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DUST CONTROL IN MINING INDUSTRY

AND

SOME ASPECTS OF SILICOSIS

BY

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A

THESIS

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Approved by J. D. Forrester
Professor of Mining

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INTRODUCTION

At the turn of the century, a greater demand for minerals resulted in a widespread increase in the mining operations that had been practiced during the latter part of the nineteenth century. With the introduction of reciprocating and rotating drills, most orebodies could be broken more easily and in sizes that could be handled more readily than had been previously the case. With this progress, however, came diseases caused by unhealthful working conditions that grew worse as the mines reached greater depths and production reached higher figures. The toll in sickness and death due to harmful dust in mine openings mounted until government as well as private enterprises set up research laboratories to find ways and means of alleviating such unhealthful conditions. Most of the industrial countries in the world have done more work on controlling dust during the last few decades than they had ever done before. Large sums of money have been and are being spent on this problem. At present, with increasing demands on the part of labor for better working conditions and for the establishment of higher health standards, the mining industry has had to take immediate, additional steps toward making the working places safer and more healthful.

The deleterious effect on human beings of dust in mine air is well-known. It is the duty of engineers, therefore, to take measures to eliminate it. It is now definitely established that of all the various types of dust encountered in mine air, silica dust is the most harmful. This dust, if inhaled over a period of time, causes the disease, silicosis, which in most countries is compensated for as a physical disability. The prevention or alleviation of this scourge is analyzed in three broad aspects:

1. If the mine air is as clean as outside atmospheric air, silicosis will not be contracted. Therefore, it follows that mine air should be purified to a state comparable with air found on the surface.

2. If the mine air cannot be purified sufficiently, the men should be adequately protected or removed to prevent exposure to conditions leading to silicosis.

3. If a person contracts silicosis, he must be taken care of, and either cured or adequately compensated for his physical disability.

This investigation is an attempt to show the effect of auxiliary ventilation on the control of dust in mines and also to review the second and third points listed above, showing how the phases of the problem, namely, prevention, and cure and economic aspects, are being handled in various mining countries.

A great part of this study is a compilation of the different preventive measures being used in various countries to combat dust. A tour of the metal mines in the United States of America and Canada to study the methods adopted by various mining companies was made during the summer months of 1946 and 1947. The ventilation departments of all the mining companies made available pertinent data concerning dust control and gave me much additional assistance which is hereby gratefully adknowledged. Although it is impossible to name all of the mining companies that were helpful during my tour, I wish to mention particularly the Anaconda Copper Mining Company at Butte, Montana; the Homestake Gold Mining Company at Lead, South Dakota; the Bunker Hill and Sullivan Mining Company at Kellogg, Idaho; the Climax Molybdenum Company at Climax, Colorado; the Eagle-Picher Mining Company, Picher, Oklahoma; the Park Utah Mining Company at Heber, Utah; the McIntyre Porcupine Consolidated Mines at Schumacher, Ontario; the Hollinger Mines, Timmins, Ontario; and the Lake Shore Mines at Kirkland Lake, Ontario. My special thanks are due to Mr. F.F. Netzeband, consulting engineer of Keetley, Utah, for his unstinted cooperation and help in connection with this work.

I am greatly indebted to Dr. J. D. Forrester, Chairman of the Department of Mining Engineering at Missouri School of Mines, for the active interest he took in my work and for his valuable guidance. My thanks are due also to Mr. L. E. Shaffer, Associate Professor of Mining Engineering, for his useful suggestions during the experimental work at the mine and to other members on the staff of the mining and chemistry departments at the Missouri School of Mines. The photographs produced here were made for me by my friend and colleague, K. G. Ackermann, whose help is a pleasure to record.

HISTORY

Early records of the recognition of dust disease date back to the fifth century B.C., when the Romans noticed that breathing difficulty existed among certain classes of miners. Signs of this disease have been also observed in some Egyptian mummies. Even as early as the first and second centuries A.D., miners seem to have attempted to protect themselves against dust by covering their nose and mouth with bladder skins and bags.

Positive written records of disease caused by dust are recorded by Agricola[1]. He discusses comparatively the dust conditions ordinarily found in wet mines and in dry mines and states that some mines are dry or

> "are devoid of water, and this dryness causes the workmen even greater harm; for the dust which is stirred and beaten up by

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[1] De Re Metallica by Georgius Agricola (1556). Translated by Herbert C. Hoover and Lou H. Hoover. Published by the Mining Magazine, London. 1912. Book VI.

> digging penetrates into the windpipe and lungs and produces difficulty in breathing....If the dust has corrosive qualities it eats away the lungs, and implants consumption in the body; hence in the mines of the Carpathian Mountains women are found who have married seven husbands, all of whom this terrible consumption has carried off to a premature death. Protection used was to fasten loose veils over their faces.
>
> Pliny describes in his book about Romans taking these precautions in this way: 'Those employed in the works preparing vermilion, cover their faces with bladder-skin, that they may not inhale the pernicious powder, yet they can see through the skin.'"

Later, sporadic work was done in Europe, but apparently no definite steps of major character were taken to control dust in mines or to protect the miners.

It was at the beginning of this century that the study of this disease was intensified. The countries that have contributed most toward checking this hazard are South Africa, the United States of America, Canada, and Great Britain.

Dust in mines and its effects on the worker is a two-fold problem. First, dust has to be controlled at its source in the mine; and secondly, its after-effects on the miner have to be treated medically.

DUST CONTROL IN THE MINE

In regard to the first aspect of the question with which we are concerned it is understood that the working places should be ventilated by a continuous flow of fresh air to remove any dust or gases which may arise from blasting, drilling, timbering, loading or other activities of the workers or of machinery or equipment used by them.

In order to have adequate ventilation, it is often necessary to induce ventilation mechanically by means of fans. In spite of having a large volume of fresh, pure air going through the mine, the air is of little value unless it is supplied to all of the working places.

This investigation was undertaken to determine the best way in which auxiliary ventilation to working places can be produced to be of maximum benefit. Although the experiments conducted consider only one aspect of dust control, namely, by ventilation alone, a combination of ventilation with other factors mentioned under "Field Observations" are necessary to achieve the best results.

Sampling and Counting Procedure

Although various devices are used for taking samples of mine air three types of instruments are commonly used in the mining industry, viz. Konimeter, Midget Impinger, and the Thermal Precipitator*.

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*For description of Konimeter, Midget Impinger, and Thermal Precipitator see Appendix C

In this investigation, with the exception of some work with the konimeter in the Canadian mines, the Midget Impinger was used in all cases and the standard procedure established by the U. S. Bureau of Mines[2] was

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[2] Information circular 7026, June 1938, A technique for the use of the Impinger method by C. E. Brown and H. H. Schrenk, U. S. Bureau of Mines.

followed. The Thermal precipitator is at present used only in large research laboratories and has not come into general use in the mines.

All samples taken by the Midget Impinger were collected in an isopropyl alcohol medium. This was diluted to 25 c.c. and, after agitating it well, the Sedgwick-Rafter counting cell was filled and allowed to settle for 30 minutes. The cell was then put under the microscope for counting. A Bausch & Lomb microscope using 10x objective and 20x eyepiece was used keeping the tube length at 160 mm giving a magnification of 1000 on the microprojector screen. The source of light was obtained by a direct current, carbon arc. The microscope stage was operated at the screen by remote controls. The microscope and the microprojector assembly is illustrated in Figure 3.

The formula[3] used for calculating the dust concentration is

$$\frac{4\text{x count x 1000 x diluted sample in cc}}{\text{time of sample (1 min.} = \text{0.1 cubic foot of air sample}} = \text{millions of particles per cubic ft.}$$

Two cells were made of each sample and the average count of the two was taken in all cases.

The Isopropyl alcohol after use was collected and distilled to be used again.

Experimental Procedure

Part of this investigation was conducted at the Experimental Mine operated by the Missouri School of Mines 1½ miles west of Rolla, and was carried out under conditions similar to those obtaining in any normally operated mine. The main flow of air through the workings was by natural ventilation that averaged 10,000 c.f.m. A Coppus Ventair Blower Type TM,

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[3] F. F. Netzeband, Consulting Engineer, Keetley, Utah. Personal communications.

size 4, with an eight-inch tube was installed in the fresh air section of the mine to supply air to the working face. This blower was run by electricity supplied by a gasoline-driven 6.3 kva single-phase generator set up in the compressor house outside the mine. The fan has a rated output of 1200 c.f.m.; at its peak, it was delivering 930 c.f.m. at the working face.

In order to determine the settling rate of dust, two types of powdered rock of equal weight and same ratio of fineness as shown in Table 1 were ejected from a funnel by means of compressed air into a dead end drift where no air was moving. Samples of the air in the drift were then taken at approximately 5 minute intervals for a period of one hour.

Table I

Wt. in grams	Mesh size	Type of rock samples
234	+45	a) Limestone rock with low Silica content
105	+100	
56	+200	b) Granitiferous rock with high Silica content
27	+325	
23	-325	

There are three major operations taking place in any active mine; namely, drilling, blasting and loading. Table II shows the dust count in all three operations, as determined in the Experimental Mine.

Table II
Dust count in drilling, blasting, and loading at the Experimental Mine

Type of Operation	Temp. Dry	Temp. Wet	Dust Count m.p.p.c.f.	Condition
Drilling	65	64	125.5	Dry drilling with no auxiliary ventilation. Count is the average of 25 samples. Blasting samples taken 15 minutes after blast with auxiliary ventilation on.
Blasting	65	64	97.2	
Loading	65	64	50.7	

It is apparent from the data of Table II that the most dust is created during drilling operations. As described under 'Field Observations', among the various methods of dust control, ventilation is one means of allaying this dust.

The quantity of air to be delivered into a mine is determined by the size of the mine opening. In order to have a directed flow of air, it has to be regulated by suitable doors and blockings. The volume of these openings could be reduced by isolating unworked and abandoned workings. In a drift, the volume of space where the air movement is not directed by a steady current of air, circulation could be established by delivering fresh air as close to the face as possible. The fine dust created during drilling should be diluted rapidly in order that the driller standing two or three feet from the mouth of the drill hole will breathe as little of it as possible. Exhaust air from the drill tends to create a turbulence, thus keeping the dust stirred up and contribute to no 'directed flow'. In the tests at the Experimental Mine, the ventilation pipe from the Coppus blower was placed at different positions in the drift and at different distances from the face.

Air jets for ventilation were compared to ventair blower by analysis of samples of air delivered to the working face by each in turn.

In order to determine the effect of auxiliary ventilation in raises, the fan tube was placed in different positions in the raise (Figure 2) and the result of dilution of dust is recorded in Table 7.

Table III

Dust count with fan tube at different distances from the face.
Tube in upper left-hand corner of drift.

Quantity of air c.f.m.	Distance in ft.	Dust count m.p.p.c.f.	Time of sample	Average for each dist.
930	60	8.1 9.7 10.2 8.4	2 mins.	9.1
930	50	9.2 7.6 8.3	2 mins.	8.36
930	40	5.6 5.1 4.7 3.8	2 mins.	4.8
930	30	3.2 1.4 2.3 1.8	2 mins.	2.17
930	20	0.6 0.8 1.2 1.6	2 mins.	1.05
930	10	0.6 0.5 1.1 0.7	2 mins.	0.75

Table IV

Dust count with fan tube at different positions in the drift

Distance from face, 20 feet

Position of fan tubing at 20' from face	Operation	Quantity of air c.f.m.	Dust count m.p.p.c.f.	Average	
				For hole	For position
Top left hand corner	Drilling (Burn holes)	800	17.6* 3.5** 2.7***	7.9	
	Drilling (Back holes)		13.2 2.4 2.7	6.1	7.1
	Drilling (Lifters)		15.6 4.0 2.3	7.3	
Halfway down	Drilling (Burn holes)	800	57.3 16.5 19.8	31.2	
	Drilling (Back holes)		51.3 13.7 18.4	27.8	28.1
	Drilling (Lifters)		49.8 14.1 15.0	26.3	
Lower side of drift	Drilling (Burn holes)	800	69.3 27.6 39.24	45.38	
	Drilling (Back holes)		42.7 17.3 24.9	28.3	33.16
	Drilling (Lifters)		39.4 16.3 21.7	25.8	

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* In each set of figures this first figure is the dust count for collaring and 1st foot of hole.

** and *** In each set of figures these two figures are the counts for the dust from the remaining 4 ft. of hole.

Table V

Dust count with different volumes of air with fan tube at constant distance from the face.
(Tube in upper-left-hand corner of drift)

Quantity of air c.f.m.	Distance from fan tube to face	Time of Sample	Count m.p.p.c.f.	Average for each volume
500	20	2 mins.	5.8 7.2 3.9 9.02	6.48
750	20	2 mins.	2.6 1.7 3.2 1.18	2.17
930	20	2 mins.	0.6 0.8 1.2 1.6	1.05

Table VI

Results of dust count obtained when using air-jet ventilation compared with fan pipe ventilation.

Ventilation by	Quantity of air c.f.m.	Distance from face	Dust in the ventilating air	Count during drilling
Compressed air-jet	200	25'	Nil	10.3
8" dia. fan pipe	600	25'	0.8	2.7

Table VII

Raise samples, see Fig. 2

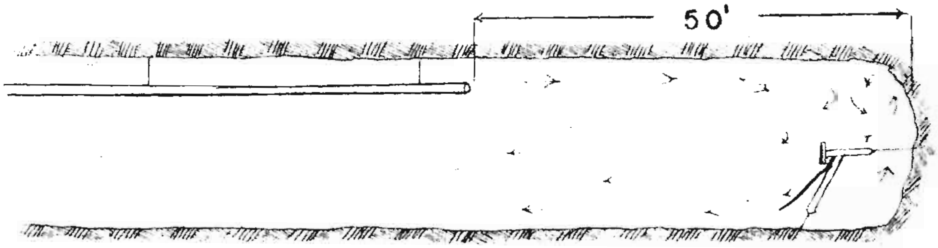
Position No.	Quantity	Sample No.	Dust count m.p.p.c.f.	Average
1	550	1	12.4	8.08
	550	2	8.4	
	550	3	7.2	
	550	4	4.3	
2	550	1	8.2	4.5
	550	2	3.9	
	550	3	3.1	
	550	4	1.7	

Table VIII

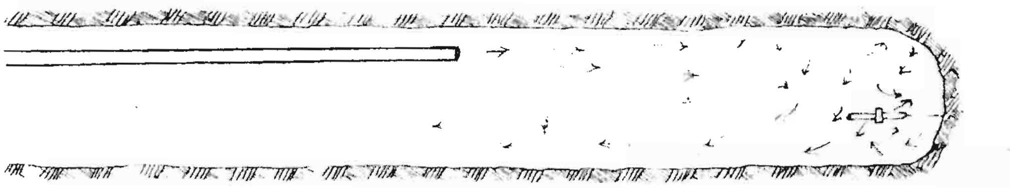
Dust settling

Time after dispersal	Count for Limestone rock m.p.p.c.f.	Count for Granite
After 1 minutes	513.6	166.50
After 5 minutes	90.3	13.98
After 15 minutes	41.4	3.90
After 25 minutes	12.9	3.30
After 35 minutes	9.3	2.19
After 45 minutes	6.6	1.08

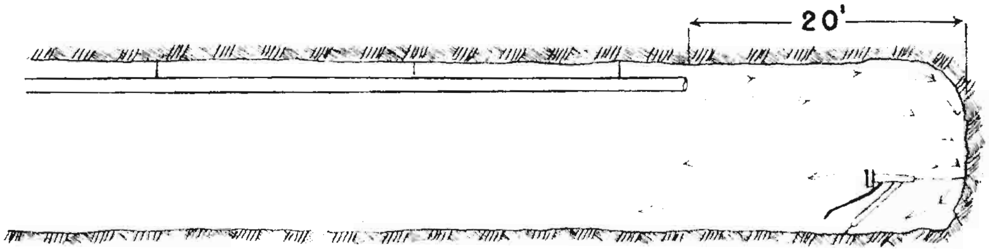
DRIFT VENTILATION



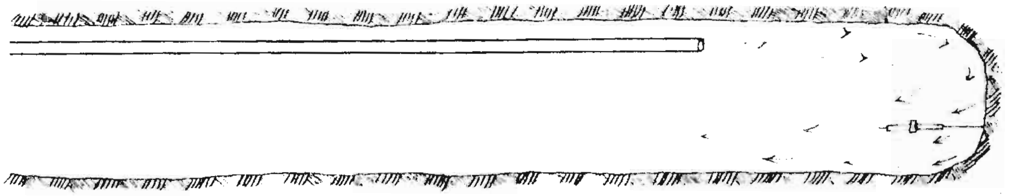
SECTION. Incorrect position of fan tube



PLAN. Showing air circulation & air lock



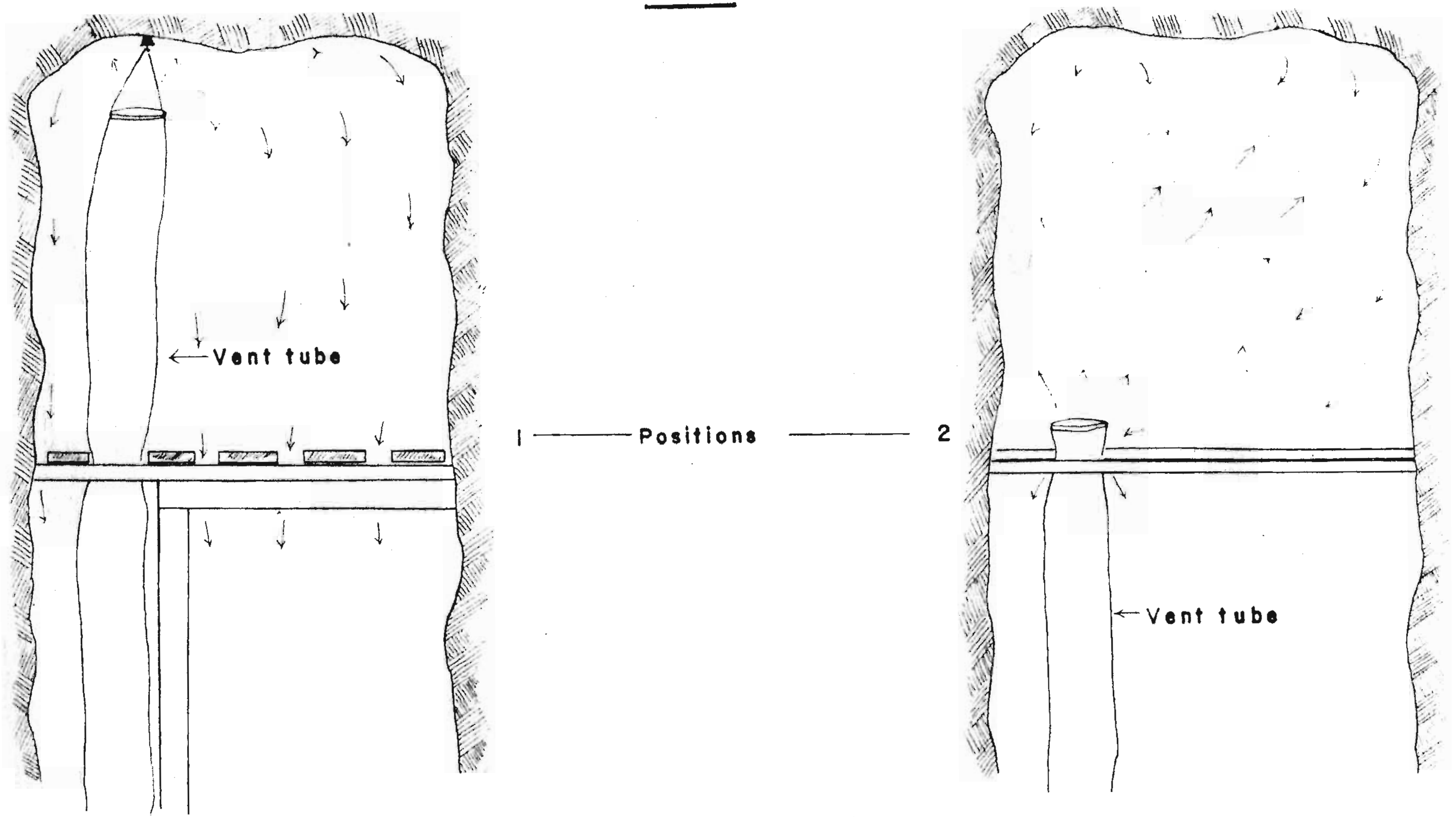
SECTION. Correct position of fan tube



PLAN. Showing efficient air movement

FIG. I

FIG. 2



RAISE VENTILATION

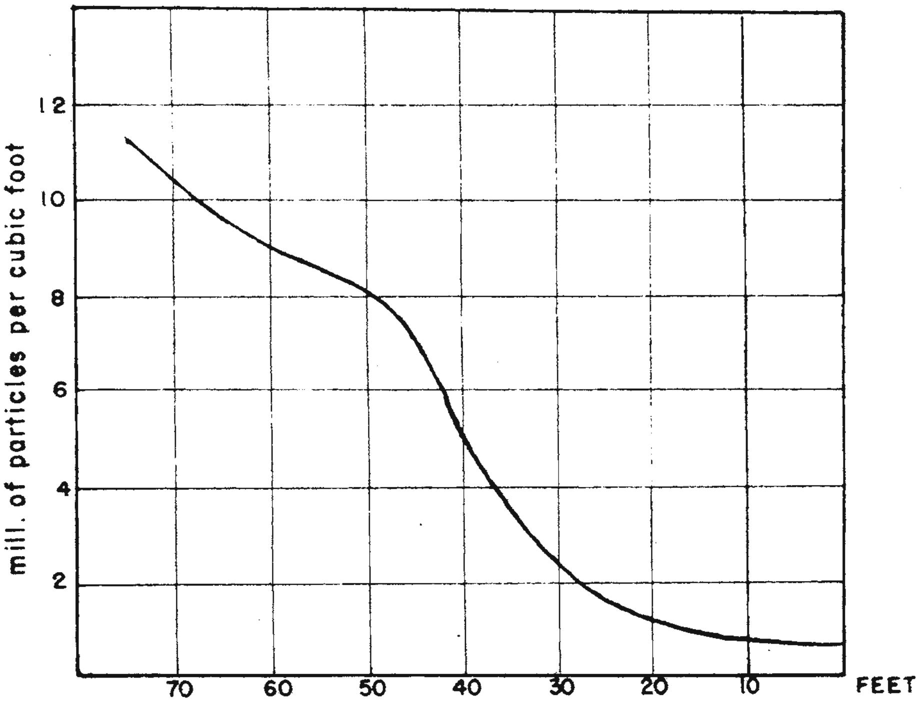


CHART 1. Effect of distances on dust count

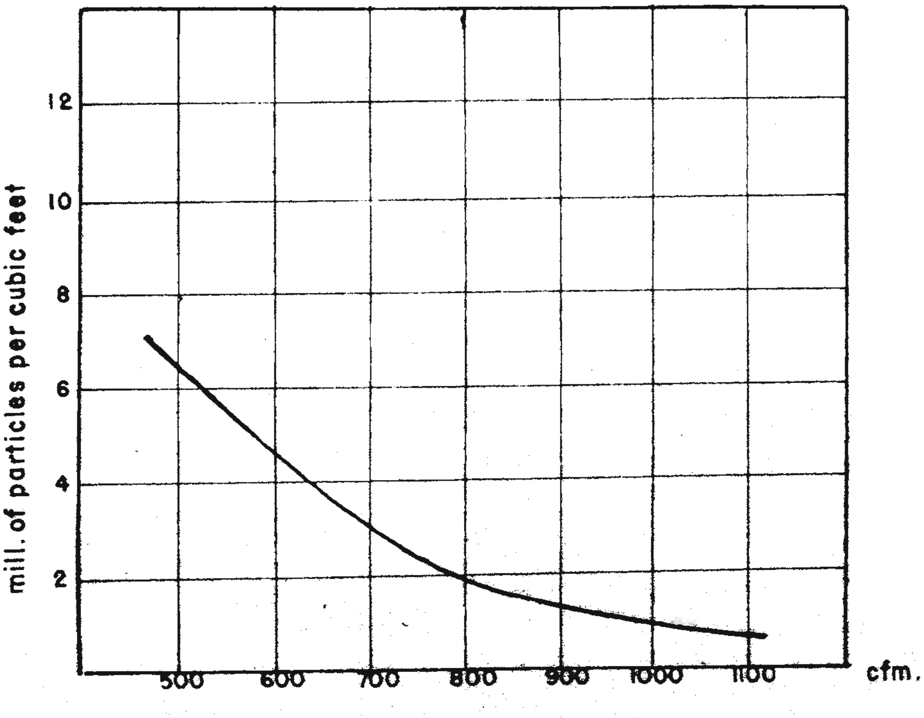


CHART 2. Effect of volume of air on dust count

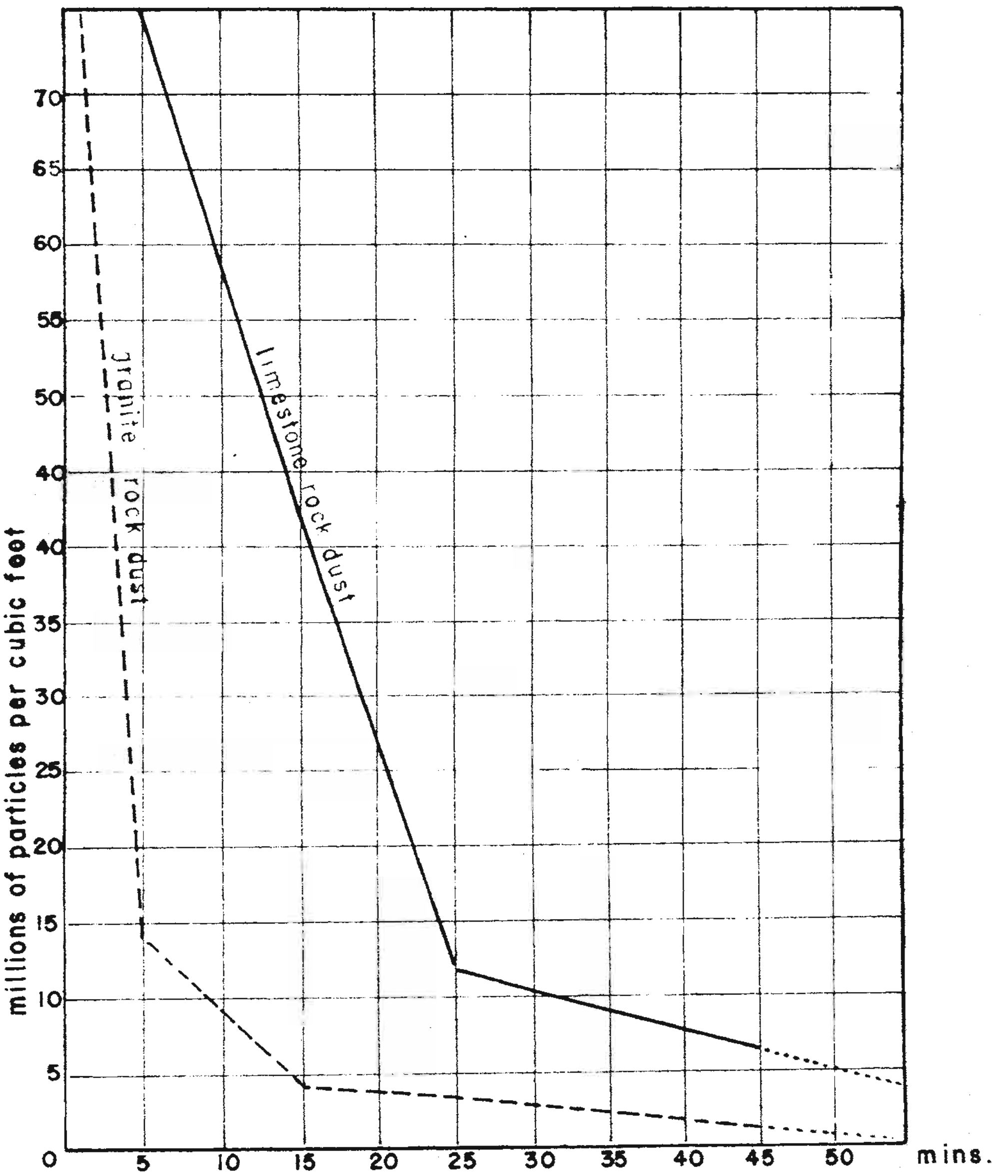


CHART 3. Showing settling rate

The following conclusions may be drawn from the foregoing data:

1. Air exhausted from the drills sets up a brisk whirl of air at the face that develops a lock which is not penetrated by a feeble ventilation current. In such cases, dust dilution is minimized.

2. To break this air lock, a current of air sweeping the face is needed.

3. From chart (1) it is seen that the closer the open end of the fan tube is brought to the face, the more the air lock is disrupted and the greater the dilution of dust; the maximum distance of the tube from the face should be not more than twenty feet.

4. A study of Table VI shows that ventilation by an air-jet alone is not adequate in dealing with the dissipation of dust; but, instead, a large volume of air that reaches up to the face is necessary.

5. A study of charts (1 and 2) shows that the distance from the end of the tube to the face is more important than either the amount of air delivered or the position of the tube in the drift.

6. For ventilating raises, the position of the fan tube seems more important than the amount of air, as shown in Table VII.

7. The settling-time tests as shown in chart (3) indicate that dust produced by rocks of different mineral constituents have different rates of settling. The dissipation of such different types of dust has a bearing on the velocity and amount of air used in ventilating the working place.

FIELD OBSERVATIONS

Ventilation in Shafts

The air entering a downcast shaft picks up dust caused by the evaporation of dust-bearing water dripping from the skips, shaft lining and loading chutes. The loading of skips from shaft chutes and the short circuiting of foul air through doors into the shaft also tend to contaminate the downcast air.

The two latter factors leading to dust in a shaft can, in many cases, be corrected by proper mine operation control, but the evaporation of dirty water cannot be avoided because of the fact that ore is almost invariably hoisted in the downcast shafts; and, in the interest of dust prevention in the workings, the ore must be handled wet.

Blasting Operations

Blasting is one of the major sources of dangerous dust in mining operations. Besides developing fine dust that tends to remain suspended in the mine air because of the large amount of water vapor produced after blasting, noxious gases also result. The water vapor is made up of particles so fine that they remain suspended instead of bringing down the dust. Larger particles of water from sprays or atomizers, on the contrary, rapidly clear the air of dust. The noxious gases, particularly the oxides of nitrogen and sulphur, tend to accelerate the harmful effects of silicosis. This was recognized in many countries, and regulations were introduced to prevent the exposure of workmen to such gases. Regulations set up by most of the leading mining countries prohibit the following:

a) Blasting more than once in twenty-four hours.

b) Blasting the cut and round separately on the same shift.

c) The re-entry of persons into the mine until working places and traveling ways are clear of fumes and dust and after the expiration of an interval fixed by the inspector of mines. (generally 30 minutes).

d) The re-entry of persons into dead ends before the whole volume of air beyond the last through ventilation connection has been replaced by fresh air.

d) The re-entry into dead ends until the water blast has been in operation for at least thirty minutes, fifteen minutes immediately after blasting and again for fifteen minutes immediately before the entry of the next shift.

A strict adherence to the above provisions will eliminate the exposure of any person to dangerous fumes.

Drilling and Other Operations that Produce Dust

Many mining operations involve the rubbing of rock with other materials, such as rock or machinery. Drilling, loading and the passage of ore in the chutes and cars all produce dust in the process, and this happens when the men are actually at work.

Of these, drilling is a major source of dust. The introduction of water-feed hammer-drills, however, has reduced considerably the amount of dust produced. Besides wet drilling, adequate ventilation at the place of work tends to dilute the concentration of dust.

During the entire drilling operation, most of the dust seems to be created during the collaring of a hole. This is shown in the table below.

Time of Sample	Dust Count	Conditions
Prior to starting drilling	0.21	Auxiliary fan delivering 800 c.f.m. Dry drilling samples recorded are average of six samples.
Collaring of hole including 1 foot of drilling	17.3	
Rest of the five feet	3.5	

This table illustrates the necessity for the use of water during collaring. In many mines an extra water hose is provided for this purpose. Although the miner prefers to collar a hole dry for his convenience, a logical reasoning of the risk involved will soon convince him of the advisability of using wet collaring.

Another source of dust during the drilling cycle is the blowing out of the holes by means of compressed air in order to pull the drill steel out or to clean the holes before charging with explosives. Such holes should be wetted down before turning on the air.

In stoping operations, generally there is a current of air going up from the lower level to the upper level since the lower level is warmer than the upper level. As these two levels are connected by raises there is ample opening for the air to pass through. In this case measures are to be taken to direct this current of air along the working face of the stope. As stopes have supports put in them, these supports can be covered up at convenient points to direct and control the flow of air. In many deep mines the method of supporting the stope is so arranged that the air is made to follow the working face prior to reaching the upper level. Sometimes it is found necessary to use compressed air blowers to accelerate the movement.

In back stopes where no connection exists between the lower and upper levels the same method as mentioned above with slight modifications such as a door or stopping in the level below the stope may be used with advantage.

The operation of mechanical scrapers is a secondary source of dust. Although relatively few men are exposed to dust resulting from this operation, it was noticed at the mines visited that most slushing in stopes was done with the operator sitting on the windward side of the air current, which completely protected him from any dust created. But in development workings, the problem becomes a little more difficult. In such places, besides adequate ventilation, water blasts are constantly used to keep the muck pile wet.

Loading cars from a chute creates considerable dust that is carried away by the air current. If the chutes happen to be on an intake airway, the air gets contaminated even before entering the other working places. To prevent this, atomizers which break water particles into such fine size as to form a mist that brings down the dust in the air are installed at vantage points in the levels.

Water sprays are almost universally employed at tipples or dumping stations to catch as much of the dust as possible when the ore is dumped into the shaft chute.

In some mines where the primary crushing of the ore is done underground at the bottom of the hoisting shaft, the crushers are completely enclosed, and by means of an exhaust fan, the air is taken out to be filtered through suitable dust traps.

In places where dust concentration is unavoidably high, workers are required to use approved dust respirators.

Summary of Field Observations

1. Proper control of ventilation in the down shaft to prevent contamination due to leakage of return air through doors in shafts and keep down excess of humidity.
2. Compliance of the blasting hour schedule to avoid blasting during shift when full complement of men are at work in the mine.
3. Improved ventilation in stopes by adequate control to make the air flow along the working face.
4. Use of water sprays and atomizers at the sources of dust to keep it down.
5. Wet drilling and keeping the muck pile wet while at work.
6. Properly enclosing crushers installed underground and providing suitable dust traps.
7. Use of auxiliary ventilation in places where it is essential.
8. Use of protective dust respirators in bad working places.
9. Education of the workmen with regard to dust hazards.

APPENDIX A

Medical Control

Two factors are involved in the incidence of silicosis; namely, the silica dust and the worker. If either one of them is removed, there is no problem. But in practice this is not possible; and as long as mining is carried on for the winning of ore, men will be exposed to certain amounts of dust. Therefore, in addition to engineering control of dust, certain medical precautions can be taken to guard against this disease.

Silicosis is a chronic condition of the lungs caused by the inhalation of fine air-borne silica (SiO_2) particles of sufficient concentration and over a period of time long enough to produce fibrous nodules in the walls of the air sacs of the lung; nodules that can be recognized under an X-ray.

Mavrogordato,[4] in discussing the harmful effect of silica dust states, "That it is only particles below 5 microns (1 micron = 1:1000 of 1 mm.) and less that take part in silicosis production ----- that the minimum quantity of this dust of fibrosis producing size required to set up a Witwatersrand Simple Silicosis is from one and a half to two grams". He concludes that the number and size of the particles that go to make up this mass of air-borne dust of fibrosis-producing size is of no particular significance, hence that the mass-distribution of air-borne dust is of greater importance than its size-frequency.

Although no standard has been set up as to the permissible amount of silica dust particles that may be present in mine air to prevent silicosis, mines in the United States and Canada[5] try to keep the amount to within

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[4] Mavrogordato, A., A Grammer of Witwatersrand Silicosis, Journ. of the Chem. Met. and Min. Soc. of South Africa. April 1940, page 440.

[5] Gibson, C. S., Ventilation as Silicosis Prevention. Trans. C.I.M.M. Vol. XLV. 1942, pp. 273-294.

five million particles per c.f. or 200 particles per c.c. administered. The research organization is sponsored by the McIntyre Porcupine Mines, Ltd., Ontario, Canada. It is a non-profit organization, and the royalty realized through control of aluminum therapy is devoted to furthering research in the prevention of silicosis.

The treatment is given in two ways:

1. Prophylactic treatment
2. Therapeutic treatment

Prophylactic treatment

During the past four years, the mass treatment by aluminum dust of men employed in mines in Canada has been carried on by dispersing fine aluminum dust in change houses. Specially prepared aluminum powder is dispersed by means of compressed air ejectors in the room just before the men come into the change house prior to starting work. For a ten minute exposure, the amount of powder to be dispersed in order to attain sufficient concentration has been determined to be one gram of powder for each thousand cubic feet of room capacity. The men take from ten to fifteen minutes to change to work clothes, and during that time they breathe the air laden with aluminum dust. This guards them against any silica dust they might breathe during the shift.

Therapeutic treatment

Miners whose chest X-rays show any dust accumulation are given a special therapeutic treatment. The treatment is two minutes long at the beginning and is gradually increased to a maximum of ten minutes. The treatment is given by attaching a mouth-piece tube directly to the exhaust end of a small ball mill where fresh aluminum powder is made.

Aluminum therapy is a preventive, and not a cure. It has been emphasized by the proponents of this treatment that aluminum therapy is not a substitute for proper ventilation and dust control, but only an adjunct. Dr. Robson[6] states: "Proper ventilation and dust control are extremely difficult to maintain at all times and in all places. Aluminum is to be used only to take care of that small percentage of silica dust which is not removed by accepted modern methods".

A thorough medical control program is necessary in all dusty industries. This program consists of a pre-employment examination that includes an X-ray of the chest. Persons who show any susceptibility towards tuberculosis or any other lung affliction should not be employed in an industry where their lung condition will be aggravated. Periodic examination of all workmen must be made, and any person who shows signs of a lung infection should be transferred to a job where his condition will have a chance to improve.

Aluminum therapy is gaining more and more favor in the mining countries of the world; and although its adoption for mass treatment of the workers has not been universally accepted because of a lack of positive proof of its efficacy, there are reasons that favor this treatment. To quote Dr. Robson[7], "For the sake of argument, let us assume that the benefits derived are in certain cases psychological. Treatment is still justified in that it has provided in these silicotic cases a feeling that something is being done to alleviate their suffering and restore to them and their families the feeling of confidence so necessary to their well-being."

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[6] Robson, W. D., Aluminum Therapy and Silicosis Prevention, Medical Aspects. Trans. C.I.M.M. Vol. L, 1947, p. 63

[7] Robson, W. D., op.cit., p. 22.

APPENDIX B

Economic and Legal Aspects:

One of the important factors that should be considered in successful dust control is the cost of such preventive methods. Unless these methods are economically feasible, their universal application by mining companies both large and small will be impossible.

Money paid as compensation for silicosis has been costing the mining industry large amounts and has involved frequent court disputes with additional expenditures to fight racketeers. The compensation laws for silicosis in many countries are very stringent, and small companies are affected more seriously than larger ones.

The magnitude of this problem can be judged by the following statements. The Committee on the Economic, Legal and Insurance phases of the silicosis problem set up by the United States Government in 1938 reported[8] "That approximately one million industrial workers may be exposed to a silica hazard, reference is made to potential rather than actual exposure".

Harrington and Davenport[9] mention that in 1935 about $100,000,000 in silicosis claims were pending in courts in the United States.

They state also that, "The total amount paid for silcosis compensation since the enactment of the miner's phthisis laws of South Africa to 1934 exceed £ 14,000,000 (about $70,000,000). The cost per ton of ore milled has been about 6d. (about twelve cents) and per ounce of gold recovered 1s.7d. (about thirty-eight cents); the cost per underground

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[8] National Silicosis Conference Report on Economic, Legal and Insurance Phases. Bulletin No. 21, Part 3, U.S. Government Printing Press. 1938.

[9] Review of Literature on Effects of Breathing Dusts with Special Reference to Silicosis. U. S. Bureau of Mines Bulletin 400. 1937

European shift was about 4s. (one dollar). In Canada it is said that cost of silicosis compensation is $1\frac{1}{4}$ per cent of the total mine pay roll, although only $2\frac{1}{2}$ per cent of the men employed by the mining companies are actually exposed. The estimated cost of each case to the company is $11,000 to $12,000. It has also been said that for every five dollars spent in mining and concentrating a ton of gold ore, one dollar is required for silicosis."

It is argued that an employer engaged in manufacturing certain products by a process that gives rise to dusty conditions should be solely responsible for any liability that may result. This statement is rather hard on such an employer. Consideration must be given as to whether the employer is taking effective steps to prevent unhealthy conditions from existing or is at least making an effort, within economic and technical limits, to reduce such conditions to a minimum.

An employer producing articles whose price is not government-controlled is likely to raise the price of such articles to cover the additional expense incurred in improving the working conditions of his employees. This expense is ultimately paid by the consumer. On the other hand, when government has control over the price, the employer has to bear the entire cost of improving working conditions. In either case, however, the employee, who is the beneficiary, should not be made to share the expense. If cumulative liability is apparent, the present employer should not be made to pay the entire cost of compensation to the worker who might have developed his physical disability while working in different camps where conditions were more conducive to the development of the disease than in his present place of work. In such cases, his present employer is not wholly responsible, and the State should make provision for paying at least part of the compensation.

A physical disability resulting from silicosis should be treated the same way as any disability due to accident or other bodily injury. In the case of accidents, the compensation is paid according to the loss in the earning capacity of the individual. Similar consideration is warranted in the case of silicosis.

For the purpose of compensation, the disease is classed in different stages, according to its severity. These are as follows:

a) The anti-primary stage, or the stage in which the first signs of damage to the lungs appear after employment in a mine.

b) The primary stage, in which definite signs of silicosis are noticed, either by X-ray or by impairment of capacity for work, to a certain extent.

c) The secondary stage, in which definite signs of illness are apparent, with the capacity for work being seriously and permanently impaired.

In South Africa the compensation laws provide for a lump sum grant in the first two stages and a monthly pension in the third stage.

In Canada, especially in Ontario, the compensation is paid entirely on the basis of the claimant's loss of ability to work, and a regular pension is paid to the claimant. In case of death from silicosis, the dependants of the deceased get the pension. The payment is made out of a fund set up for each mining district, to which every company operating in that district contributes in accordance with the amount of its pay roll.

A similar point of view is taken in the United States, but because of the uncertainty of diagnosing silicosis in its early stages a lump sum award, based on the salary of the claimant, is made usually.

The compensation laws of other mining countries resemble those of South Africa, which seems to have developed a working system of compensation for this disease.

APPENDIX C

There are three types of instruments commonly used for obtaining samples of dust in the atmosphere. They are described briefly as follows:

Konimeter

Sir Robert Kotze[10] is credited with the design of the konimeter in 1916. A large number of samples can be taken on a glass slide coated with a thin film of adhesive such as nujol. As many as 30 samples can be taken on one slide which is fixed in such a way that it can be revolved. The mine air is drawn through a jet by a spring propelled pump; the air impinging on the slide at a high velocity. Any dust in the air is deposited on the adhesive as a small spot on the slide. The capacity of the pump is 5 c.c. per stroke. The narrow end of the jet is about 0.5 mm. from the glass slide. The strength of the spring on the pump plunger is sufficient to produce the necessary velocity.

The greased slide is placed facing the jet and pressed against a spring to make it air tight. A cover plate is screwed on top. The slide can be revolved by means of a worm pinion that engages teeth in its outer circumference. Numbers are stamped on the ring to indicate the number of the samples taken. To operate the Konimeter the instrument held where the sample is to be taken and the pump plunger is pushed up against a spring. The plunger is released by means of a trigger. The jet usually is held at right angles to the direction of the air current.

After the samples have been taken, the slide is removed from the instrument and the spots are given an acid bath to remove organic particles and the slide then is heated in an electric muffle furnace to a temperature of about 900 deg. F. This leaves a clear field in which to count the dust

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[10] Norman, George H. C., Tech. Pub. No. 857, A.I.M.E., Mining Technology 1937. Methods of Sampling and Dust Determination in the Mines in Ontario.

particles under a microscope.

Midget Impinger

The Midget Impinger was developed by the U. S. Bureau of Mines[11]. It is a device for taking samples of dust-laden air by passing air at high velocity through a liquid medium, usually Isopropyl alcohol. The air is transmitted through the apparatus by using a suction pump. The dust particles are trapped in the liquid as the air passes through.

The impinger is a cylinderical tube enclosed in an air-tight flask. It has an orifice 1 mm. in diameter that allows air, under a controlled pressure, to pass through it at the rate of 0.1 cubic foot a minute.

The suction pump is operated by turning a hand crank at such a speed as is necessary to maintain a pressure that will cause the desired volume of air to pass through the orifice. The rate at which the pump crank should be turned to give the controlled pressure, as indicated by the pressure gauge, is determined by a Sargent Wet Test Meter before tests are begun. The operating characteristics of the pump are thus calibrated for use in dust collecting. A gauge pressure of about 12 inches is usually observed.

The impinger flask is filled to the 10 cc. mark with collecting liquid and the stopper holding the impinger tube is tightly fixed. To take a sample a rubber tube from the pump is attached to the flask, and the opening of the impinger is exposed to the air to be sampled. When the pump is cranked for a certain period of time, a certain volume of air is sucked through the impinger and the liquid, and the dust in the air is trapped in the liquid.

The sample is then diluted to 25 cc. in the laboratory and a repre-

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[11] Littlefield, J. B., Feicht, F. L., and Schrenk, H. H., The Bureau of Mines Midget Impinger for Dust Sampling, Report of Investigations 3360, Bureau of Mines, 1937.

sentative sample of this liquid is transferred to a special counting cell. This cell consists of a glass slide with a circular ring mounted on top to hold about 1 ml of the sample liquid. A cover slip is placed on top and the cell allowed to stand for 30 minutes to permit the dust particles to settle to the bottom of the cell. After this period of time the cell is ready to place under a microscope. The actual counting is explained fully in "Sampling and Counting Procedure" on page 5.

Thermal Precipitator

This instrument was originally devised by Whytlaw-Gray and Lomax[12] in England. The principle underlying the working of this instrument is that when a body is heated in a dusty atmosphere, a dust free space zone forms around the hot body, while the dust tends to settle on any nearby object that is cooler. This principle is made use of in collecting samples of mine air. Two glass slides are placed on either side of a wire that is heated electrically. A known volume of air is allowed to pass between the slides, and, because the dust particles are unable to penetrate the dust free zone around the wire, they settle on the glass slides. After the slides are taken from the Thermal Precipitator they are placed in a muffle furnace and are heated to approximately 900°F to remove any volatile matter that may have been collected with the dust. They are cooled and then are placed under the microscope, and the dust counted at a magnification of 1000 to 1500.

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[12] Patterson, H. A., The sampling of mine dust with the Thermal Precipitator, Jour. of the Chem. Met. and Min. Soc. of South Africa, May 1939. pp. 375-379.

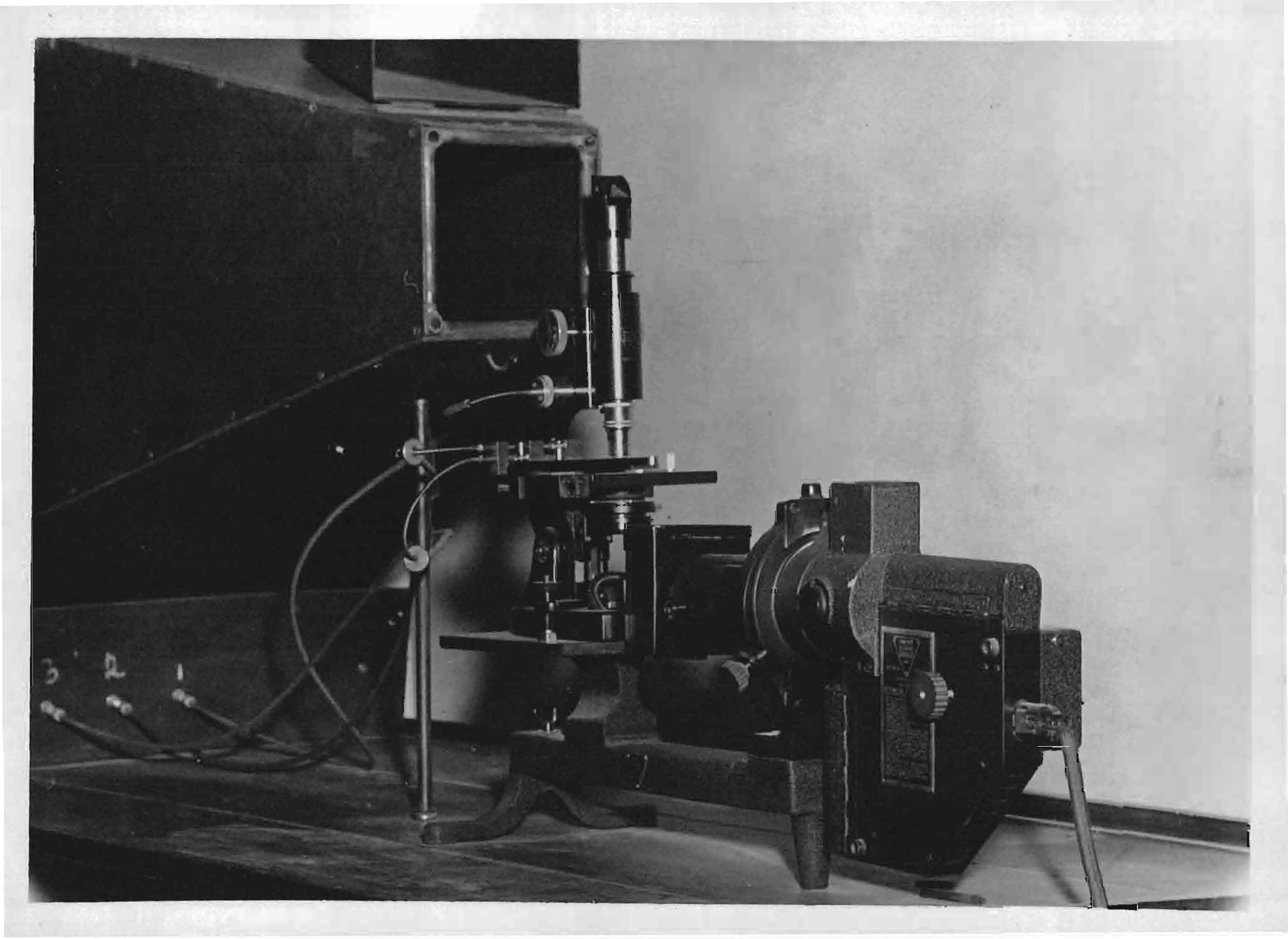

Figure 3. Microscope with microprojector showing remote controls at the screen in the Laboratory at the Missouri School of Mines.

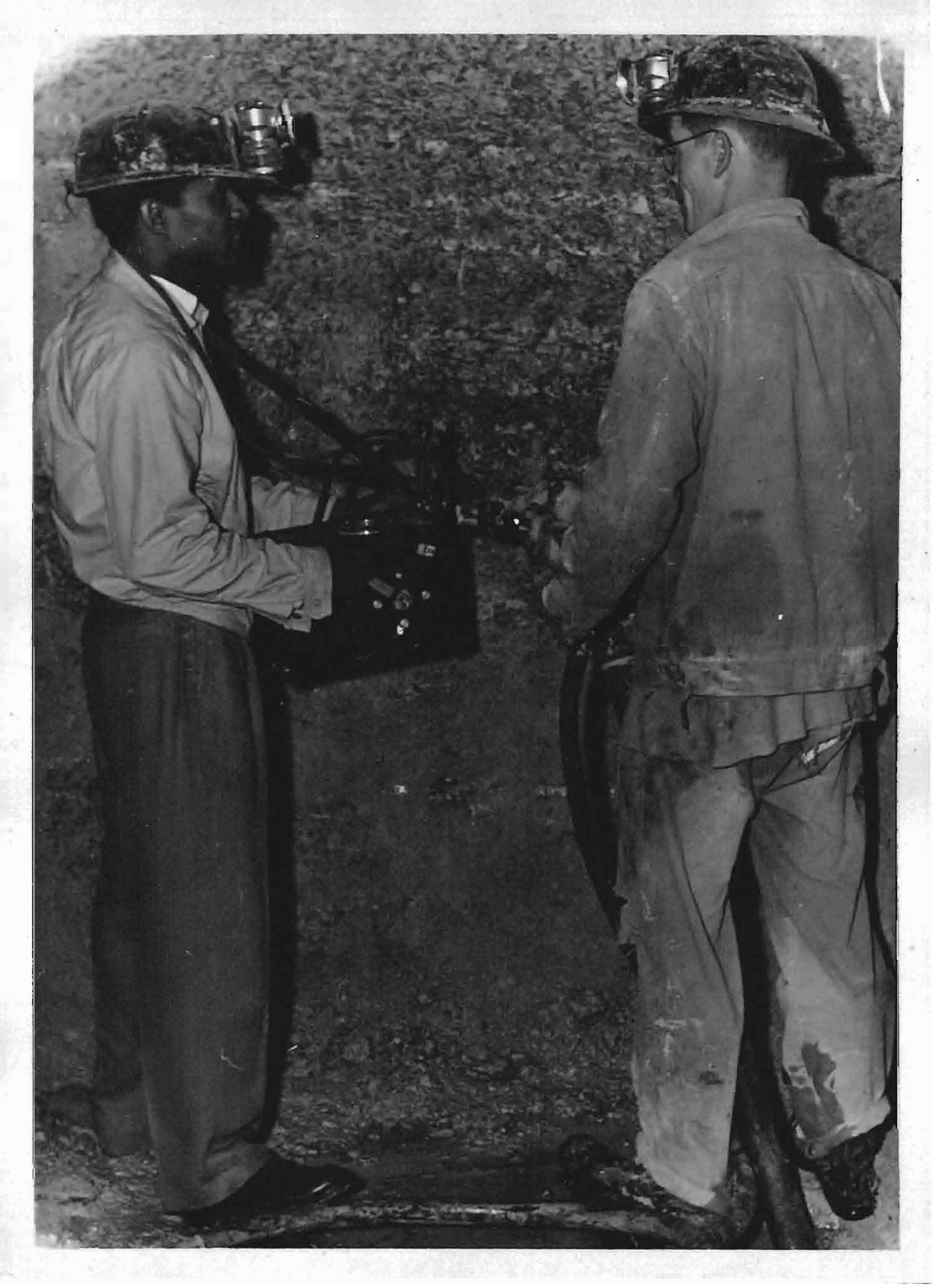

Figure 4. Taking mine air samples with a Midget-Impinger during drilling at the Experimental Mine

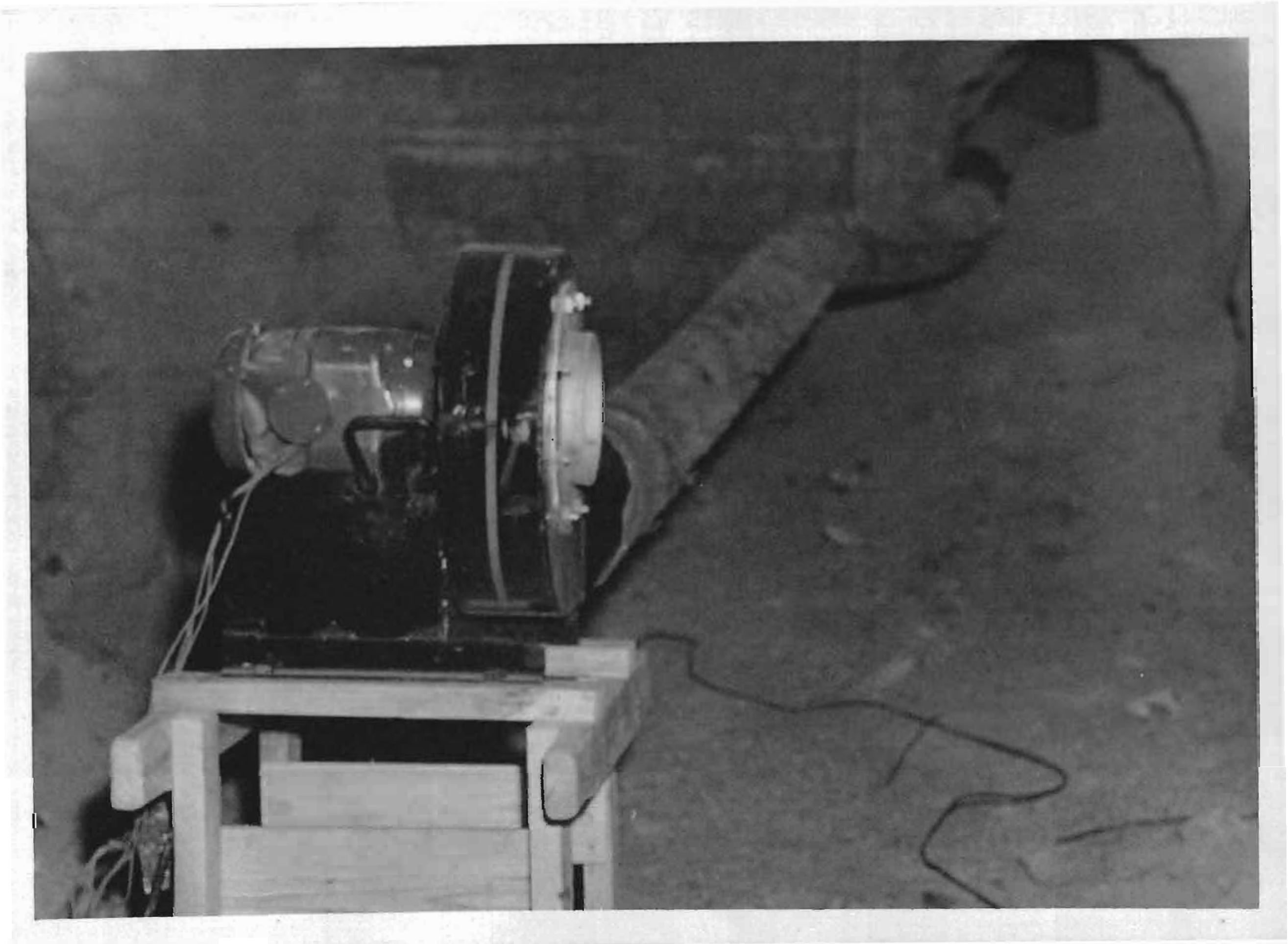

Figure 5. Coppus Ventair Blower Mounted on a stand and installed in the fresh air section of the experimental mine.

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VITA

Mathuramuthoo Subramanyam, son of Rangiah Mathuramuthoo and M. Thayarammal, was born at Kolar Gold Field, Mysore State, South India, on May 1, 1916. He attended the primary and middle schools at Robertsonpet, and the high school at Bangalore. He joined the Central College at Bangalore, University of Mysore, and in 1937 received a degree of Bachelor of Science (Honors) with geology as his major subject.

Professional Record

From 1938 to 1940 he was Probationer in the Department of Mines and Explosives of the Government of Mysore. He was appointed Junior Inspector of Mines in the office of the Chief Inspector of Mines and Explosives, Mysore, in 1940, and was promoted to acting Assistant Inspector of Mines in 1945. At the end of that year, he was granted a leave of absence for foreign studies by the Mysore Government. He received a scholarship from that Government for post-graduate work at the Missouri School of Mines and Metallurgy, University of Missouri, where he has been studying since January 1946.

He acquired practical training in the mines of the Kolar Gold Field and in other mines in the State of Mysore, as well as in the inspection of explosive storage magazines and calcium carbide storage depots.

During the summers of 1946 and 1947, he toured most of the metal mines in Ontario, Canada, and mines in the western and northern states of the United States to study mining and labor welfare practices.

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