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RESPIRABLE DUST CONTROL IN THE MINES OF WEST GERMANY



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By D. P. Schlick

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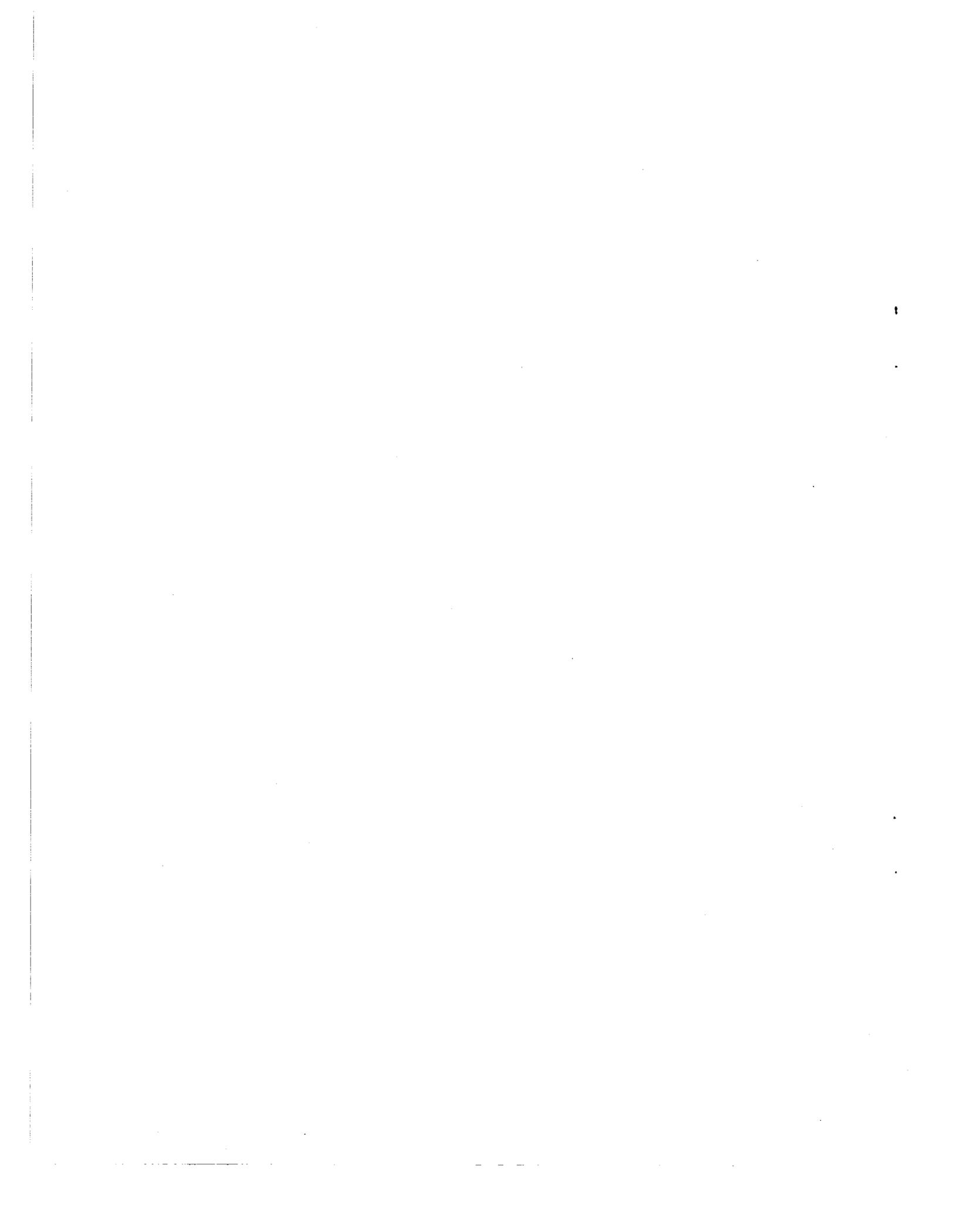
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RESPIRABLE DUST CONTROL IN THE MINES OF WEST GERMANY

by

D. P. Schlick¹

ABSTRACT

The German experience in dealing with the health hazard of respirable dust in underground mines is reported from first-hand observation in this Bureau of Mines paper. The report covers--

1. The control of dust by water infusion, water spraying, and ventilation.
2. The sampling devices (tyndalloscope, konimeter, and BAT-I) and methods used to determine the dust concentrations in mines.
3. The systems of classifying hazardous and safe dust levels in mines.
4. The research facilities devoted to theoretical and applied work on mine dust and pneumoconiotic disease.

The major research projects on dust and disease now underway in West Germany are outlined in an appendix.

INTRODUCTION

The Bureau of Mines, other Government agencies concerned with occupational health and safety, and the U.S. coal mining industry are engaged in a concerted effort to solve the problems related to respirable dust in underground mines. To achieve the allowable dust concentrations specified by the Federal Coal Mine Health and Safety Act of 1969 requires new and improved technology. Government and industry can save time and money by drawing on applicable foreign experience.

¹Acting Chief, Health Division, Coal Mine Health and Safety, Bureau of Mines, Washington, D.C. The author is a member of the United States-German Natural Resources and Environmental Pollution Control Program Panel on Dust in Mines. The information in this report was collected during a tour of West German mining facilities taken by the U.S. Members of the Panel in November 1969.

The United States-German Natural Resources and Environmental Pollution Control Program was established in 1965 to foster the free exchange of scientific information and to coordinate research on environmental problems of mutual concern. Joint panels devoted to specific problems were formed to carry out these ends, and in 1969 the Panel on Dust in Mines was created. The Panel held its first meeting in November 1969 when U.S. members traveled to West Germany to tour mining and research facilities, and this paper presents an overview of the German practices and programs in respirable dust control.

METHODS OF CONTROLLING RESPIRABLE DUST

Water Infusion

Water infusion, water sprays, and ventilation are the most important methods used in West Germany to suppress respirable coal mine dust. Of the three, water infusion is by far the most widely used; it accounts for over 90 percent of the control technology in West Germany's underground coal mines. The use of water infusion for abatement of respirable dust came accidentally to German mines. Initially, the principle was utilized to fracture the coal and thus facilitate increased coal production. However, once its use was established, it was discovered that water infusion had a marked effect on suppressing respirable dust.

The Germans have achieved success in utilizing water infusion to the extent that German mining regulations now require water infusion where its use is physically possible. In 1958, only 4 percent of the longwall faces (the predominate mining system) were water-infused. Today, water infusion is practiced in over 50 percent of longwall faces.

The principle of water infusion is to wet the main cleavage plane of the coal seam sufficiently to suppress respirable dust during subsequent mining operations. In longwall mining, the coal seam close to the face will crumble because of the pressure differential. (See fig. 1.) This crumbling causes more cracks in the seam and thus facilitates the water infusion process.

Water infusion was first accomplished by drilling holes in the coal face and infusing water at a low pressure by means of a water pump. Further investigation determined that pressures as high as 5,000 pounds per square inch (350 kg/cm^2) were required to adequately infuse the coal seam. A high initial pressure is required to overcome the resistance in the seam. However, once the water begins to flow, the pressure falls off as the water finds a path through the small cracks in the coal.

The most practical application of water infusion has been achieved by using 2-inch-diameter boreholes 9 to 45 feet long. The holes are drilled perpendicular to an advancing face. The distance between holes varies from 1-1/2 to 2 times the length of the holes. The quantity of water employed to wet the coal is approximately equal to 1 percent of the weight of coal infused. Water infusion works best in multilevel-seam mining, a system common in Germany. Results are not as good in single-seam mining. This difference is thought to

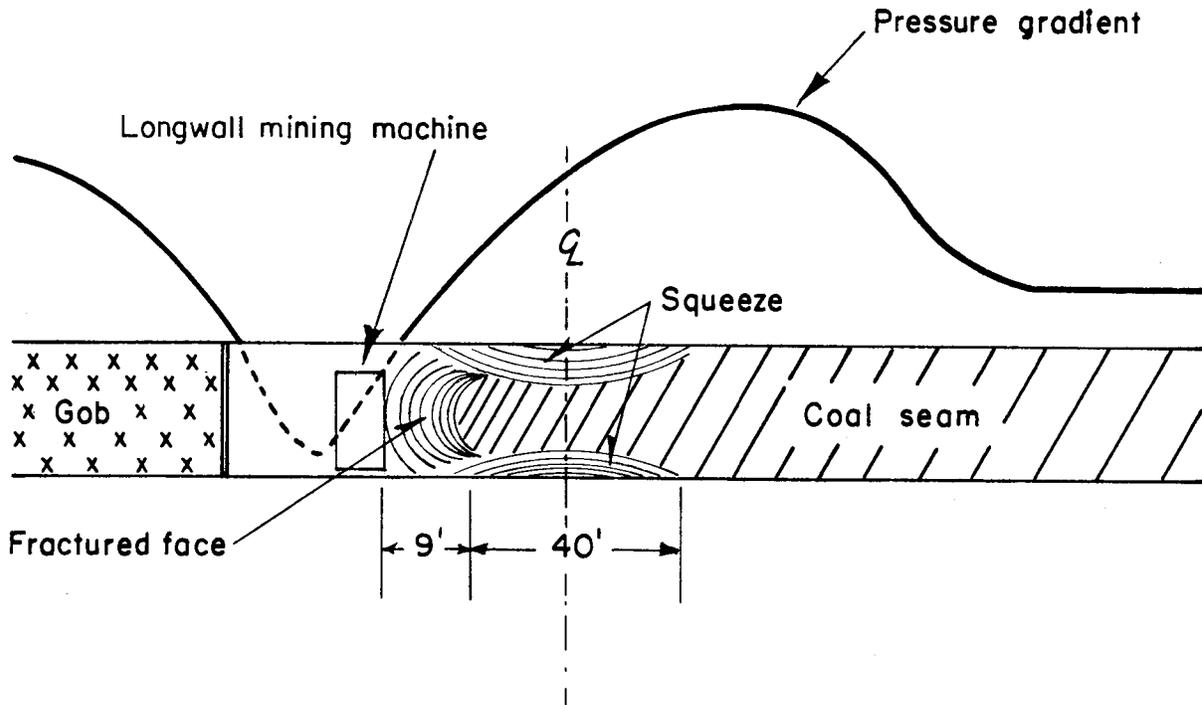


FIGURE 1. - Pressure Differential Between Face and Coal Seam Causes Crumbling and Facilitates Water Infusion.

be attributable to the tectonic nature of the coalbed. Most seam infusion takes place during the midnight shift when the longwall faces are usually idle.

Wetting Agents

Water with a wetting agent, either calcium chloride (CaCl_2) or magnesium chloride (MgCl_2), was reported to unquestionably further reduce respirable dust when added to the infusion process. The chemical additive is compressed into solid cartridges similar in size to normal explosive cartridges and inserted into the hole prior to infusion. The infused water then passes around the cartridge on its way into the coal seam. Figure 2 illustrates the effect that a wetting agent has upon a water drop. The best results have been achieved with an amount of wetting agent between 0.1 and 0.5 percent of the weight of water infused. Reports are somewhat fragmentary and inconclusive; however, results indicate that wetting agents reduce respirable dust 30 to 50 percent over normal infusion practices.

Infusion of water parallel to the longwall face is theoretically promising; however, coal seam dip and the long length of faces seem to have militated against the success of this infusion practice. For instance, in longwall faces exceeding 450 feet (typical of some German mines), it is difficult to penetrate the center of the face.

In most cases, it has been observed that the quantity of water infused into the coal seam gives little indication of the distribution of the infused

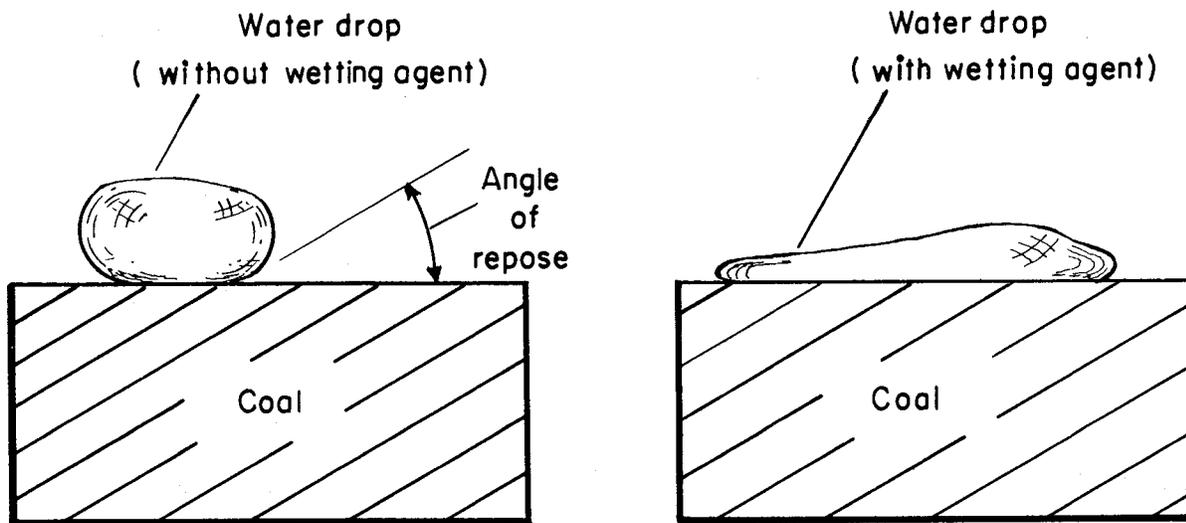


FIGURE 2. - Effect of Wetting Agent on Water Drop.

water. On the average, only half of the infused water has been found in the coal seam by moisture analysis. This odd phenomenon is under further investigation.

Equipment

The German mining industry uses compressed air pumps and electric motor driven pumps to infuse water into coal seams. Compressed air pumps capable of pumping 12 to 16 gallons per minute are used when lesser quantities of water are required. When a water volume approaching 23 to 28 gallons per minute is required, electric motor driven pumps are employed. In each case, operating pressures approach 5,000 pounds per square inch. Compressed air pumps are favored in advancing faces of short length while electric pumps are favored in advancing faces of long distances.

Various types of seals have been tested to enable water to be infused into the coal seam. A recently developed rubber seal which operates on a hydraulic principle is the most effective seal used to date. This seal becomes tighter as the water pressure increases, as illustrated in figure 3.

Water infusion can be applied in most types of mining; however, it is easier in horizontal seams. In cases of very steep pitch mining or where roof and bottom are adversely affected by humidity, extreme care should be exercised in adopting water infusion, as the extra influx of water may weaken supporting coal pillars. New water infusion practices applied to unique mining conditions should be approached in a careful manner and should not be attempted before making a comprehensive study of their effects on the total safety of the working environment. In no case should infusion drill holes penetrate the roof or floor as the inflow of water under extreme pressure will certainly have subsequent adverse effects on the roof or floor.

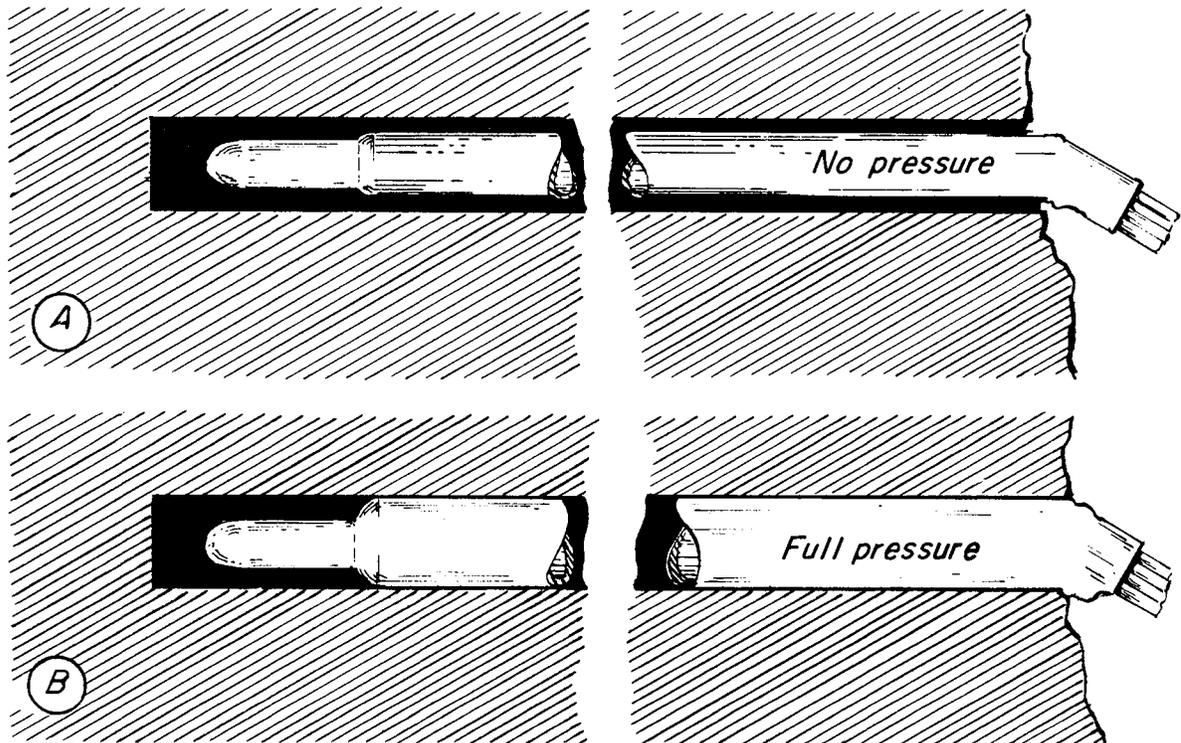


FIGURE 3. - Rubber Seal Used To Infuse Coal Seam. The seal becomes tighter as water pressure increases.

Water Sprays

In addition to water infusion, water sprays are located in longwall mining machines so as to direct water to allay dust at the source. Water sprays, operating at 200 pounds per square inch, are usually spaced along the longwall face and are actuated by a magnetic device which triggers the on-off valve as the coal-cutting head passes individual sprays.

Water spraying is also used in stowing areas and belt transfer points. Water-bag stemming is employed in rock boreholes. In some cases, a paste solution of calcium chloride is included in the water-stemming application.

Ventilation

The use of ventilation as a respirable dust control method is mainly limited to entries driven in rock. In such installations, auxiliary ventilation is provided by small-capacity exhaust fans and tubing.

A system employing a combination of water and ventilation is gaining acceptance in respirable dust control technology. The dust-laden air is sucked into the reaction zone of a ventilating machine where clean water is injected into the high-velocity area. Here, the dust and water form a sludge, which is transported to the rotor zone by a displacer. A cyclone then separates the air and sludge. The sludge is expelled by centrifugal force, and

the clean air reenters the ventilator via a diffuser. Less than a third of a quart of water is required per cubic meter of air. The ventilating machine can expel up to 5,000 cubic feet per minute of air at a 50-kilowatt power rating.

DUST SAMPLING DEVICES

In Germany, the trend is still to employ number-count or light-scattering techniques for dust sampling evaluations instead of gravimetric sampling, which is gaining acceptance in many countries throughout the world. The Germans were one of the first to establish a comprehensive dust-monitoring program and are understandably defensive about changing.

Tyndalloscope

The instrument generally used to routinely measure respirable dust in German mines is the Leitz² tyndalloscope. The tyndalloscope operates on the principle of dust particles scattering light as a beam of light passes through a dust-air mixture. Figure 4 shows the tyndalloscope and its working parts.

The tyndalloscope has been accepted in Germany for routine dust measurements because of its ease of handling and because a fixed dust concentration can easily be read in 1 minute if the mineral composition of the coal is known.

However, the instrument has several disadvantages. Little confidence can be put on the readings unless data have already been compiled about the mineral composition of the coal and dust concentrations of the environment. The readings can also be misleading because of smoke from blasting, mist from rock drills, or diesel fumes from locomotives.

During 1969, over 90,000 tyndalloscope measurements were taken in underground West German coal mines. In addition, over 3,000 readings were taken in stone-cutting operations. The measurements in the mines were taken monthly at the same locations in each coal-producing longwall face.

The normal operation is to take a series of 10 readings at 2-minute intervals. After a sample has been collected, the device is closed for 20 seconds to permit the large dust particles to settle out; then the dust concentration is read and recorded.

Every 6 months the instruments are returned to various centers for recalibration. In each case, the method used by the mine official for taking the measurements, as well as the instruments themselves, is given a thorough checking.

Konimeter

The konimeter is occasionally employed in routine respirable dust surveys. Dust particles below 5 microns that pass through an air jet are collected on a slide which has been previously coated with an adhesive jelly. The slides are evaluated under a microscope. Figure 5 shows a cross section of a konimeter.

²References to specific makes of equipment is made for identification only and does not imply endorsement by the Bureau of Mines.

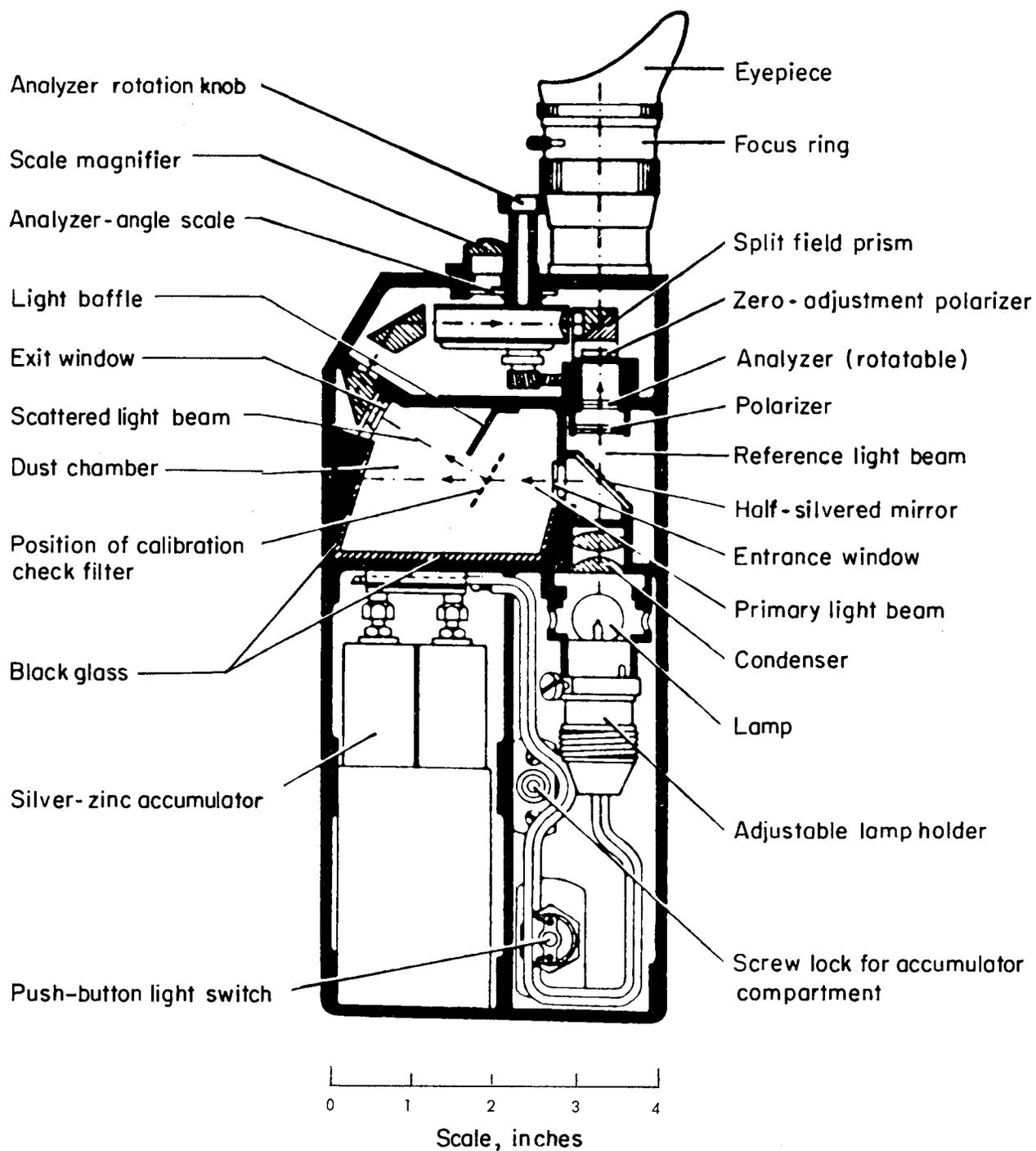


FIGURE 4. - Tyndalloscope.

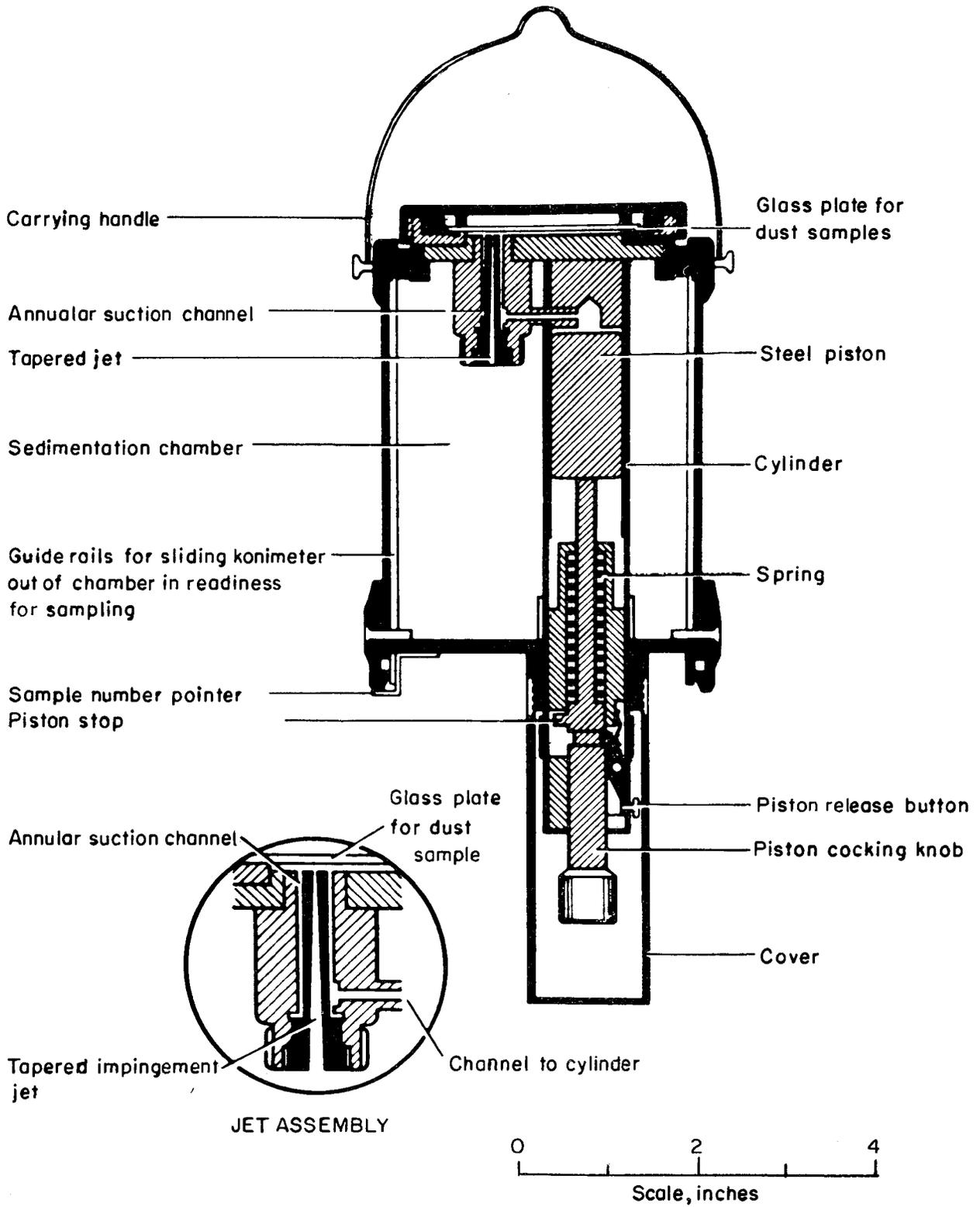


FIGURE 5. - Konimeter.

To determine the rock content of respirable coal mine dust, samples taken by the konimeter are photographed, ashed, and then photographed again. The difference in the brightness of the photographs is used to indicate the percentage ash content.

BAT-I

In the field of gravimetric dust measurements, the BAT-I, BAT-II, and BAT-III are experiencing the most use. The principle of this device is that large, nonrespirable particles are separated out by a cyclone and only smaller, respirable particles are retained on a membrane filter. Thus, the collection characteristics of this measuring device correspond to the pulmonary selection curve of the human lung.

The BAT-I has been recently modified to make it self-contained. Previously, the device was powered by compressed air. The new version has two cyclones in series, the first to settle out large particles and the second, highly efficient cyclone to collect the respirable fraction. Thus, the use of filters is not required; and, therefore, the new version requires less energy to collect a sample.

Record of Work and Dust Exposure

Since 1960, index cards, called Record of Work and Dust Exposure, have been kept on 10,000 coal miners in 11 coal mines. On this card, dust exposure, number and kind of shift worked, type of operation, and other environmental conditions in the working area of the miner are entered monthly. This index system is also used to support the research concept that pulmonary changes are largely due to the cumulative effect of dust exposure.

TWO SYSTEMS OF CLASSIFYING DUST LEVELS

Method of Dust and Silicosis Control Center

The Dust and Silicosis Control Center at Essen recommends a dust evaluation method using a tyndalloscope and a konimeter. The tyndalloscope is used to determine the dust concentration, which is expressed as a dimensionless "K" value. A konimeter is used to collect a sample which, when analyzed, will indicate the ash content.

The tyndalloscope readings are corrected to the "K" values by means of the chart shown in table 1. Mining regulations permit miners with lung impairment to work indefinitely in category I dust levels and in category II dust levels when the quartz content is below acceptable limits. When the quartz content exceeds the acceptable limit, pneumoconiosis victims receiving compensation may not work in these places, and miners slightly affected can work no longer than 500 shifts during 5 consecutive years.

Miners slightly affected with pneumoconiosis or miners below a specified age cannot work in category III dust levels. Miners having no lung impairment may work in category III levels for no more than 500 shifts during 5 consecutive years. Category IV dust levels are not permitted, and mining operations

must cease when this level is reached unless a special permit is granted by the mining inspectorate.

TABLE 1. - Evaluation of tyndallometric readings in hard coal mining

ANGLE READING TYNDALL II	INTENSITY READING TYNDALL III	ASH CONTENTS, percent																DUST LEVEL CATEGORY
		0	6	11	16	21	26	31	36	41	46	51	56	61	71	81	91	
		5	10	15	20	25	30	35	40	45	50	55	60	70	80	90	100	
2.3-2.5	4	5	5	4	4	4	4	4	3	3	3	3	3	3	3	3	3	I
2.6-2.8	5	6	6	5	5	5	5	5	4	4	4	4	4	4	4	3	3	I
2.9-3.0	6	7	7	7	6	6	6	6	5	5	5	5	5	5	4	4	4	I
3.1-3.3	7	8	8	8	7	7	7	7	6	6	6	6	6	5	5	5	4	I
3.4-3.5	8	10	9	9	8	8	8	8	7	7	7	7	6	6	5	5	5	I
3.6-3.7	9	11	11	10	9	9	9	8	8	8	8	7	7	7	6	6	6	II
3.8-3.9	10	12	12	11	11	10	10	9	9	9	8	8	8	8	7	7	7	II
4.0-4.1	11	13	13	12	12	11	11	10	10	10	9	9	9	8	8	7	7	II
4.2	12	15	14	13	13	12	12	11	11	10	10	10	9	9	9	8	8	II
4.3-4.4	13	16	15	14	14	13	13	12	12	11	11	11	10	10	9	9	8	II
4.5-4.6	14	17	16	15	15	14	14	13	13	12	12	11	11	11	10	9	9	II
4.7	15	18	17	17	16	15	15	14	14	13	12	12	12	11	11	10	10	II
4.8-4.9	16	19	18	18	17	16	16	15	14	14	13	13	13	12	11	11	10	II
5.0	17	21	20	19	18	17	17	16	15	15	14	14	13	13	12	11	11	III
5.1-5.2	18	22	21	20	19	18	18	17	16	16	15	15	14	14	13	12	12	III
5.3	19	23	22	21	20	19	19	18	17	17	16	16	15	14	14	13	12	III
5.4-5.5	20	24	23	22	21	20	20	19	18	17	17	16	16	15	14	14	13	III
5.6	21	26	24	23	22	21	20	19	18	18	17	17	16	15	14	13	13	III
5.7	22	27	25	24	23	22	21	20	19	19	18	17	17	16	15	14	14	III
5.8	23	28	27	25	24	23	22	22	21	20	19	19	18	17	16	16	15	III
5.9-6.0	24	29	28	26	25	24	23	23	22	21	20	20	19	18	17	16	15	III
6.1	25	30	29	28	26	25	24	23	23	22	21	20	20	19	18	17	16	III
6.2	26	32	30	29	27	26	25	24	24	23	22	21	21	20	19	18	17	III
6.3	27	33	31	30	29	27	26	25	24	24	23	22	21	20	19	18	17	III
6.4	28	34	32	31	30	28	27	26	25	24	24	23	22	21	20	19	18	III
6.5-6.7	29-30	36	34	33	31	30	29	28	27	26	25	24	23	22	21	20	19	III
6.8-6.9	31-32	38	36	35	33	32	31	30	29	28	27	26	25	24	23	21	20	III
7.0-7.1	33-34	41	39	37	35	34	33	31	30	29	28	27	27	25	24	23	21	III
7.2-7.3	35-36	43	41	39	38	36	35	33	32	31	30	29	28	27	25	24	23	III
7.4-7.5	37-38	46	43	41	40	38	37	35	34	33	32	31	30	28	27	25	24	III
7.6-7.7	39-40	48	46	44	42	40	39	37	36	35	33	32	31	30	28	27	25	III
7.8-7.9	41-42	51	48	46	44	42	41	39	38	36	35	34	33	31	30	28	27	III
8.0-8.1	43-44	53	50	48	46	44	42	41	39	38	37	36	34	33	31	29	28	III
8.2-8.3	45-46	55	53	50	48	46	44	43	41	40	38	37	36	34	33	31	29	III
8.4	47-48	58	55	53	50	48	46	45	43	42	40	39	38	36	34	32	30	III
8.5-8.6	49-50	60	57	55	52	50	48	47	45	43	42	40	39	37	35	33	32	III
8.7-8.8	51-52	63	60	57	55	52	50	48	47	45	43	42	41	39	37	35	33	III
8.9-9.0	53-54	65	62	59	57	54	52	50	48	47	45	44	42	41	38	36	34	III
9.1	55-56	68	64	61	59	56	54	52	50	49	47	45	44	42	40	38	36	III
9.2-9.3	57-58	70	67	64	61	58	56	54	52	50	49	47	45	44	41	39	37	III
9.4	59-60	73	69	66	63	60	58	56	54	52	50	49	47	45	43	40	38	III
9.5-9.6	61-62	75	71	68	65	62	60	58	56	54	52	50	49	47	44	42	39	III
9.7-9.8	63-64	77	73	70	67	64	62	60	58	56	54	52	50	48	45	43	41	III
9.9	65-66	80	76	72	69	66	64	62	59	57	55	54	52	50	47	44	42	III
10.0-10.1	67-68	82	78	75	71	68	66	63	61	59	57	55	53	51	48	46	43	III
10.2	69-70	85	80	77	74	71	68	65	63	61	59	57	55	53	50	47	45	III
10.3-10.4	71-72	87	83	79	76	73	70	67	65	62	60	58	57	54	51	48	46	III
10.5	73-74	90	85	81	78	75	72	69	67	64	62	60	58	56	53	50	47	III
10.6	75-76	92	87	84	80	77	74	71	68	66	64	62	60	57	54	51	48	III
10.7-10.8	77-78	95	90	86	82	79	76	73	70	68	65	63	61	59	55	52	50	III
10.9	79-80	97	92	88	84	81	78	75	72	69	67	65	63	60	57	54	51	III
11.0-11.1	81-82	99	94	90	86	83	80	77	74	71	69	67	64	62	58	55	52	III
11.2	83-84	102	97	92	88	85	82	78	76	73	71	68	66	63	60	56	54	III
11.3	85-86	104	99	95	91	87	83	80	77	75	72	70	68	65	61	58	55	III
11.4-11.5	87-88	107	101	97	93	89	85	82	79	76	74	71	69	66	63	59	56	III
11.6	89-90	109	104	99	95	91	87	84	81	78	76	73	71	68	64	60	57	III
11.7	91-92	112	106	101	97	93	89	86	83	80	77	75	72	69	65	62	59	III
11.8	93-94	114	108	103	99	95	91	88	85	82	79	76	74	71	67	63	60	III
11.9-12.0	95-96	116	111	106	101	97	93	90	86	83	81	78	76	72	68	65	61	III
12.1	97-98	119	113	108	103	99	95	92	88	85	82	80	77	74	70	66	62	III

Method of Silicosis Research Institute

Another method of classifying dust levels in coal and metal mines is recommended by the Silicosis Research Institute located in Bochum. This method is also based on dust particles below 5 microns. The mineral composition of the dust samples are determined; once the composition is known, a "mineral factor" is assigned to the sample. Examples of "mineral factors" are listed in table 2. The "mineral factor" depicts the silicogenetic effect of the mineral on the lung. It is used to determine a "dust mineral value" according to the following formula:

$$\text{Dust mineral value} = \text{Percentage of mineral by weight} \times \text{mineral factor} \\ (\text{for konimetry in area, pct}).$$

A typical calculation with this formula might be--

<u>Mineral composition of dust,</u> <u>percent by weight</u>	<u>Mineral factor</u>	<u>Dust mineral value</u>
Quartz..... 6	× 1.00	= 6.00
Mica group.....12	× .50	= 6.00
Clay group.....20	× .20	= 4.00
Coal group.....50	× .01	= .50
Alkaline group.....12	× .00	= .00
	Dust mineral value =	<u>16.50</u>

The "dust mineral value" is in turn used to determine the "dust value" by the following formula:

$$\text{Dust value} = \frac{\text{Respirable dust concentration in mg/m}^3 \times \text{dust mineral value}}{10}$$

If, for example, the sample had a respirable dust concentration of 40 mg/m³ (from tyndallometric measurement) and a "dust mineral value" of 16.5 (from preceding calculation), the dust value would be

$$\frac{40 \times 16.5}{10} = 66.$$

Dust conditions are characterized by these "dust values." The magnitude of these figures indicates the degree of silicosis hazard presumably inherent in a given dust mixture. The classification of "dust values" is given in table 3. In the preceding example, "dust level" 66 falls in category III.

When the dust concentration is in category I, mining operations are considered generally safe. Categories III and IV are considered hazardous, and corrective action is imperative. Very few longwall mining sections were viewed which registered readings above category II.

Pneumoconiosis is unlikely to be contracted by miners working in a category I dust level during a normal work life. Exposure to category II dust levels carries little risk, whereas values in and above category III significantly increase the risk of a worker's developing pneumoconiosis. Dust

exposures in category IV indicate a serious dust condition requiring immediate control measures.

TABLE 2. - Mineral factor classification

Group	Mineral factor	Minerals
A.....	1.2	Cristobalite (in calcined diatomaceous earth).
B.....	1.0	Quartz, cristobalite, tridymite.
C.....	.7	Talc, steatite, asbestos.
D Quartz.....25 pct.	.7	Mica group: Mica-like minerals, feldspar, hornblende, augite, chlorite, serpentine, sillimanite, mullite, fluorspar, vitreous amorphous sinter products, amorphous SiO ₂ .
Do.....6-25 pct.	.5	
Do.....1- 5 pct.	.3	
Do.....0	.2	
E.....	.2	Clay group: Clay minerals, hydrated amorphous SiO ₂ .
F.....	.1	Ore and carbonate group: Carbonates; sulfates; sulfides (excepting their Ca compounds); dolomite; magnesite; barite; siderite; Pb, Zn, Cu, and Mn ores; pyrites.
G.....	.01	Coal group: Coal, coke, soot, graphite.
H.....	.01	Iron oxide group: Iron oxide, hydroxides, limonites, hematite, etc.
I.....	0	Alkali group: Calcite, gypsum, rock salt, potash salts.

TABLE 3. - Classification of hazardous and safe dust levels

Dust value	Dust level category	Hazard level
0-25.....	I	Safe dust conditions.
26-50.....	II	Generally safe conditions.
51-100.....	III	Hazardous conditions, increasing with period of exposure. Dust control recommended.
Above 100.....	IV	Serious dust conditions. Dust control imperative.

RESEARCH FACILITIES

Three institutes are actively engaged in respirable dust research. They conduct and evaluate special investigational surveys, present criteria for respirable dust assessment, and develop instrumentation for respirable dust monitoring. Of the 61 respirable dust research projects associated with the Commission of the European Communities,³ 30 are being investigated in West Germany. (See appendix.)

Dust Research Institute

The Dust Research Institute located in Bonn is primarily interested in noncoal problems concerning surface mining and industrial plants. The Institute carries out special research studies in dust and air-pollution monitoring and control. The Dust Research Institute also publishes a widely read journal concerned with dust entitled "Staub."

Dust and Silicosis Control Center

The Dust and Silicosis Control Center of the West German Coal Mining Association located in Essen was established by the West German coal mining industry. This research unit organizes and conducts routine and special dust surveys in coal mines and trains dust control personnel employed by mining companies. The Institute has established research projects to determine what factors affect the discharge of dust. Research studies are also underway to determine the permeability of coal relative to water infusion practices.

Silicosis Research Institute

The Silicosis Research Institute of the Miners Compensation Board is located in Bochum. This organization operates as a semiautonomous company responsible for the protection of workers in coal and metal mining. The Institute does advisory work for the mining industry and the Government mine inspectorate. It undertakes testing and approval of dust control devices. Routine surveys are not executed at this institution.

CONCLUSION

The Germans have had extensive experience in mine dust control. Two broad areas are particularly pertinent to the U.S. situation: The development of practical technology to suppress dust by water infusion and the development of instrumentation, presently unfamiliar to U.S. industry, for dust monitoring and analysis. In general, U.S. panel members concurred that knowledge of the German experience in dust control might suggest solutions and avoid duplication of research. The German members of the Panel will visit the United States in October 1970 to acquaint themselves with counterpart activities under development in U.S. mines.

³Commission of the European Communities (ECSC). Technical Measures of Dust Prevention and Suppression in Mines. Mine Climate. State of Research at 1 January 1968. Luxembourg, 1968.

APPENDIX.--WEST GERMAN RESEARCH PROJECTS ON RESPIRABLE MINE DUST

Dust and Silicosis Control Center

1. Development of a spraying apparatus to allay dust during caving by wetting the debris to be used in powered support faces.
2. Research into the factors causing stirring-up of dust during shot-firing. Development of new processes to reduce the production of dust and to precipitate it.
3. Behavior of dust in ventilation air, including:
 - a. Distribution of dust in ventilation air.
 - b. Sedimentation of dust.
 - c. Influence of ventilating air quantity, velocity, turbulence, and direction on dust concentration.
 - d. Behavior of dust in a turbulent current of air (theoretical and experimental investigation).
4. Development and trial of new dedusting processes using aspiration and precipitation for use in:
 - a. Winning machines and roadway-heading machines.
 - b. Stowing operations.
 - c. Moving or fixed transfer points.
 - d. Shot-firing.
 - e. Roadways driven in the solid associated with faces of high dustiness.
5. Development of apparatus for measuring fine dusts. Intended to operate over long periods and based on fractional separation of the dust.
6. Research into the relationships between the quantities and the mineralogical composition of suspended dust which enter into workers' lungs and the nature and structure of the substances giving rise to the dust and the way in which they break up.
7. Application of water infusion in the seams of intensively mechanized faces with high rates of advance, paying particular attention to deep or remote infusion, coupled with the development of apparatus, high-pressure hoses, and armatures required for this application.

8. Development of measures against dust produced by winning and loading machines.

9. Shots fired in water.

10. Physical principles and development of apparatus to determine the concentration of dust in mines and to produce size analyses thereof.

11. Development of dust-measuring recorder--

a. Allowing transmission of measured values to a central control point.

b. Allowing remote indication of the removal of dust beyond dedusting installation.

12. Development of the BAT-I filtration sampling apparatus for fine particles of dust, in the form of a self-powered sampling device.

13. Research into the physical properties of coals and rocks and the behavior of the dust formed therefrom.

14. Research into the spectroscopic determination of the inorganic components of mine dusts and of the dusts which penetrate into the lungs.

15. Development of a routine quantitative X-ray analysis method to determine the mineral content of dusts occurring in coal mines.

16. Research into the relationship between pneumoconiotic diseases and dustiness.

17. Research into the influence of activity, geological conditions, and occupation on the development of pneumoconiotic diseases.

18. Special research in certain mine workings with regard to anomalies in the frequency and seriousness of pneumoconiotic diseases.

Silicosis Research Institute

1. The addition to pneumatic stowing material of additives reducing the amount of dust freed.

2. Dust suppression measures during winning and transport in thick seams of iron ore.

3. Research into new methods of stemming for shot-firing.

4. Dedusting at loading points.

5. Development of a process for separating respirable dust according to size by sedimentation. Comparison of the diameter projected in the microscope and the Stokes diameter.

6. Development of automatic spraying system to bring down dust produced during plowing.

7. Measures to suppress dust produced by shearers.

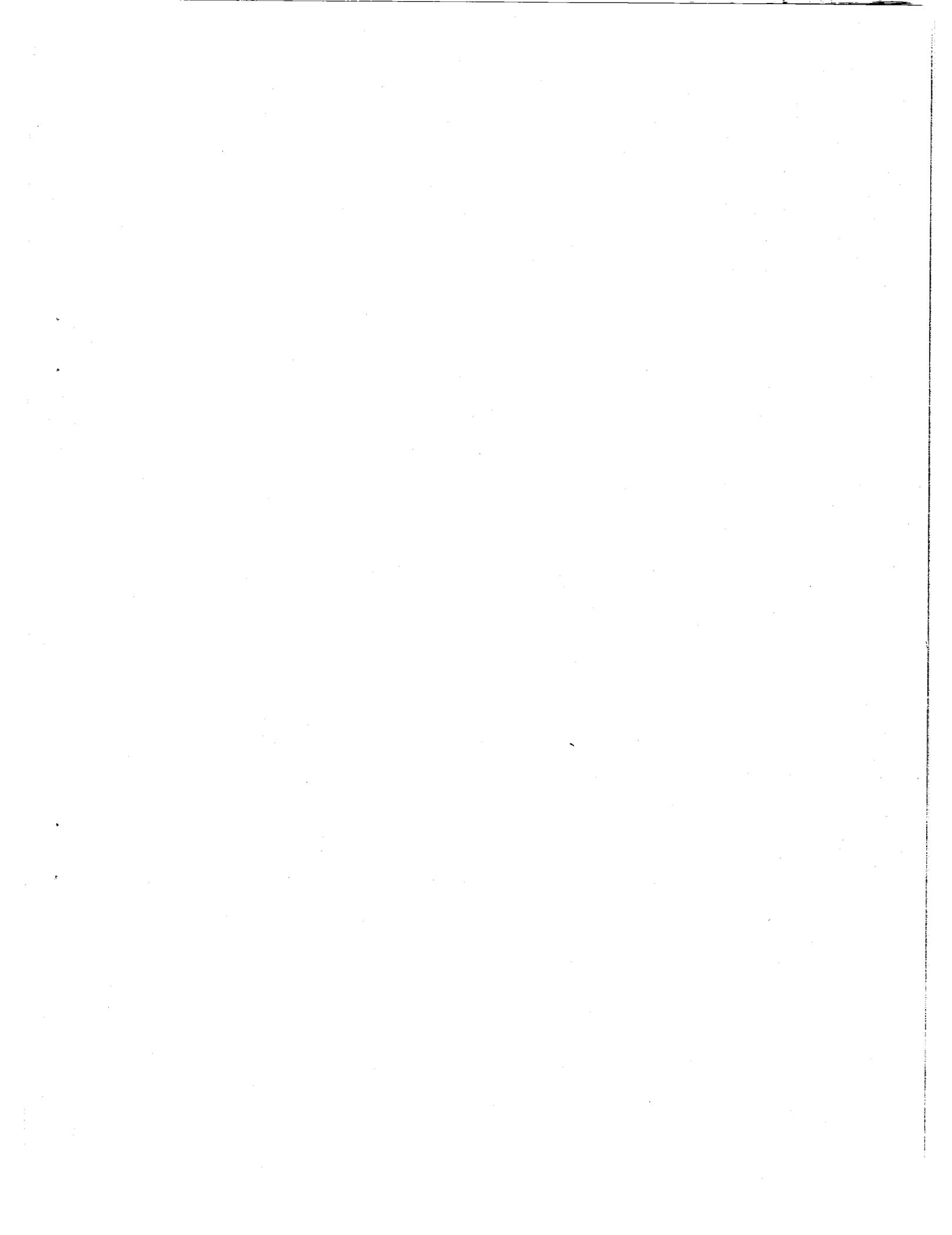
8. Development of water infusion in deep holes.

9. Use of evaporation-retarding substances in bad climatic conditions.

10. Research into the mineralogical composition of respirable dusts before and after inhalation to determine their pathogenic action in pneumoconiotic diseases. Research into the possibility of selective separation of the dust in filters and in the air passages.

11. Elimination of dust deposited by coal dust aspirating apparatus.

12. Relationships between diffused light and the magnitudes indicated by the tyndalloscope for the surface area of dust particles. Comparison of tyndalloscope readings--making allowance for the magnitudes of the surface areas of the particles--and the readings given by other measurement devices.



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