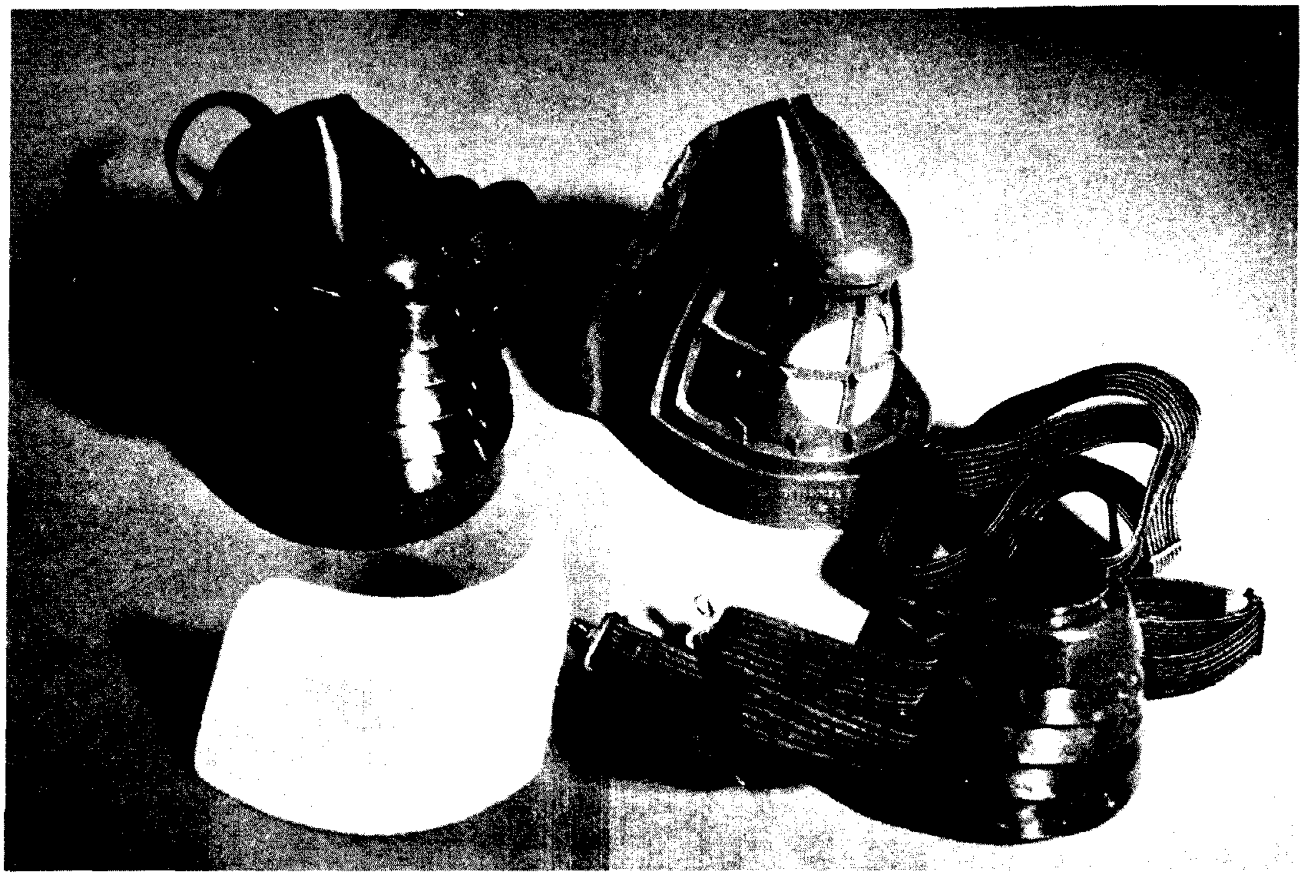


FIGURE 3-1-4

Welsh Manufacturing Company

No. 7100 "Air-Aider"

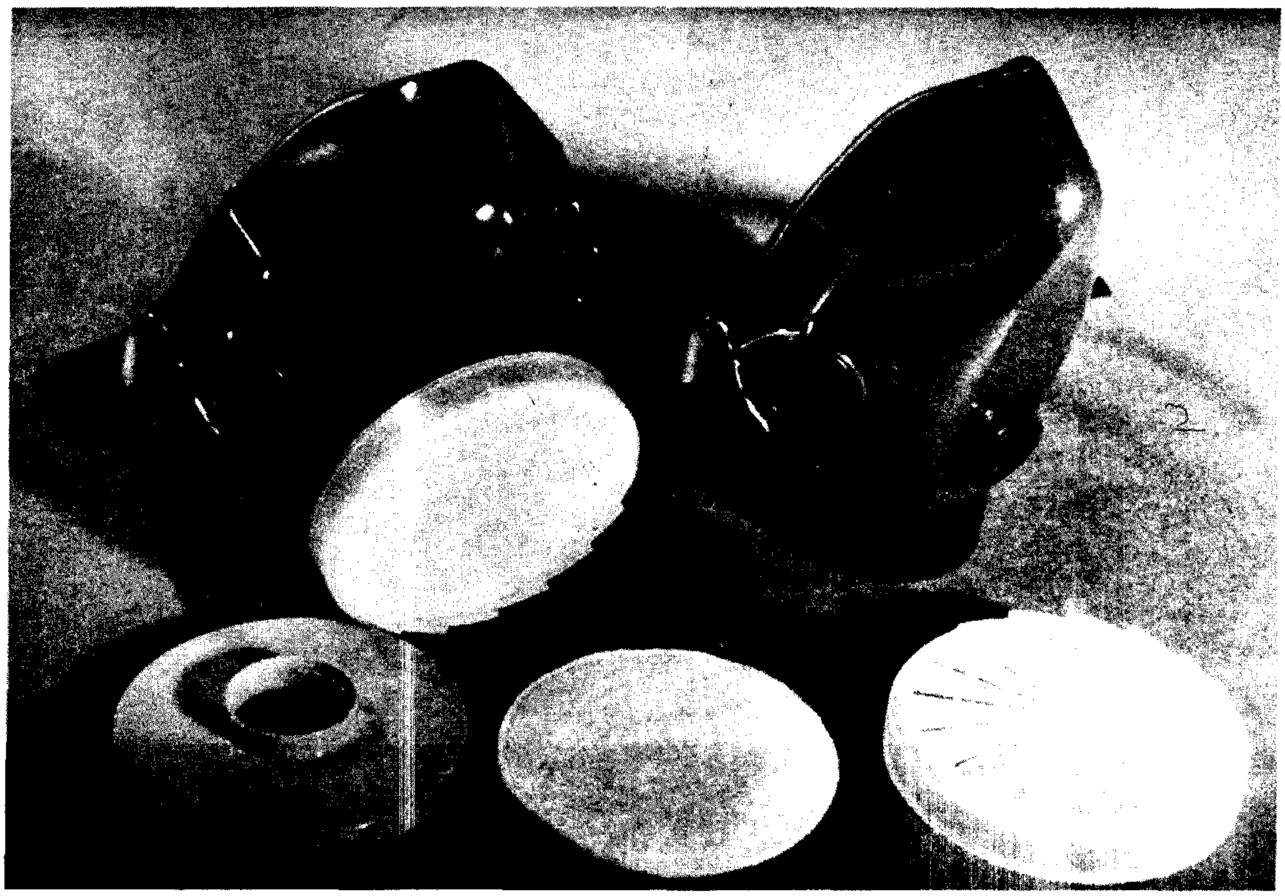


FIGURE 3-1-5

Welsh Manufacturing Company

No. 7400

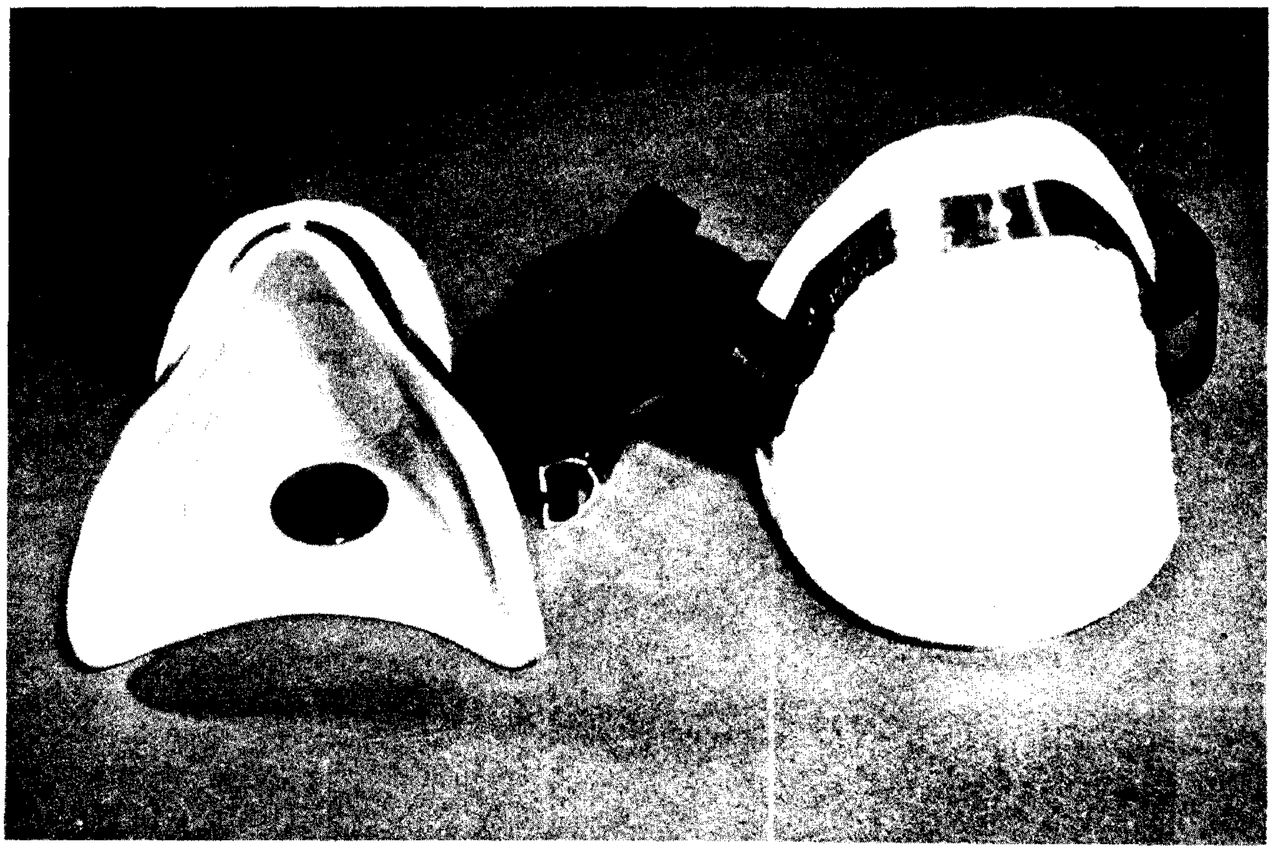


FIGURE 3-1-6

Welsh Manufacturing Company

No. 7165

APPENDIX 3-2

MINING EQUIPMENT AND CONDITIONS

3-2.1 Face Sections

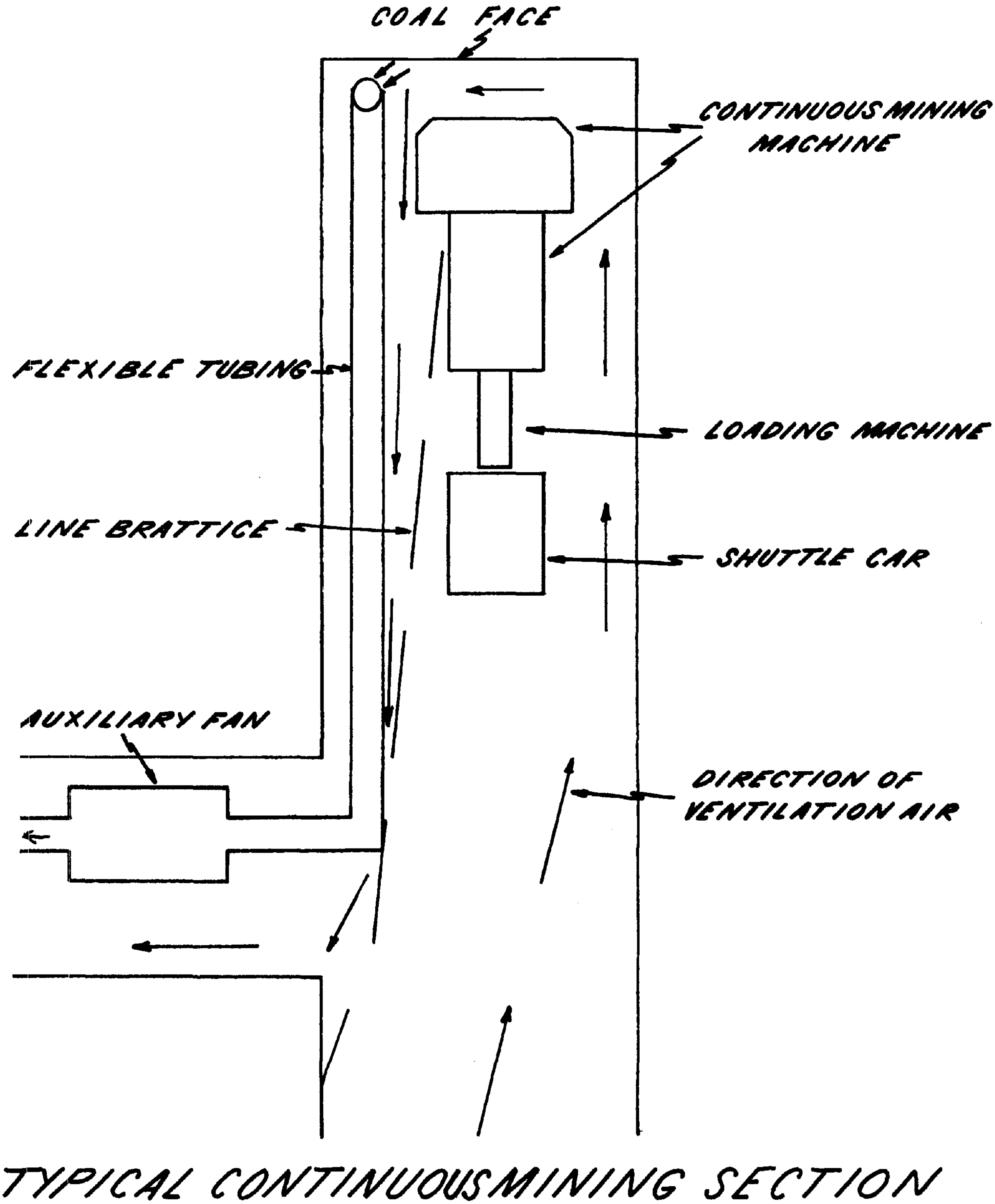
3-2.1.1 Mine A

Two continuous mining sections were utilized at Mine A. The seam was being mined in advance by Goodman 430 continuous miners. The Goodman 430 mines an area of 7.5 feet high and 12 feet wide. The coal was delivered by means of an integral conveyor to the rear of the machine and then was picked up by a Joy loader and conveyed to a shuttle car. High pressure water sprays were being used for dust control. Ventilation was by line brattice and auxiliary fan. Mining conditions were generally normal except for excessive "out gassing", i.e., evolution of methane from seam encountered in one section which necessitated periodic shut-down of the mining machine and curtailed production to some extent. Figure 3-2-1 illustrates the general configuration of equipment and ventilation.

The roof bolter who served as a test subject on one section operated a Galis roof bolting machine. The Galis machine utilizes a hollow drill bit and a dust collecting system for collecting dust produced in the roof drilling operation.

3-2.1.2 Mine B

Two continuous mining sections served as test sites at Mine B. In each section mining was accomplished using a Joy 1-CM Continuous Miner. The Joy Model 1-CM has the roof bolting machine as an integral part and roof bolting is done as the machine advances. Two roof bolters are used, one on each side of the machine, in contrast to the usual practice of a roof bolter and helper when a Galis machine is used. The roof bolting machine used on the 1-CM also has a dust collection system. On each section one roof bolter



TYPICAL CONTINUOUS MINING SECTION

FIGURE 3-2-1

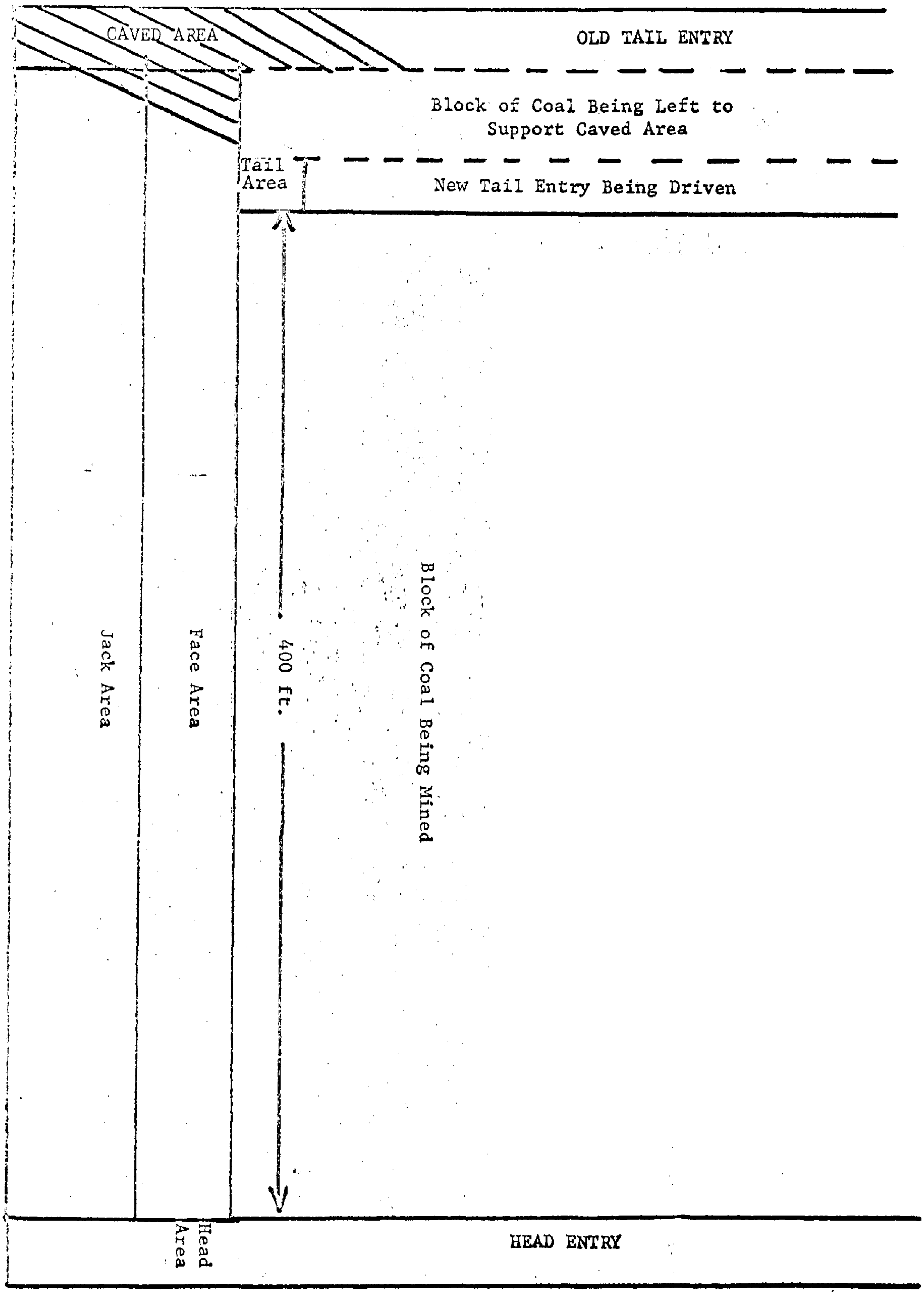
served as a test subject. In each case the right side roof bolter, as viewed from behind the machine, was used as test subject. Both sections were on retreat and were mining an area 14 feet wide and 10 feet high. Ventilation was by line brattice and auxiliary fan. High pressure water sprays were being used for suppressing dust.

Mining conditions were normal and excellent production was achieved on both sections throughout the test period.

3-2.1.3 Mine C

At Mine C a conventional mining section and a longwall section were used; both sections were operating in the coal 60 inches high. The longwall section mines coal using a Westphalia planer, or plow; at the time of testing the coal face being mined was 400 feet long. Usually the face is 440 feet long, but had been shortened to 400 feet because of caving of the tail entry. This caving restricted production to some extent since a new tail entry was being driven concurrent with operation of the plow. The longwall face could not advance any faster than the tail entry could be extended. Production averaged about 600 tons per shift, which is about 60 percent of capacity. Otherwise, operation of the section was normal throughout the test period. Figure 3-2-2 illustrates the layout of the section at the time of testing.

Operation of the conventional section was normal for the first two days of the test period. However, on the third day a large rock parting was encountered, approximately 1/2 the thickness of the coal seam. The section continued to operate, mining both the coal and the parting and by the fifth and last day of testing had worked through the area containing the rock parting. Production was slightly lower on the two days the parting was being worked. The composition of the dust may also have been affected in that there may have been more stone dust in relation to coal dust, than would be found when working only coal.



CAVED AREA
OLD TAIL ENTRY
Block of Coal Being Left to
Support Caved Area
Tail
Area
New Tail Entry Being Driven
Gob Area
Jack Area
Face Area
400 ft.
Block of Coal Being Mined
Head
Area
HEAD ENTRY

FIGURE 3-2-2

3-2.1.4 Mine D

Tests were made on a continuous mining section and a conventional section at Mine D where mining is done in a seam 54 inches high on the continuous section and 72 inches high on the conventional section.

On the continuous section, coal was being mined using a Lee Norse No. 33 mining machine. Roof bolting was done on this section (and the conventional) by Galis roof drill and bolting machines.

Operations were generally normal on both sections during the 5-day test period. Production was somewhat lower than normal on the continuous section on the first and second days of testing, due to equipment problems. Production was also adversely affected on the conventional section the second day due to mechanical problems and on the fifth day because of a Federal mine inspection.

Ventilation on both sections was by line brattice. High pressure water sprays were being used for dust suppression.

Mining data and conditions are shown in Table 3-2-1.

3-2.1.5 Mine B (EPF Testing of Welsh 7165 Respirator only)

Tests were made on two continuous mining sections and one conventional section at Mine B. In all cases, the Campbell's Creek (No. 2 Gas) seam was being mined. Seam height on the conventional section and one continuous section was 60-65 inches. On the other continuous section the seam height was 90-96 inches.

A Lee Norse No. 33 continuous mining machine was used to mine the 60 inch coal and a Joy 1-CM continuous miner was used to mine the 90-96 inch coal.

Operations were normal on all sections during the test period. As would be expected production was somewhat higher for the section mining the 90-96 inch coal.

Ventilation was by line brattice on the section using the Lee Norse No. 33 and the conventional section. Line brattice and auxiliary fan ventilation was

TABLE 3-2-1

MINING DATA BY SECTION

Mine	Mine A		Mine B		Mine C		Mine D		Mine B**		
Section	6 Left Mains	2 South on 4 Butt West	6 Left 4	14 Right Haulway	3 Right 1 West	3 Right 2 West	3 Right 1 North	2 Right 3 Mains	West Mains	3 Left New Way	6 Right Panel
Mining Method	Continuous	Continuous	Continuous	Continuous	Longwall	Conventional	Continuous	Conventional	Conventional	Continuous	Continuous
Mining Machine	Goodman 430	Goodman 430	Joy 1-CM	Joy 1-CM	Westphalia Planer	--	Lee Norse No. 33	--	--	Lee Norse No. 33	Joy 1-CM
Ventilation	Line Brattice and Auxiliary Fan	Line Brattice and Auxiliary Fan	Line Brattice and Auxiliary Fan	Line Brattice and Auxiliary Fan	Brattice	Line Brattice	Line Brattice	Line Brattice	Line Brattice	Line Brattice	Line Brattice and Auxiliary Fan
Dust Suppression	High Pressure[a] Water Sprays	High Pressure[a] Water Sprays	High Pressure[a] Water Sprays	High Pressure[a] Water Sprays	Low Pressure[b] Water Sprays	Low Pressure[b] Water Sprays	High Pressure[a] Water Sprays	Low Pressure[b] Water Sprays	Low Pressure[b] Water Sprays	High Pressure[a] Water Sprays	High Pressure[a] Water Sprays
Production, tons raw coal/day											
Test Day: 1	154	81	648	752	528	561	170	297	330	420	820
2	179	570	588	640	792	539	160	143	360	410	---
3	94	460	744	632	760	450	204	231	430	430	---
4	77	115	816	864	650	495	304	232	---*	---*	---*
5	--	--	900	512	360	550	324	165	---	---	---

* 3 day test run on Section West Mains and 3 Left New Way. One day test on 6-Right Panel.

** EPF Testing of Welsh 7165 respirator only

a. High Pressure Sprays operated with a line pressure of about 200 psi.

b. Low Pressure Sprays operated with a line pressure of about 30-50 psi.

used on the section using the Joy 11CM.

3-2.2 Rock Dusting Operations

3-2.2.1 General

Rock dusting of mine surfaces (wall, roof and floor), usually with a low silica content limestone dust, is practiced as a safeguard against coal-dust explosions in United States bituminous coal and lignite mines.

According to section 304 of the Coal Mine Health and Safety Act of 1970, "All underground areas of a coal mine except those areas in which the dust is too wet or too high in incombustible content to propagate an explosion, shall be rock dusted to within 40 feet of all working faces, unless such areas are inaccessible or unsafe to enter or unless the Secretary or his authorized representative permits an exception upon his findings that such exception will not pose a hazard to working miners. All crosscuts that are less than 40 feet from a working face shall also be rock dusted. Where rock dust is required to be applied, it shall be distributed upon the top, floor and sides of all underground areas of a coal mine and maintained in such quantities that the incombustible content of the combined coal dust, rock dust and other dust shall be not less than 65 percentum, but that the incombustible content in the return aircourses shall be not less than 80 percentum. Where methane is present in any ventilating current, the percentum of incombustible content of such combined dusts shall be increased to 1.0 and 0.4 percentum for each 0.1 percentum of methane where 65 and 80 percentum, respectively, of incombustibles are required."

3-2.2.2 Methods and Equipment

Rock dusting is usually done in different parts of the mine by one of three different methods. (Consideration of wet rock dusting is excluded from this discussion because such generates little or no airborne dust.) These are:

a. General dissemination of rock dust into return aircourses or other areas in which miners are not working by use of trickle dusters or by auxiliary ventilation fans equipped with a bin and screw conveyor feeder. With this equipment small amounts of dust can be discharged continuously into the air stream.

b. Manual application of rock dust to the exposed surfaces, i.e., roof, sides and floor, in the mine. This method is generally used in the vicinity of the working face in order to keep exposed surfaces rock dusted to within 40 feet of the actual working face.

c. Machine rock dusting, which is done in areas away from the working face such as haulage ways and cross cuts, involves blowing, under pressure, finely sized or pulverized limestone against exposed surfaces. Usually the rock dust in pneumatically conveyed from a master unit (storage tank and compressor) through hoses to the point of application. With the compressor providing air at 35 psi, it is possible to convey dust 3000 - 3500 feet through 2.5 in. diameter hose lines. Discharge rates for dust can vary from 75 to 300 pounds per minute depending on length of hose line.

With respect to machine rock dusting equipment, units vary in size from small ones capable of being moved by hand by one or two miners, to large units having tanks and a compressor mounted on the chassis, which in turn is equipped to be moved on rails in the mine, or has rubber tires for non-rail movement.

Machine rock dusting operations can be divided into three steps, as follows:

a. Filling the storage tanks or pods either from a storage silo or by emptying bags of rock dust by hand.

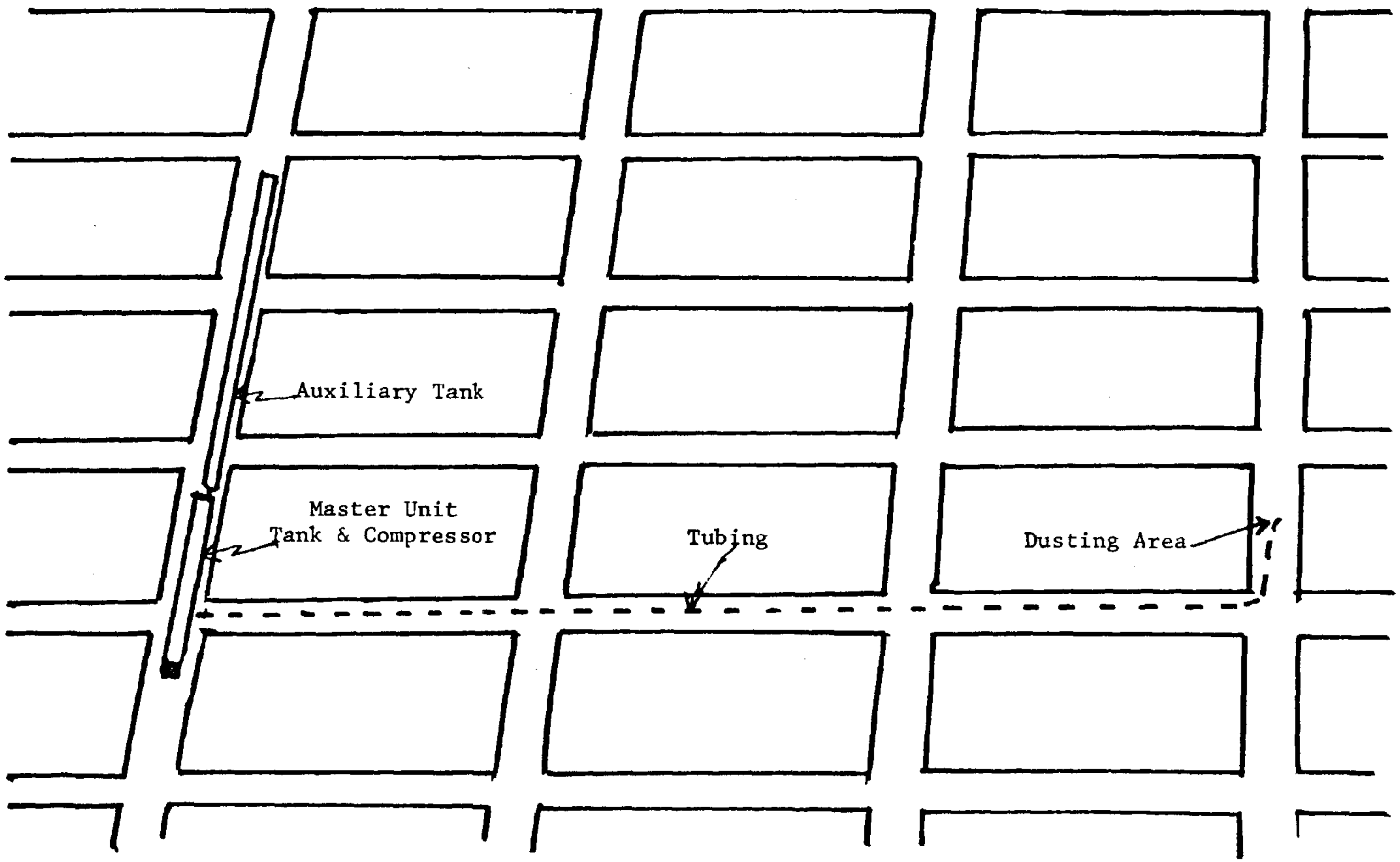
b. Laying hose lines to points of application.

c. Blowing dust against exposed surfaces.

During the first two steps little dust is present in the mine air and the miners do not wear respirators. However, during step 3 considerable airborne dust is present and the workmen wear respirators continuously throughout this operation. Time cycles for the separate steps vary with location. However, over the period of an entire shift, about two-thirds of the time is spent doing steps 1 and 2, while actual dusting is done for about one-third of the time.

A typical mine layout for mechanical rock dusting is shown in Figure 3-2-3.

Figure 3-2-3
Typical Mechanical Rock Dusting Layout



APPENDIX 3-3

3-3.1 Daily Testing Procedures

1. Observers will bring the test respirators, and dust sampling equipment to the working face.

2. Upon arrival at the face, observer will issue appropriate respirator and dust sampling equipment. NOTE: Respirators will be identified by number and the same respirator will be issued to each miner each day during the test period.

3. Observer will assist personnel with installation of equipment and insure all equipment is properly installed. Each test subject will be equipped with a respirator, together with attached cyclone and filter cassette, and sampling pump. Each man will also be wearing, or have mounted on the mining machine, a personal sampler including cyclone, filter and pump to measure dust concentrations in the atmosphere. NOTE: Observer will record on daily data sheet name of all test personnel who do not wear sampler, but place such on machine or elsewhere, and location of sampler.

4. When all equipment is installed, sampler pumps (both for "inside" and "outside" mask) will be started and miners will commence work. Observer will record time pumps were started.

5. Both sampler pumps will run continuously until the lunch period when both will be shut off when respirators are removed. At the end of lunch period, both pumps will be started when respirator is put back on. (Note: observer will record what time pumps are stopped and started). Both pumps will run continuously until work at face is concluded. Observer will record what time pumps are stopped at end of shift.

6. During the work period, the respirator will actually be worn by each miner in the same fashion he (the miner) normally uses a respirator. In other words, use will be on an intermittent basis and will be based on the miner's judgment of need. It is, however, hoped that actual use will be a minimum of two (2) hours per shift. Note: Each miner will also have a time-of-wearing device which will automatically record the amount of time the respirator is actually being worn. This is done by means of a sensing device in the facepiece which is attached by wire to a small electronic device carried by the miner. After the shift, the observers will read the time-of-wearing devices and for each miner record the time the respirator was worn.

7. During the shift, the observer in the case of each test miner will remove the grit pot (small rubber bulb) on sample cyclone attached to the respirator and remove the excess moisture. This will be done for each miner about twice a day.

8. Also during the shift, the observer will periodically inspect equipment and correct, where possible, any problems; similarly, the test subject will report any problems or irregularities to the observer.

The observer will record on the daily data sheet all such problems, irregularities, e.g., malfunction of equipment and wherever possible, the time such occurred.

9. Filters in the respirators may need to be changed during the shift. The observer will have spare filters available. Whenever, a test subject requests a new filter, the observer will assist in the changing of the filter. During the time the filter is being changed, both sampling pumps will be turned off. NOTE: The observer will record the miner's name the time the filter was changed, the time the sampling pumps were shut off and turned back on.

10. At the conclusion of the shift, the observer will collect all respirators and equipment and pack such for transporting to the surface.

11. After equipment reached surface, the laboratory technicians will remove the dust sampler filters. Those used on the respirator sampling equipment will be specially processed to remove moisture.

After moisture removal is accomplished, these filters, along with other filters from personal samplers used to measure dust concentration in mine atmosphere, will be packaged and mailed, first class to:

Prof. William A. Burgess
Harvard University Schcol of Public Health
Department of Environmental Health Sciences
665 Huntington Avenue
Boston, Mass. 02155

Prior to use, each filter will have been tared (weighed) on a specially sensitive balance by Harvard and numbered. The laboratory technician will take special care to record number of each filter, the respirator sampler or mine atmosphere sampler in which it (the filter) was used and name of the miner wearing respirator or mine atmosphere sampler.

12. All respirators will be thoroughly cleaned, filter changed and repaired if necessary. Sampling equipment will also be cleaned, inspected and pumps recharged.

13. The time-of-wearing devices will be read and data recorded on daily data sheet. (NOTE: This data will also be recorded on appropriate cards accompanying filters from respirator sampler.) These devices will then be reset using automatic resetter.

14. All respirator equipment (except items being recharged will be packed up for use next day).

APPENDIX 3-4

Location of Sampling Equipment

3-4.1 General

For each miner or test subject, the amount of dust in the ambient air which the subject could breathe, and in the air in the mask of the respirator being used by the test subject, was determined. Ideally, this would be done by having the subject wear both sampling systems. However, while all the miners wore the in-mask sampling systems, such was not always possible for the ambient air sampling system. In general, the miner wore the ambient air sampling equipment in the high mines, that is, where seam height exceeded six feet. On the other hand, when the test work was undertaken in mines with seam heights of five feet or less, it was often necessary to position the ambient air samplers on the mining machine, or other mining equipment; in both cases, the sampling equipment was in proximity to the miner's work area.

As has been previously mentioned, the wearing of the test sampling systems resulted in almost doubling the weight (to about 10 pounds) normally carried by the miner. Moreover, even in the high mines test equipment interfered, albeit only to some extent, with the miner's ability to perform his regular tasks. This situation was exacerbated by conditions in the low coal mines. For instance, the sampling pumps interfered with the ability of the man to stoop, and in some cases, the space available for a man to sit when he operated the mining equipment was quite limited and he could not easily wear both sample pumps. Therefore, it was necessary to position the ambient air sampling system elsewhere.

The ambient air sampling equipment was positioned in consonance with the Bureau of Mines procedure* which provides that such equipment should be within 36 inches and inby the operator. (Inby signifies being between the operator and the coal face being mined.) The position of the ambient air sampling equipment is shown for continuous mining machine operators, cutting machine operators, coal drillers, and shuttle car operators, Figure 3-4-1; Figures 3-4-2 and 3-4-3 illustrate the position of the ambient air samplers on the longwall section. As a matter of interest, when the ambient air sampler was also worn by the miner it was pinned to the left side of his shirt about six inches below his face.

3-4.2 Location of Samplers

The position of the ambient air samplers at the various mines used in the test program are as follows:

a. Mine A

Worn by the test subject.

b. Mine B

Worn by the test subject, with the exception of test subjects No. 14 and 19, both of whom were shuttle car operators. In the case of these men the ambient air sampling system was attached to the side of the shuttle car, 24 inches away from the man and at the level of his face, Figure 3-4-1.

c. Mine C

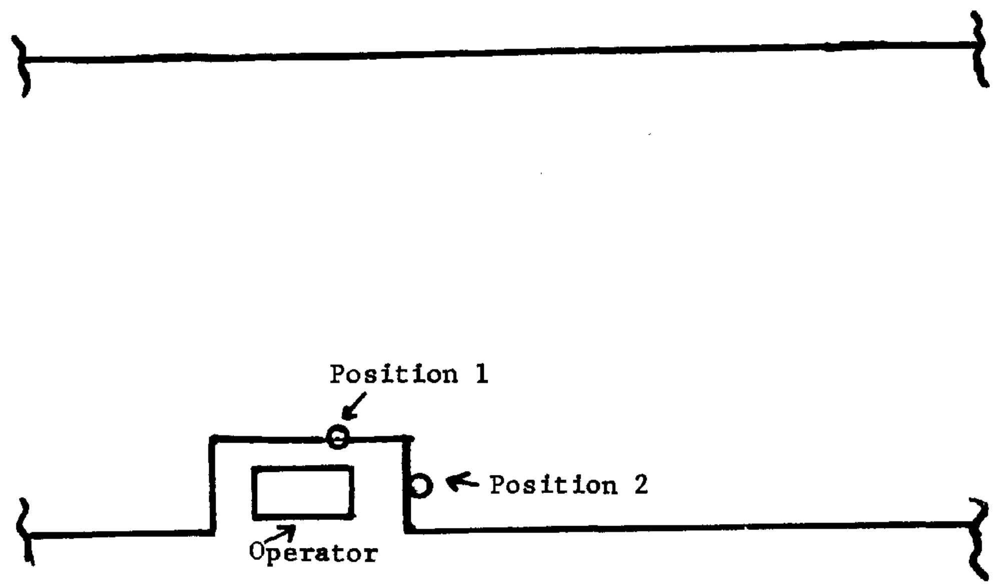
(1) Longwall Section

(a) Longwall Machine Headgate Operator - suspended from roof, 60 inches above the floor, 24 inches behind the head of the operator, and in the same horizontal plane as his breathing zone.

*Sampling and Evaluating Respirable Coal Mine Dust, U.S. Bureau of Mines Information Circular 8503, February 1971.

FIGURE 3-4-1

AMBIENT AIR SAMPLING LOCATIONS

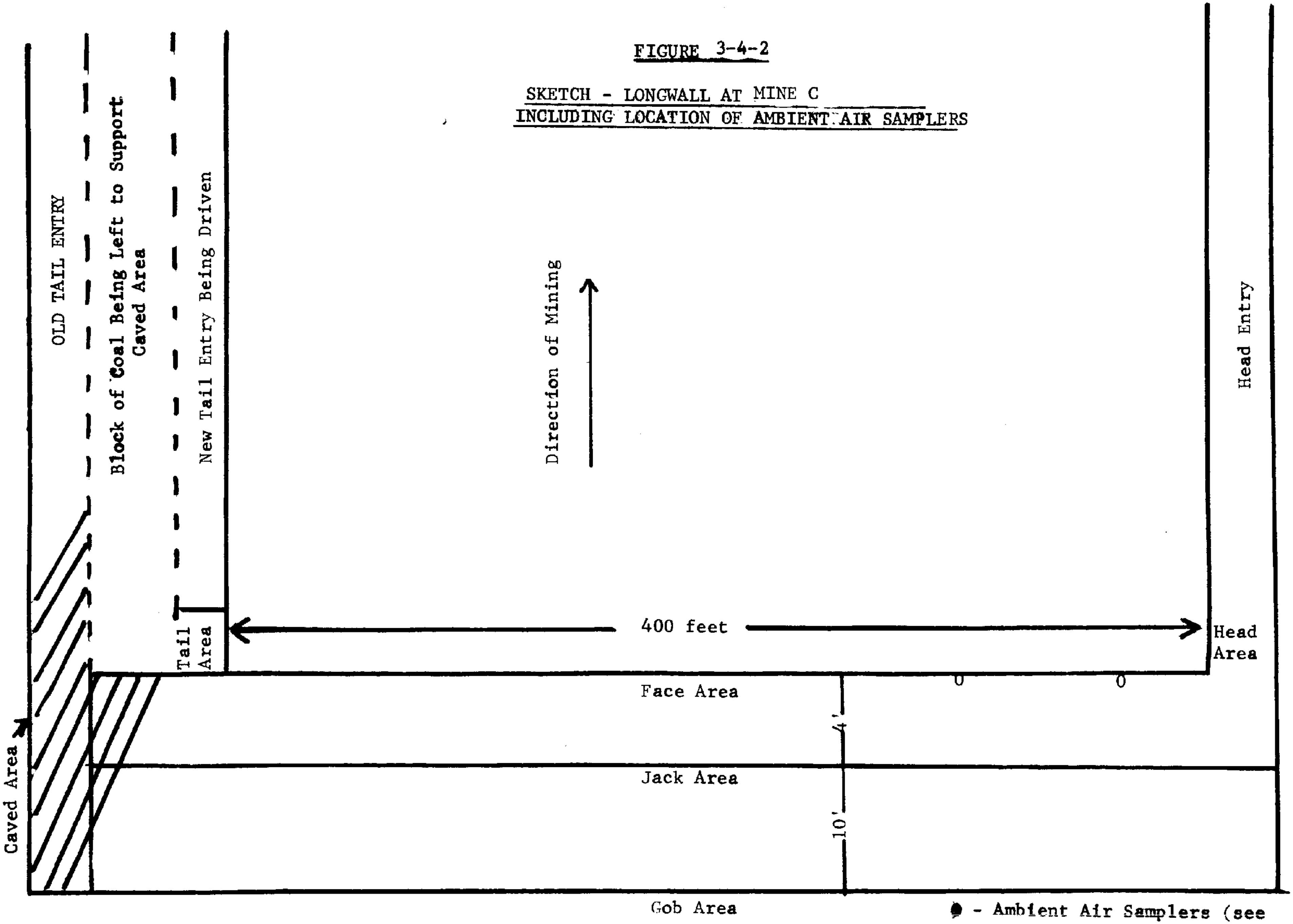


Sketch showing relative position of Ambient Air Sampler with respect to operator of equipment such as, Continuous Mining Machine, Shuttle Car, Cutting Machine, Coal Drilling Machine.

Continuous Mining Machine	Position 2, 18-inches from operator, at the level of the operators face.
Shuttle Car	Position 1, at face level, 18-inches from the operators face
Cutting Machine	Position 2, at the level, of the operators face, within 36-inches of operator.
Coal Drilling Machine	Position 2, 6-inches below the level of the operators face and within 36-inches of operator's face.

FIGURE 3-4-2

SKETCH - LONGWALL AT MINE C
INCLUDING LOCATION OF AMBIENT AIR SAMPLERS



● - Ambient Air Samplers (see figure 3-4-3 for further details

NOTE: Sketch not to scale

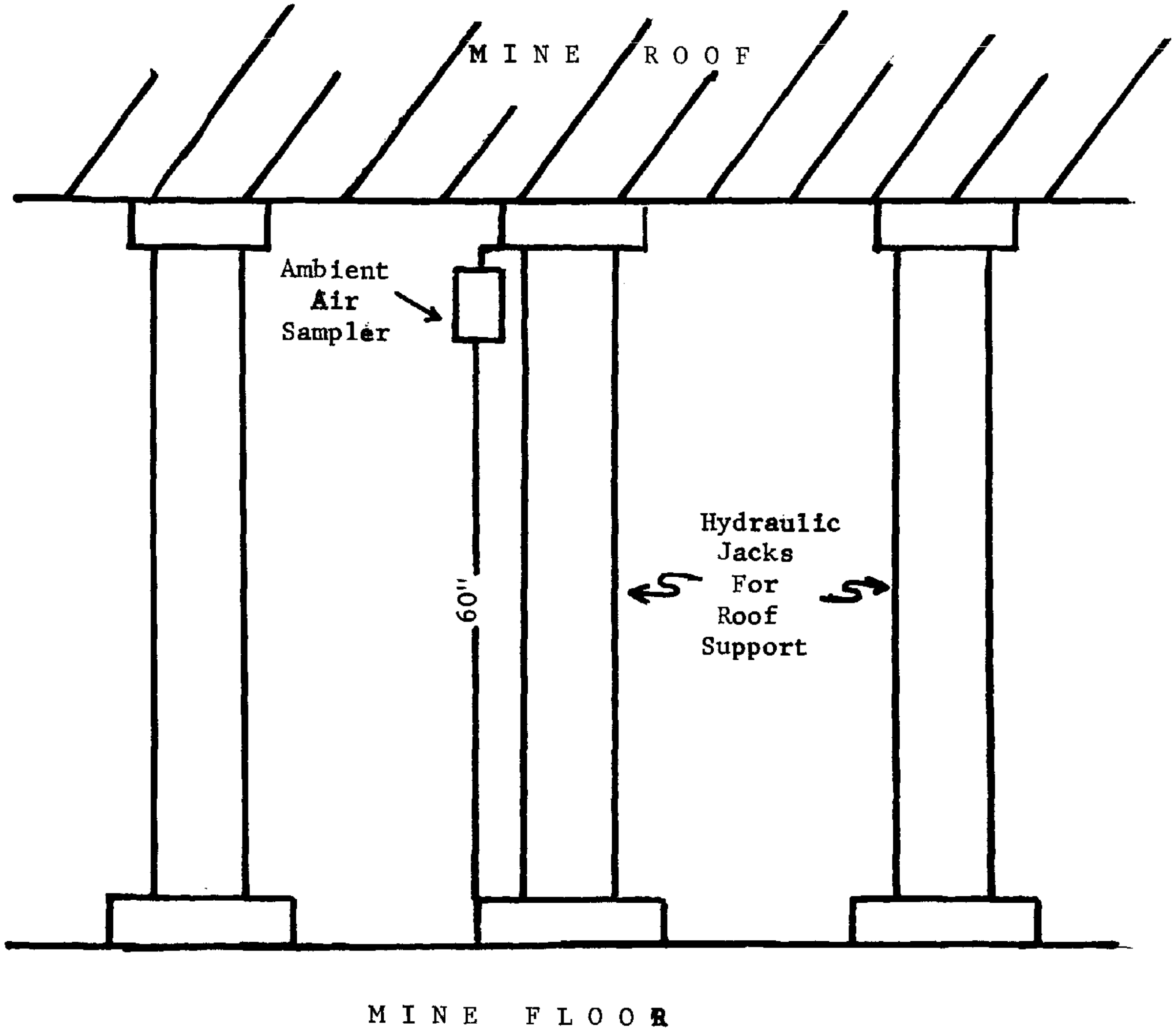


FIGURE 3-4-3
SKETCH SHOWING LOCATION OF AMBIENT AIR SAMPLER
FOR JACK MACHINE OPERATORS

Not to Scale

c. Mine C - continued

(b) Longwall Machine Tail Operator - Suspended from roof, 48 inches above floor, 24 inches from operator's head, and in the same horizontal plane as his breathing zone.

(c) No. 1 Jack Machine Operator - Suspended from jack, 60 inches above floor, 40 feet from headgate, and in the same horizontal plane as the operator's breathing zone, Figures 3-4-2 and 3-4-3.

(d) No. 2 Jack Machine Operator - Suspended from jack, 60 inches above floor, 100 feet from headgate, and in the same horizontal plane as operator's breathing zone, Figure 3-4-2 and 3-4-3.

The location selected for positioning the ambient air samplers for both jack machine operators was the operator's "station". At the start of the shift, the jack machine operator reports to his station, which is usually an area central to the jacks he is responsible for moving. He remains at or near this location throughout much of the shift; periodically (about four times per shift) he leaves the station to adjust the jacks, taking from 10 to 30 minutes each time, depending on conditions. The No. 1 jack machine operator was responsible for the jacks from the headgate to his station, 40 feet from the headgate. The No. 2 jack machine operator was responsible for the jacks from this point, 40 feet from the headgate to a point 140 feet from the headgate. His station was about in the middle of his assigned area.

(e) Observer - Worn by test subject.

(2) Conventional Section

(a) Cutting Machine Operator - On cutting machine, within 36 inches of and inby the operator - same level as the Operator's face, Figure 3-4-1.

(b) Loading Machine Operator - On the loading machine, within 30 inches of and inby the operator - at the same level as the operator's face, Figure 3-4-1.

(c) Shuttle Car Operator - On the shuttle car, within 18 inches of the operator and at the same level as the operator's face, Figure 3-4-1.

(d) Coal Driller - On the drilling machine, within 36 inches of and inby the operator, and six inches below the level of the operator's face, Figure 3-4-1.

(e) Observer - Worn by test subject.

d. Mine D

(1) Continuous Section

(a) Continuous Mining Machine Operator - On the mining machine, within 18 inches of and inby the operator, at the same level as the operator's face, Figure 3-4-1.

(b) Continuous Mining Machine Helper - Worn by test subject.

(c) Shuttle Car Operator (2) - On the shuttle car, within 18 inches of the operator and at the same level as the operator's face, Figure 3-4-1.

(d) Observer - Worn by test subject.

(2) Conventional Section

(a) Loading Machine Operator - Worn by test subject.

(b) Cutting Machine Operator - On the cutting machine, within 36 inches of an inby the operator, at the same level as the operator's face, Figure 3-4-1.

(c) Coal Driller - Worn by the test subject.

(d) Shuttle Car Operator - On shuttle car, within 18 inches of the operator and at the same level as the operator's face, Figure 3-4-1.

d. Mine D - (2) Conventional Section - continued

(e) Observer - Worn by test subject.

(3) Rock Dusting Crew - Ambient air samplers were worn by test subjects.

e. Mine B - (EPF Testing of Welsh 7165 respirator only)

The Welsh Model 7165 respirator was tested by shuttle car operators. In all cases the ambient air sampler was mounted on the shuttle car 18-24 inches from the operator and at the same level as the operator's face, Figure 3-4-1.

APPENDIX 3-5

IN-MINE TEST PROGRAM FOR RESPIRATOR EFFECTIVENESS

DAILY RECORD

Date ____________________ Mine __________________________ Section ____________________

Ventilation ____

Water Usage ______________________________ Production ______________________________

Sample Pump Log

Test Personnel	AM On	AM Off	PM On	PM Off
( ) ____________________	____	_____	____	_____
( ) ____________________	____	_____	____	_____
( ) ____________________	____	_____	____	_____
( ) ____________________	____	_____	____	_____
( ) ____________________	____	_____	____	_____

General Observation

Test Personnel	Physical Activity Hvy	Physical Activity Med.	Physical Activity Lght	Head Harness Use Reg.	Head Harness Use Other*	Possition of Mine Air Sampler **
( ) ________________	____	____	____	____	_____	____________________________
( ) ________________	____	____	____	____	_____	____________________________
( ) ________________	____	____	____	____	_____	____________________________
( ) ________________	____	____	____	____	_____	____________________________
( ) ________________	____	____	____	____	_____	____________________________

Remarks

____

____

____

____

* Describe in Remarks
** On Man or on Machine

EASTERN ASSOCIATED COAL CORP.
RESEARCH CENTER
138 ROBIN STREET
EVERETT, MASSACHUSETTS 02149

APPENDIX 3-6

GCA RDM 101-4 RESPIRABLE DUST MONITOR

The GCA RDM-101-4 Respirable Dust Monitor, manufactured by GCA Corporation, is a battery-powered portable instrument for measuring dust concentrations. The dust concentration is determined, in milligrams per cubic meter, by beta absorption. For measurement of respirable dust the 10 mm AEC cyclone is used as a pre-collector. Particles passing through the cyclone are collected on an impaction disk. The dust collected on the thin plastic impaction disk absorbs beta-radiation produced by a carbon 14 source. The penetration of this low energy beta radiation depends almost exclusively on the mass per unit area of the absorber, and is independent of the chemical composition or physical characteristics of the absorbing matter. At the start of the measurement period, an initial beta count is performed electronically, and another at the end of the period. The difference between the two counts is related to the amount of dust collected on the impaction disk during the measurement period. The electronic circuitry computes the dust concentration in mg/M3, from this data and actuates a readout display.

The sampling and measurement period for the RDM-101-4 is 4 minutes. The battery capacity is limited to 2 hours total operating time or, in the case of the RDM-101-4, a total of 30 separate dust measurements.

APPENDIX 3-7

TPF IN-MINE TESTING

3-7.1 Facial Measurements

In order to select a suitable set of test subjects representing a variety of different face shape classification as described by Hyatt[7/], (see Figure 3-13), a panel of 44 miners were subjected to facial measurements. The three measurements made were 1) Menton-nasal root depression, 2) lip length and 3) bizygomatic breath. The distribution of this panel according to face shape classification is shown in Figure A3-7-1.

From this panel of 44, 9 test subjects representing 8 different classifications were selected, Table 3-7-1. (There was no one with face shape classification I.)

3-7.2 In-Mine Test Procedures

Each test subject wore 6 different respirators, each respirator being about one-half of a working shift. The different model respirators tested were:

a. MSA 66
b. MSA 77
c. AO R-2090
d. Welsh 7100
e. Welsh 7400
f. Welsh 7165

The respirator units tested were altered to the extent that a sampling probe was inserted through the facepiece in the same location as that used during the EPF study.

During the half-shift period during which a particular model of respirator was used by the test subject, four, four-minute sampling operations were conducted using two GCA RDM-101-4 respirable dust monitors.

Just prior to sampling, the test subject would put the respirator on, and adjust the head harness and face fit and carry out a leak detection test in accordance with manufacturer's instructions. Once the respirator was properly adjusted and no leaks detected, the sampling line from one GCA unit was connected to the sampling port through the respirator facepiece; the sampling line to the other GCA monitor sampled ambient air just in from the miner's face.

Both GCA monitors were started simultaneously and during the four-minute sampling period the miner performed his regular work. After the first sampling period, a second sampling operation was conducted a few minutes later.

The second set of the same two sampling operations was conducted a minimum of one hour later.

TABLE 3-7-1

TEST SUBJECTS - TRUE PROTECTION FACTOR

Job Classification	Number	Face Shape Classification (see Figure 3-13)
Continuous Mining Machine Operator	1	C
Cutting Machine Operator	1	B
Loading Machine Operator	1	E
	1	H
Roof Bolter	1	A
	1	F
Bratticeman	1	D
Timberman	1	E
Research Engineer	1	G

APPENDIX 3-8

EPF LESS THAN 1.0 AND MORE THAN 20

3-8.1 EPF Less than 1.0

A total of 188 (172 involving intermittent wearing of the respirator), EPF's were obtained during the in-mine testing. Of these, 16 were less than 1.0 and a value of 1.0 or below would indicate that the man received no protection at all from wearing his respirator. In fact, if the value is below 1.0, it would appear that the man breathed more dust while using a respirator than he would have if he had not used a respirator at all. However, since the test subjects wore their respirators intermittently, this may or may not be so. It is possible that extraneous dust was introduced into the mask as the respirator bounced against the man's dusty clothes while it (the respirator), was being worn hanging loosely around the neck. This dust may or may not have gotten into the man's breathing zone.

These EPF values below 1.0 are shown in Table 3-8-1 together with other data associated with the values, and the following comments can be made:

1. A total of 43 different people took part in the study. Of these, 13 subjects had EPF values below 1.0. Of these 13, 3 subjects obtained values below 1.0 on 2 out of the 5 days they took part in the test study.

2. The percent of time the respirators were worn on the days when values below 1.0 were obtained was essentially the same time as on those days when higher EPF values were obtained. Thus, low values were not necessarily obtained because little use was made of the respirator. Moreover, values below 1.0 were obtained with respirator usage as high as 86

TABLE 3-8-1

EPF VALUES BELOW 1.0

Test Subject Identification No.	Test Day, No.*	Ambient Air Dust Concentration mg/M3	EPF	Time Respirator Worn, %
11	4	0.73	0.90	61
12	1	0.12	0.41	86
12	4	0.48	0.65	58
13	4	0.24	0.31	51
14	2	0.12	0.61	52
14	4	0.37	0.41	53
24	1	1.16	0.59	34
24	2	0.89	0.16	42
26	4	0.51	0.54	50
27	4	1.57	0.73	38
28	4	0.80	0.73	72
30	5	0.27	0.33	76
31	4	0.54	0.89	16
38	2	0.30	0.90	27
39	4	1.01	0.54	35
40	4	0.30	0.70	42

* Days after start of testing

percent of the working shift, and as low as 16 percent.

3. Ten (62%) of the sixteen values below 1.0 were obtained on the fourth day of testing. This may indicate that the men were becoming tired of wearing the test equipment. Since wearing this equipment is somewhat inconvenient, perhaps uncomfortable, adds to the weight the miner carries and interferes, to some extent, with the performance of normal tasks, it is understandable the miner could become tired and therefore, become less careful about the manner in which he wore his respirator. On the other hand, the last day of testing would provide a psychological uplift in that "this was the last day". It was observed that the subject miners seemed in the best spirits on Monday and Friday; on Monday, it was a new experience and on Friday, it was almost over.

4. In 13 (81%) out of the 16 cases, the dust concentration in the mine air was below 1.0 mg/M3 and in only one case was the dust concentration slightly above 1.5 mg/M3. There is no obvious explanation why the low EPF's are predominantly found with low dust concentrations. However, almost every miner who uses a respirator will tell you he wears such "when it's dusty", and it has been observed more care appears to be exercised with higher levels of visible dust and less care with low levels. This per se, does not explain the higher in-mask dust concentrations (EPF's below 1.0) than in the ambient air. It may be that less care in wearing the respirator coupled with introduction of dust from clothing or differences in respirable dust concentrations between ambient air sampling point and in-mask sampling point account for this aforementioned predominance.

3-8.2 EPF Higher than 20

Of the 188 EPF values obtained 12 were over 20.0, Table 3-8-2. These 12 values were obtained by 10 different test subjects and 9 (75%) values were obtained on the first two days of testing with 6 (50%) being obtained on the second day.

Perhaps, importantly in 9 out of the 12 cases the ambient air dust concentration was 4.50 mg/M3 or higher. It is felt that one of the reasons for the high EPF might be the fact that miners appear to take more care in wearing a respirator when the visible dust is high and presumably the respirable dust is likewise.

TABLE 3-8-2

EPF VALUES ABOVE 20.0

Test Subject Identification Number	Test Day, No.*	Ambient Air Dust Concentration mg/M3**	EPF	Time Respirator Worn, %
6	2	2.33	29.2	43
10	4	7.22	63.4	33
15	2	4.51	28.0	66
20	5	3.66	25.5	34
28	2	6.67	47.1	20
31	1	5.21	28.8	33
39	1	5.59	23.5	49
39	2	1.60	21.7	27
41	1	6.46	31.6	51
42	2	7.63	34.5	50
42	4	9.08	41.6	47
46	2	8.33	20.7	46

* Days after start of testing

** As measured by personal sampler

APPENDIX 3-9

Coal Miners' Job Classifications

While the miner's job classification is indicative of the major task he performs each day, it is by no means descriptive of the many different things a particular miner may do daily. Importantly, the present job classification of a given coal miner is much influenced by seniority in that a miner usually progresses up through the ranks and therefore, the miners who have the highest job classifications and who operate the complex mining machines have held a variety of lower job classifications over the years. Consequently, as the needs arise, many miners can and do perform a variety of job assignments; this flexibility in job assignment is permitted under provisions of the contract with the union.

In an operating coal mine, the actual mining of coal is taking place in a number of locations, each separated from the others; often, one mining location may be a quarter of a mile from the next nearest one. At each location, a section crew (the size and composition of which will be dependent on the type of mining being done and on other factors) is responsible not only for mining the coal, but such other things as transporting the coal to a designated loading point, placement of roof bolts and timber, maintenance of proper ventilation on the section, application of rock dust when needed, certain routine maintenance and repair of equipment, and general clean-up of the section. Simplifying a bit, the individual section crew might be viewed as a company within a company. As such, each section crew pretty much takes care of its own needs, particularly in terms of bringing necessary supplies from the storage point to the section.

At the start of a shift, the section foreman will decide what additional supplies are needed and send, for example, two men, a shuttle car operator and bratticeman, to get these. The regular assignment of the shuttle car operator is, of course, to transport mined coal to the loading point. The bratticeman's main assignment is the hanging of line brattice and the installation of auxiliary fan ventilation; since both of these are done intermittently, the bratticeman is available to perform other tasks. Similarly, the roof bolter and bratticeman may assist the timberman in setting timbers for roof support. In the case of an equipment breakdown, the section mechanic will usually be assisted, as is necessary, by other members of the section crew until the machine is operating again.

While the average coal miner performs a rather wide variety of jobs, there are some constraints. Certain jobs in some areas require that state certification be obtained before a miner can hold the classification and perform the job. In this situation, the certified miners can still work on lesser jobs not requiring certification.

APPENDIX 4-1

TESTING PROGRAM FOR MINER ACCEPTABILITY OF SINGLE-USE RESPIRATORS

A4-1.1 General

A short time ago, three models of single-use dust respirators became available for underground coal mine use by being given Bureau of Mines approval under Schedule 21-b; these were, the American Optical "Dust Demon" Model R1040, the Welsh Model 7165 and the 3M Model 8710.

With the availability of these units, it appeared desirable to determine, if possible, protection provided by these respirators under actual working conditions. However, before undertaking a test program to determine such effectiveness, it seemed appropriate to determine the acceptability, or lack thereof, of these single use respirators to working miners.

A4-1.2 Test Procedures

A test group, consisting of from 10 to 25 people, was selected at each mine. These test subjects, who were volunteers, were, in general, regular users of dust respirators and usually represented a cross section of job classifications that normally make use of respirators. Different age levels and differences in work experience were included to the extent practical.

After the test subjects were selected, the group was brought together before going underground and the following was done:

a. Objectives of project were explained

b. Test respirators were issued to all test subjects

c. Proper procedure for putting on and taking off the test unit was demonstrated, following which test subjects performed such operations and were checked, and questions raised by test subjects were answered.

d. Test subjects were instructed to return used respirators at the end of the work shift and to obtain a new unit for the next day.

At the end of each work shift, the test subjects were met, the used respirator was collected and a new one issued, and the miners participating in the test were questioned on whether they had experienced any difficulties in carrying out the test procedures.

At the start of the test period, the name, age, years of experience as a miner and present job classification was recorded for each miner. At the end of the test period, each test subject was interviewed individually, using an unstructured interview approach to determine whether he liked or disliked the respirator, and to determine which characteristics of the respirator were advantageous and which, disadvantageous. The test subject was queried concerning what he (the test subject) thought should be done to improve the respirator for use in coal mines. In some cases, test subjects objected strenuously to continuing the test beyond the first day because of substantive difficulties experienced in wearing the test respirator; in such a situation, the test subject was interviewed and the subject did not participate further.

Used respirators collected were shipped to the Research Center for examination.

APPENDIX 4-2

RESPIRATORS USED IN TEST STUDY

A4-2.1 General

Three single-use respirators examined were, the American Optical Corporation "Dust Demon", the Welsh Manufacturing Company Model No. 7165 and the Minnesota Mining and Manufacturing Company Model No. 8710. A description of each is set forth below.

A4-2.2 Minnesota Mining and Manufacturing Company Model 8710 (see Figure 4-1)

The No. 8710 is essentially a preformed non-woven fabric filter covered by a second filter having finer fabric. A small metal band is used at the bridge of the nose to effect a proper facial fit. A 2-strap rubber head harness is used. The rubber elastic straps, which are of fixed length, are fastened to the filter-facepiece by sonic welding. Dimensions of the respirator are, height 4.5 inches (114 mm), width 5.25 inches (133 mm), depth 2.25 inches (57 mm); the weight is 0.25 ounces (7 g).

A4-2.3 American Optical Corporation "Dust Demon" Model R1040 (see Figure 4-2)

American Optical "Dust Demon" is essentially a large, preformed cup-shaped filter stiffened by a metal band which extends about two-thirds of the way around the outside edge. The metal band also serves as an anchor point for the head harness and can be bent in order to secure a proper fit around the bridge of the wearer's nose. Fastened to the inside edge is a ring of polyurethane foam used to provide a facial seal. The respirator is 5 inches (127 mm) in diameter, 3 inches (76 mm) in depth, and weighs 1.75 ounces (50 grams). A double-strap head harness, which is adjustable in length, is used.

FIGURE 4-2-1

3M MODEL 8710

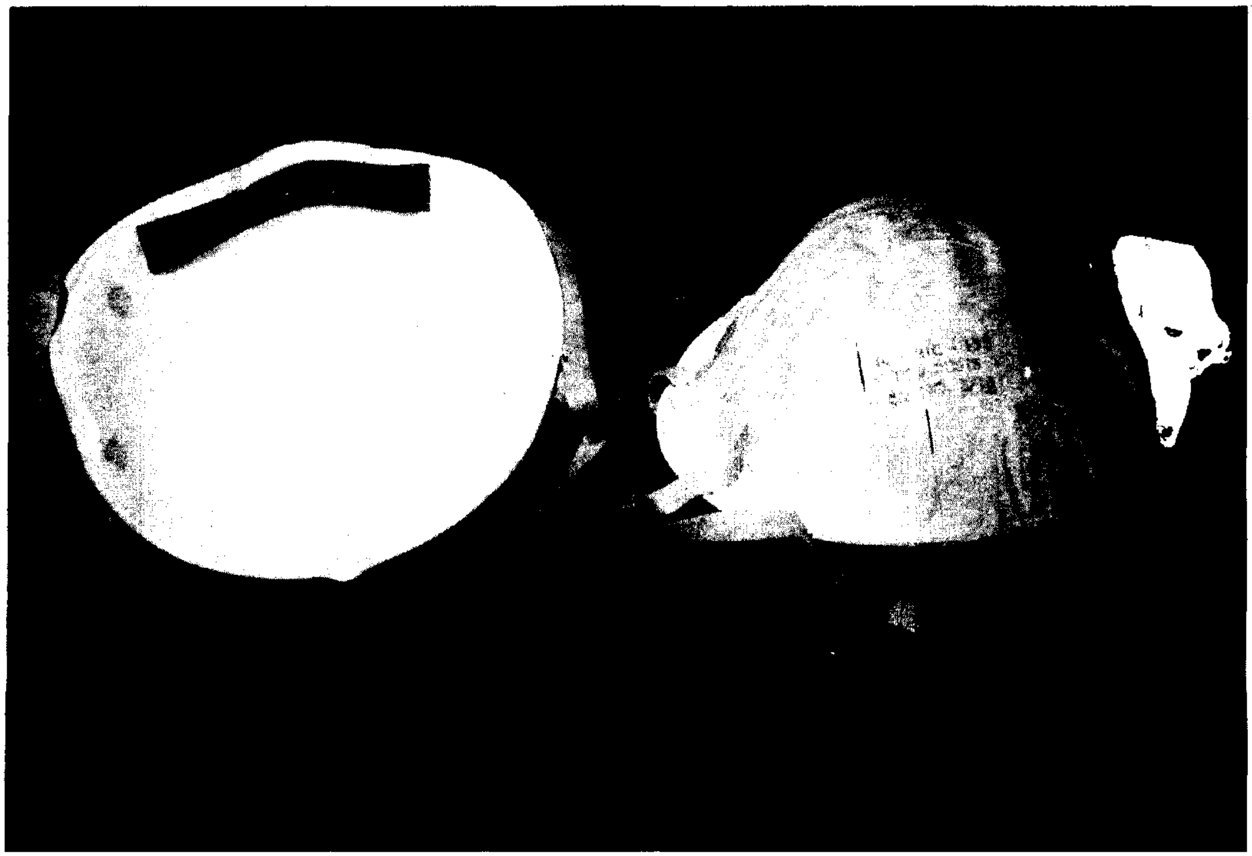


FIGURE 4-2-2

AMERICAN OPTICAL MODEL R1040

A4-2.4 Welsh Manufacturing Company Model 7165 (see Figure 4-3)

The 7165 is essentially a single-use version of the Welsh Model 7100. The facepiece is formed from lightweight plastic to which a filter is attached using staples. On the exterior edge is a metal band that can be bent to adjust the seal around the wearer's bridge of the nose. This metal band is used to stiffen the sealing edges and serves as the anchor point for the 2-strap head harness. The head harness is adjustable in length. The respirator is 3.5 inches (89 mm) wide, and 3.0 inches (76 mm) in depth, and weighs 3.18 ounces.

FIGURE 4-2-3

WELSH MODEL 7165