American Experience with Coal Worker's Pneumoconiosis

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SYNOPSIS

The Federal Coal Mine Health and Safety Act became effective in 1969. Passage of the Act was motivated by a high rate of pneumoconiosis and accidents in bituminous mines and involvement of an aroused and informed public. The paper discusses the development of dust standards for prevention of coal worker's pneumoconiosis and technical problems encountered by the industry in meeting these standards through ventilation and dust suppression, and identifies research efforts which may serve to reduce dust generation significantly. The prevalence of pneumoconiosis is traced from studies conducted in anthracite mines in 1928 to more recent studies in bituminous mines in 1973 which reflect the impact of improved dust conditions on pneumoconiosis prevalence

The social significance of the Act is also stressed especially in terms of rights of miners and new concepts of disability benefits. Compensation costs approximate $1 billion per year for the period 1970 to 1980. The Act establishes precedents for the United States for protective worker legislation and this may establish patterns for other countries having a mining industry.

Industrial hygiene in the United States had its roots in the studies of silicosis in the hard-rock mining industry conducted by the United States Public Health Service and the United States Bureau of Mines. The first of these investigations was undertaken in the Tri-State Mining Area of Missouri, Kansas, and Oklahoma and later extended to other regions. Although the data collected in the course of these early studies were quite incomplete by modern standards, it was possible to estimate that the prevalence of silicosis among miners in certain mining areas may have been as high as 75 per cent. Because of an apathetic attitude on the part of legislators, employers, labour unions, and the general public, little was accomplished in the application of preventive procedures until about 1940. However, attitudes began to change in the mid-1930's when it was discovered that hundreds of workers had died or were serioulsy incapacitated because of dust exposures in the construction of a water diversion tunnel in West Virginia. At first it was thought that the morbidity and mortality were due to a rapidly developing type of silicosis, but later investigators, after gaining an insight to possible dust concentrations in the tunnel, attributed the deaths to a dust overloading of the lungs.

The tunnel incident motivated a national silicosis conference, called by the Secretary of Labour in 1937.[1] Out of this meeting came guidelines for preventive programmes which encompassed legislative requirements and inclusion of silicosis as a compensatable disease in workmen's compensation plans. The results proved to be an initial step in the evolution of protective legislation, which was to culminate some 30 years later in the passage of the Federal Coal Mine Health and Safety Act. It probably is the most advanced example of protective labour legislation in the world, and its merits will long be debated by economists and social scientists.

As a result of the national silicosis conference, the hard-rock metal mining industry began to apply engineering controls in the late 1930's and early '40's. In 1956 the Congress again became interested in health and safety problems in the metal mining industry and requested the United States Public Health Service and the United States Bureau of Mines to re-evaluate the prevalence of silicosis in the metal mining industry. This study,[2] conducted between 1958 and 1961, included about 50 per cent of the nation's underground mining population employed in 67 mines.Of 14 076 miners examined, 476 or 3,4 per cent were found to have silicosis; 65 per cent of the 476 were classified as having simple silicosis and 35 per cent as having complicated silicosis. No silicosis was detected among miners with less than 15 years' of underground experience, and most of the detected cases occurred among those who had worked for some period of time before dust controls were universally applied in the mining industry. This investigation led to the belief that with the continuance of dust control efforts, silicosis in the metal mining industry could be virtually eliminated in another 15 to 20 years.

Beginning in the mid-1930's, the Division of Industrial Hygiene, Public Health Service, embarked on a series of epidemiologic studies to determine the pathologic effects of various types of dusts, including silica, non-siliceous, and coal mine dusts. Although the entire programme was never completed, classic epidemiologic investigations were made in the granite cutting sheds of Vermont[3] and the anthracite mines of Pennsylvania.[4] The granite study served as the basis of the American hygienic standard for silica dust of 5 MPPCF, which was based on the observation that silicosis did not occur in workers exposed to dust concentrations of 10 MPPCF or less with a silica content of 30 per cent. As an outgrowth of the investigation, engineering and medical controls were applied in the industry. A follow-up study some 30 years later indicated that silicosis was not detectable among workers who came into the industry after the application of engineering controls.[5]

Experience with the coal mining industry, however, has not been as successful. Between 1928 and 1931, the Public Health Service conducted an exhaustive study of workers in the anthracite industry of Pennsylvania.[4] This study defined a disease condition, then called anthraco-silicosis, which resembled closely a pathologic condition later defined by British and European investigators as coal worker's pneumoconiosis. The term anthraco-silicosis was used because the investigators believed that the basic disease was silicosis, modified by a biologic reaction to coal dust. The disease was characterized anatomically by a generalized fibrotic change throughout both lungs, with excessive amounts of carbonaceous and siliceous material. It was usually accompanied by compensating emphysema and often by cardiac changes in the later phases of the disease. The chief subjective symptoms found in the early stages were shortness of breath, cough, and pain in the chest; later stages involved weakness and

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hemoptysis. In the more advanced cases pulmonary infection and a moderate or marked decreased capacity for work was evidenced. About 23 per cent of the miners showed evidence of the disease. Based on available evidence, the safe limit of exposure appeared to be about 25 MPPCF.

Subsequent studies conducted by the Public Health Service[6] and other investigators failed to demonstrate the presence of a similar disease among bituminous workers, although classical silicosis was often evident among rock workers and others in occupations exposed to silica dust. The absence of anthraco-silicosis in bituminous miners was attributed to the lower silica content of bituminous coal.

By 1950, however, British investigators had determined that coal worker's pneumoconiosis occurred in both bituminous and anthracite workers[7] and that the prevalence rate was a function of the rank of coal. This finding in part confirmed the American experience since anthracite is a higher-rank coal.

By 1949, however, Gordon and co-workers[8] reported finding anthraco-silicosis in American bituminous workers. Information available to the Public Health Service in 1952 indicated that a major cause of morbidity among bituminous workers was a chronic disease of the respiratory system. A case study in various clinics in the Appalachian coal region demonstrated the presence of a disease similar in roentgenographic appearance to that described by British investigators.[9] The sudden appearance of the disease in bituminous miners was probably related to the introduction of mechanical mining equipment which increased dust concentrations as it boosted production rates.

The decade between 1952 and 1962 saw no progress in clarification of the problem, since neither the Public Health Service nor the Bureau of Mines had legal authority to conduct investigations in the mining industry without permission and co-operation of mine management. Because of economic conditions in the coal industry, neither management nor labour were anxious to identify a potentially serious health problem. During the same period Congress was indifferent to budget requests from both agencies to investigate health problems in the industry. In 1962, however, through the efforts of a concerned Senator, Congress appropriated funds for the Public Health Service to conduct a prevalence study of pneumoconiosis in the bituminous industry. This study, conducted between 1962 and 1965, revealed that 9,8 per cent of the working miners and 19,8 per cent of the non-working miners examined had roentgenographic evidence of pneumoconiosis.[10]

Despite this prevalence, which was confirmed by other investigators, apathy resulted in a failure to enact preventive measures. Again, however, tragedy intervened. In November 1968, a coal mine explosion in West Virginia, which killed over 60 miners, focused attention of the American public on the need for legislative control of safety and health hazards in the coal mining industry. The tragedy set in motion a public information trend, which through the medium of television, brought 'black lung', the layman's term for coal pneumoconiosis, into practically every American household. Shortly after the West Virginia tragedy, the Bureau of Mines was requested to draft legislation for federal control of health and safety hazards in coal mines. By this time the Congress was convinced that the individual states could not or would not deal adequately with the problem. The concept of federal legislation was a drastic reversal of the traditional policy which permitted states to deal with health and safety problems in private industry. Hearings held by both houses of Congress had to consider the emotional attitudes of various groups and individuals as well as scientific facts.[11] Dust standards had to be developed in a relatively short period without the benefit of detailed epidemiologic information, and determinations had to be made on the feasibility of attaining recommended standards with present technology.

FEDERAL COAL MINE HEALTH AND SAFETY ACT

The Federal Coal Mine Health and Safety Act[12] became effective in April 1970. Responsibility for enforcement of the Act was transferred in 1973 from the Bureau of Mines, United States Department of the Interior, to a newly-created agency of the same Department, the Mine Safety and Enforcement Administration. The Act, which applies to both health and safety in all coal mines, has a number of unusual health protection features which ultimately may establish new trends in the entire mining industry for dust control, compensation benefits, and worker's rights. Social legislation affecting workers usually has had its origin in European legilsation, and later was modified and adopted by the United States. It will be interesting to note the influence this American legislation may have on other countries in which mining is a major industry.

Major features of the Act relating to health are:

1. The standard established for exposure to coal mine dust is 2,0 mg/m^3. From the effective date of the Act until December 30, 1972, all mines could operate at a level of 3,0 mg/m^3 or, by permission of the Interim Compliance Board, at a level between 3,0 and 4,5 mg/m^3. After December 30, 1972, all mines were expected to comply with the 2,0 mg/m^3 standard; certain mines could operate with a variance at a level between 2 and 3 mg/m^3. All measurements given in the Act are based on samples taken with the dust sampling instrument developed by the Mining Research Establishment of Great Britain.
2. Each coal mine operator is required to sample each mining section using a procedure defined by the Bureau of Mines. A standard sampling cycle is a full-shift dust determination taken once each month at the high risk occupation sites for five consecutive shifts. Additional samples are also required; these samples, along with identifying data, are submitted to a Bureau of Mines laboratory for compliance determinations.
3. Penalties for failure to meet the existing dust standard are established. Mining sections which do not meet the standard can be closed by the enforcing agency.
4. Noise levels at all mining operations shall not exceed 90 dBA for an eight-hour exposure. Personal protective equipment cannot be used as a method of compliance.
5. The operator of each coal mine shall make available to each miner an opportunity to have a chest X-ray at no cost to the miner. The X-ray must be made at a facility approved for the purpose by the Public Health Service. Each miner should have a chest X-ray within six months after employment. Additional chest X-rays and other medical examinations specified by the Secretary of Health, Education and Welfare are required at various intervals specified in the Act. The confidential results of all examinations are available only to individual miners, their private physicians, and a designated government representative.
6. Miners with evidence of pneumoconiosis have the option of transferring to another position in the mine where the concentration of respirable dust is less than 2,0 mg/m^3 without a reduction in his rate of pay. After December 30, 1972, he had the right to be transferred to a position where the dust exposure is less than 1,0 mg/m^3.

7. Between the effective date of the Act and December 30, 1972, miners with X-ray evidence of complicated pneumoconiosis accompanied by sufficient respiratory impairment were eligible for federal benefit payments. This right was also available to active and former miners and widows or dependants of miners with 10 years of coal mining experience who died of respiratory complications. The date of death or departure from the coal mining industry was not a factor in determining eligibility. After December 30, 1972, the mining company of last employment would assume compensation costs for all eligible miners on duty at that time and those subsequently employed in those states which do not have a compensation schedule for coal worker's pneumoconiosis. If the state provides compensation benefits less than those provided for in the federal Act, the mining company of last employment has to supplement the state payment to assure comparability with the federal payment.

DUST EVALUATION PROCEDURES

Prior to legislative hearings, a joint committee of the Public Health Service and the Bureau of Mines had decided that future dust evaluations and standards would be based on gravimetric rather than dust-counting procedures. This was a far-reaching decision since essentially it meant abandoning the traditional American method of dust evaluation and the basis for American dust standards. The committee, however, was convinced that this was a necessary step since European research had proved a relationship between the mass of dust retained by the lungs and pathology, whereas such a relationship was not apparent when based on the count procedure. The gravimetric method also was in accordance with the recommendation of the 1959 International Pneumoconiosis Conference.[13,14] Additionally, this technique offered other advantages, especially that of eliminating the long laborious procedure of dust sampling.

After reviewing all available gravimetric instruments, the committee decided on two which would meet established criteria: the Mining Research Establishment Dust Sampler (MRE) and the Atomic Energy Commission Cyclone.[15] Both had pre-size selectors which meant that the dust being deposited on the filter was in the respirable range and the collection efficiency of both instruments paralleled closely the pulmonary deposition curve of the British Medical Research Council. The MRE instrument sampled particles of less than 7 micrometres, whereas the AEC cyclone sampled particles of less than 10 micrometres. Because of the difference in design of the two instruments, the MRE could only be used as an area sampler, while the AEC cyclone could be used as a personal sampler.

When this decision was made standards had not been proposed for the gravimetric instruments, so it was necessary to compare gravimetric concentrations with dust counts. To obtain these data and to compare the effectiveness of the two instruments, a study was conducted by the Bureau of Mines using the MRE, the AEC cyclone, and the midget impinger.[16] A comparison of findings from the three instruments is shown in Fig. 1. The only standard for coal mine dust was 25 MPPCF, a recommendation of the Bureau of Mines. From Fig. 1 it can be noted that 25 MPPCF was equivalent to approximately 2 mg/m^3 when measured with the MRE instrument and 1 mg/m^3 when measured by the AEC Cyclone. This ratio between the MRE and the AEC cyclone, 1,88:1, was close to the calculated ratio, based on the design of the AEC cyclone at that time. The actual ratio found in the study was 1,97:1. The study also pointed out the tremendous task confronting the industry in terms of dust control. Dust concentrations ranged from 0,5 mg/m^3 to

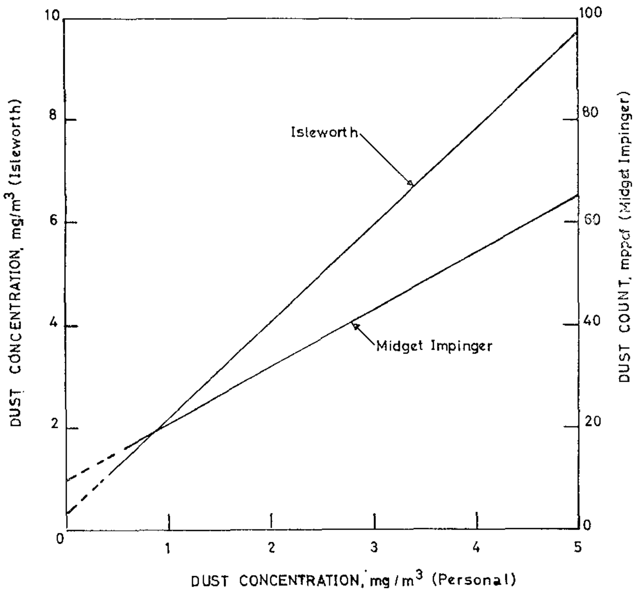

Fig. 1. Relationship between data collected with the personal sampler and that collected with the MRE and midget impinger.

57 mg/m^3. Concentrations at the mining machine, which was the focal point of exposure, ranged from 0,5 to 22 mg/m^3, with a mean value of 7,7 mg/m^3 when measured by the MRE instrument.

The study concluded that either the MRE or the AEC cyclone could be used for dust evaluations, and that results obtained by the two instruments were interchangeable. The advantage of the AEC cyclone was that it could be used as a personal sampler. The MRE was selected, however, as the reference instrument because it was in commercial production and was the instrument being used by the National Coal Board. The use of a common instrument by the United States and Great Britain meant that dust evaluations by the two agencies would be comparable.

STANDARDS

When it became obvious that Congress would adopt legislation for the control of coal worker's pneumoconiosis it was apparent that a standard for coal mine dust would be essential. The Bureau of Mines' recommendation of 25 MPPCF came from the Public Health Service study of anthracite workers, and its adaptability to bituminous mines was questionable. Although the National Coal Board of Great Britain had been conducting a long-term epidemiologic investigation which would ultimately result in a standard for coal mine dust, the results of this study were not available.

Based on data and sources of information from Great Britain and studies made in the State of Pennsylvania, the Public Health Service in December 1968 recommended an interim coal dust standard. The standard recommended a concentration of respirable coal mine dust not to exceed 3,0 mg/m^3 when measured by the MRE instrument or 1,6 mg/m^3 when measured by the AEC cyclone.

A question immediately arose concerning whether present technology would permit all mines to meet this standard in the immediate future, and for this reason a feasibility standard of 4,5 mg/m^3 was suggested until it could be demonstrated that technology was available to meet the 3,0 mg/m^3 standard.

Before setting a standard for the proposed legislation, the Committee of the House of Representatives requested a meeting with the National Coal Board to review its experience in developing and applying standards. During the course of the discussions, the National Coal Board provided the Congressional committee with its information on the prevalence of pneumoconiosis for various dust concentrations for exposures of 35 years. These data are shown in Table I.[17]

TABLE I

PREVALENCE OF COAL WORKER'S PNEUMOCONIOSIS COMPARED WITH DUST CONCENTRATIONS

National Coal Board Data

Concentration of respirable dust mg/m^3	Duration of exposure years	Percentage of persons expected to develop pneumoconiosis	
		Category I	Category II
2,0	35	<3	0
3,0	35	5	<2
4,5	35	15	<5
7,0	35	35	15

Although this information gave the committee concrete data on which it could focus, certain questions were left unresolved. First, should the standard provide for the complete elimination of the disease in the exposed population or could some level of disease be tolerated? Secondly, few American miners work for 35 years in underground mines; therefore their dose could be calculated on a 25 to 30-year exposure period. The final decision of the committee was that no worker should be exposed to an undue risk of pneumoconiosis regardless of the duration of employment. The standard finally incorporated into the legislation, 2,0 mg/m^3 when measured by the MRE instrument, was based on the concept of total prevention.

This decision by the Congressional committee came as something of a shock to industry and governmental agencies since in the past Congress had been reluctant to recommend restrictive standards for industry. This attitude had been reflected in 1967 when hearings had been held by a subcommittee of the Joint Committee on Atomic Energy on the matter of lung cancer among underground uranium miners.[18] Although scientific evidence suggested that an exposure exceeding 30 picocuries of alpha activity per litre of air in the work environment would lead to an elevated lung cancer rate, the committee made a strong recommendation that the standard be retained at 100 picocuries per litre. As Congress considered the proposed Federal Coal Mine Health and Safety Act, it became more evident that the attitude reflected in the uranium mine hearings was no longer the prevalent mood of Congress. This change probably was the result of public indignation. Upon passage of the legislation, coal mines were permitted to have exposures of 3,0 mg/m^3 until December 30, 1972, a period of about 20 months, when the 2,0 mg/m^3 standard became mandatory. Mines unable to comply with the 3-mg concentration could request permission from an Interim Compliance Board to allow a level not exceeding 4,5 mg/m^3. After December 30, 1972, this Board could permit mines unable to meet the 2-mg standard to have a concentration of 3 mg/m^3.

DUST CONCENTRATIONS

In 1968 when legislation was first proposed, there were few available data to indicate levels of existing dust concentrations in bituminous mines. To remedy this deficiency, the Bureau of Mines initiated a study in April 1969 to measure the exposures of various occupations in underground coal mines. Results demonstrated that only a small number of the mines could meet the proposed dust standard using existing technology.[16] The mean occupational exposures ranged from 3,2 mg/m^3 to 8,4 mg/m^3, when measured by the MRE instrument.

Individual samples, which ranged from a low of 0,02 mg/m^3 to a high of 58 mg/m^3, were especially alarming when it was learned that it was the intent of Congress to consider it an infraction of the regulations if a single dust sample exceeded 2,0 mg/m^3. Technical personnel associated with the development of the legislation had presumed that the standard was to apply to a 40-hour average work week. In other words, it was assumed that the concentration could fluctuate above and below the standard as long as the average was at or below the recommended standard. In the final legislation the concept of average concentration was adopted, but the bill had a provison that two years after the effective date of the Act the Secretary of the Department of Health, Education and Welfare and the Secretary of the Department of the Interior would determine the feasibility of decision-making based on the result of a single sample. The two secretaries later determined that this was not a feasible procedure. Compliance now is determined on the results of a five-day sampling period.

DUST CONTROL

Once it became apparent that the mines would have to meet a standard of 2,0 mg/m^3 there was great apprehension in both the mining industry and technical personnel of governmental agencies that many mines would have to close because of their inability to meet stringent dust standards. To assist mines in meeting their responsibilities, the Bureau of Mines sponsored a symposium on dust control in underground coal mines. Although the symposium covered a variety of dust-control procedures, including water infusion, machine design, and life support systems, the immediately applicable procedures were improved ventilation and the use of water for dust suppression.

A Bureau of Mines representative presented a paper on the use of auxiliary ventilation as a method of control.[19] Although the method was not applicable to all coal mining methods, it did demonstrate that ventilation was an effective method of control, especially when applied to the continuous mining machine. Calculations based on the theory of small-particle behaviour and air motion indicated that an airflow between 0,35 and 0,5 m/s across the entry should result in significantly lower dust concentrations. On the basis of previous investigations related to methane control it was apparent that a method for achieving the desired entry velocity could be attained through use of a high-pressure auxiliary fan while maintaining the end of the exhaust tubing about 1,5m from the face. A diagram of this system is shown in Fig. 2; its use on advancing mining sections using continuous coal mining machines resulted in dramatic reductions in dust concentrations. Reduction of face-generated respirable dust in seven mines is shown in Fig. 3, and the relationship between entry velocity and face dust concentrations is illustrated in Fig. 4.

Although other experiments and research on dust control methods, such as the use of foams, design of cutting bits, and water infusion are under way, ventilation and water suppression remain the most important methods.

Although there has been significant progress through ventilation and dust suppression, the primary technique should be preventing the generation of dust. The Department

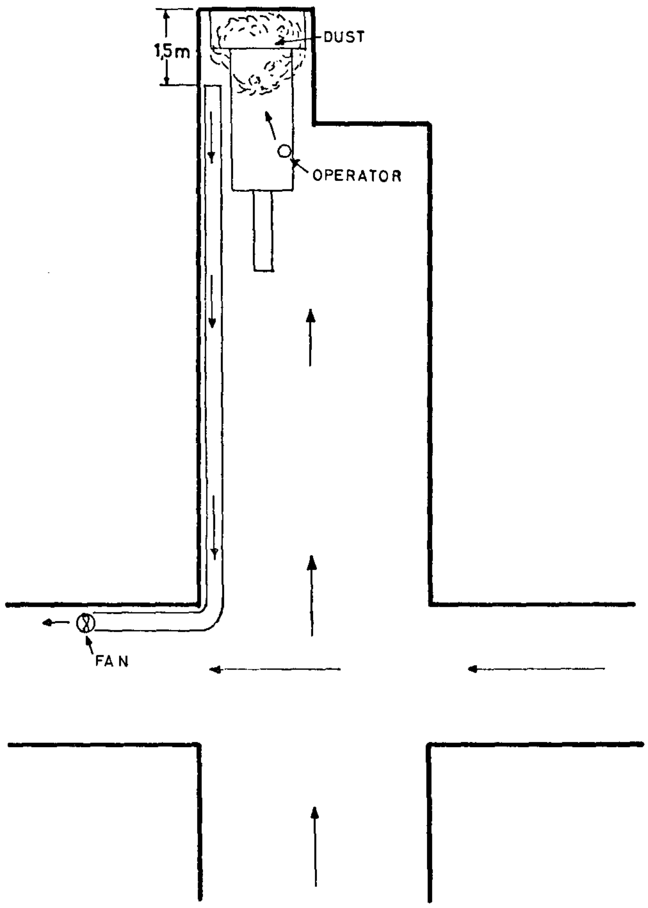

Fig. 2. Auxiliary ventilation system.

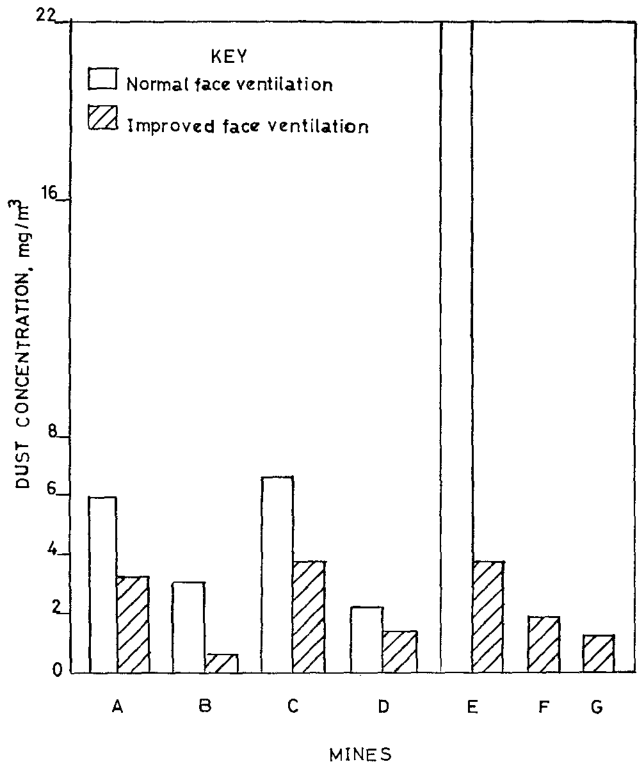

Fig. 3. Face-generated respirable dust concentrations at continuous mining machine.

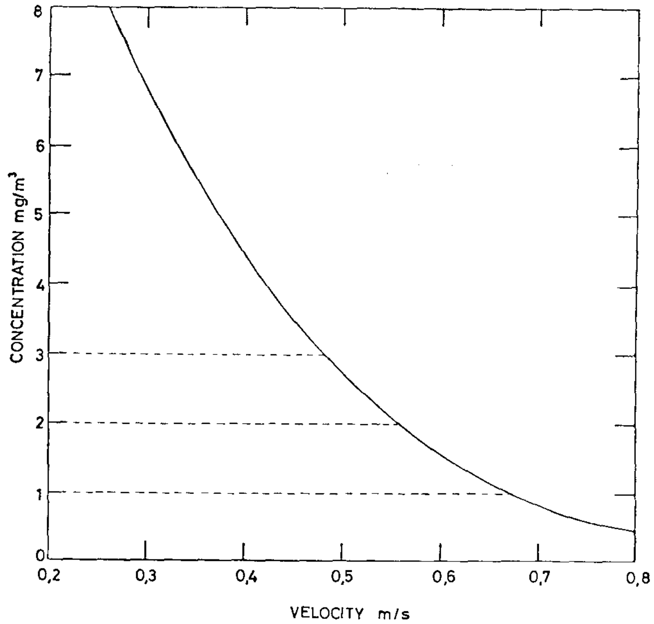

Fig. 4. Upper limit curve for entry velocity vs. face dust concentrations.

of the Interior has been conducting experiments along these lines especially in the areas of water infusion and machine design. Although water infusion is an accepted European practice, it has not been used widely in the United States. Recent experiments in those coal beds that are infusible suggest that such a procedure may be effective in reducing the formation of dust during coal extraction.[20] Other work is being directed to the design of cutting bits. In 1973, a fullscale research mining machine with modified bits and blocks was placed underground in a working section. In experimental investigations to date, initial results indicate that an 89 per cent reduction in dust generation could be obtained using a cut 9 cm deep with a drum speed of 9 rpm. Other benefits identified by this experiment include lower power requirements per ton of coal removed from the face and an extended bit life.[21]

PRESENT DUST CONCENTRATIONS

Since the passage of the Act there has been a constant improvement in conditions. In the 1968-69 dust survey by the Bureau of Mines, 51 per cent of all mining sections studied had mean concentrations exceeding 4,5 mg/m^3; by June 1972 almost 100 per cent of the mining sections had concentrations less than 4,5 mg/m^3; 77 per cent had mean concentrations less than 2,0 mg/m^3; and 33 per cent were at levels less than 1 mg/m^3.[21] (See Table II.) A comparison was also made among dust exposures of 21 underground occupations included in the 1968-69 survey. In 1968-69, only

TABLE II

COMPARISON BETWEEN MEAN DUST CONCENTRATION OF 'HIGH-RISK' SAMPLES, ORIGINAL 29 MINES VERSUS ALL MINES

Respirable dust	(Per cent below stated concentrate) 1 mg/m^3	2 mg/m^3	3 mg/m^3	4,5 mg/m^3
Survey data 1968-69, 155 sections	6,5	20,6	28,4	49,0
Sampling programme 1970-71, 288 sections	13,2	35,4	59,4	84,7
Sampling programme 1971-72, 305 sections	14,8	49,8	74,1	94,1
Sampling programme June 1971	21,3	63,2	88,9	99,9
Sampling programme June 1972	33,0	76,9	94,9	99,9

eight occupations had exposures of less than 2,0 mg/m³. By June 1972 all sampled occupations had average dust exposures of less than 3,0 mg/m³. (See Table III.)

TABLE III

COMPARISON OF MEAN DUST EXPOSURES, SELECTED OCCUPATIONS

Occupation	Survey data 1968-69, 29 mines	Dust programme July 1970 to June 1971, 29 mines	Dust programme July 1971 to June 1972, 29 mines	Dust programme July 1971 to June 1972, all mines
	mg/m³	mg/m³	mg/m³	mg/m³
Continuous miner operator	6,5	3,1	2,6	2,1
Loading machine operator	6,0	2,7	2,2	1,7
Cutting machine operator	5,9	2,9	2,2	1,7
Shuttle car operator	2,3	1,6	1,5	1,4
Labourer	10,4	2,9	1,2	1,7
Timberman	3,9	1,7	1,7	2,2
Roof bolter	3,9	2,3	1,9	2,1

By January 1, 1973, the Act required that all mine personnel should be exposed to no more than 2,0 mg/m³. The annual report of the Secretary of the Interior stated that in December 1973, 94 per cent of the 2 854 sections sampled were able to meet the dust requirement of 2 mg/m³, and about 60 per cent of these sections had respirable dust concentrations of less than 1,0 mg/m³ in the high-risk occupation categories.[21]

PREVALENCE OF PNEUMOCONIOSIS

Although there are a number of theories to explain the pathologic process of coal pneumoconiosis, the basic cause is the inhalation and accumulation by the lungs of coal mine dust. Some investigators are of the opinion that in the etiology of the disease, free silica components of coal mine dust may produce a synergistic action.[22] Others, however, do not believe that silica is involved.[23] American coals contain from 1 per cent to 5 per cent free silica. A typical American bituminous coal from the Pittsburgh seam has the following analysis:[24]

Moisture	1,3%
Volatile matter	34,6%
Fixed carbon	54,0%
Ash	10,0%

A number of trace elements found in coal mine dust are known to have potential toxicologic and carcinogenic properties. Among them are beryllium, arsenic, and lead. Freedman and Sharkey[25] have identified 36 trace elements in West Virginia coals; results of their studies are shown in Table IV. These investigators compared trace elements in lungs of individuals without exposure to coal mine dust to lungs of coal miners and found that miners' lungs contained significantly higher concentrations of aluminium, beryllium, barium, boron, silver, and vanadium. (See Table V.) Whether the presence of higher values for certain trace metals has any part in the disease process has yet to be determined; however, there is no substantial evidence indicating that either a toxicologic or carcinogenic effect is related to these trace metals. A biostatistical study by Enterline,[26] based on 1950 mortality and census records, showed a death rate for bituminous miners about twice that of the general working male population. More specifically, the death rate for respiratory diseases was about five times that of the general working male population and about twice for cancer of the respiratory system. A rate of this magnitude suggests a possible occupational relationship.

TABLE IV

ELEMENTS FOUND IN WEST VIRGINIA COALS

Element	Concentration range % (in ash)	Element	Concentration range % (in ash)
Li	0,005 – 1,00	Co	0,005 – 0,10
Na	0,3 – 10,0	Cr	0,01 – 0,05
K	0,4 – 4,0	Cu	0,006 – 0,50
Rb	0,03 – 0,1	Ga	0,005 – 0,10
Ca	0,1 – 35,0	Ge	0,005 – 0,25
Sr	0,1 – 1,0	Hg	0,008 – 0,06
Ba	0,05 – 5,00	La	0,035 – 0,10
Mg	0,1 – 2,0	Mn	0,004 – 1,0
Al	5,0 – 50,0	Mo	0,006 – 0,15
Si	3,0 – 80,0	Ni	0,006 – 0,50
Fe	1,0 – 80,0	P	0,2 – 8,0
Ti	0,2 – 6,0	Pb	0,15 – 0,20
Ag	0,000 5 – 0,02	Sb	0,005 – 0,03
As	0,7 – 0,3	Sn	0,01 – 0,20
B	0,02 – 6,0	V	0,01 – 0,15
Be	0,000 5 – 0,1	W	0,01 – 0,05
Bi	0,004 – 0,01	Zn	0,05 – 0,24
Cd	0,007 – 0,05	Zr	0,009 – 0,09

TABLE V

COMPARISON OF LEVELS OF ELEMENTS IN MINERS' LUNGS WITH NORMAL LUNGS

(Micrograms per dried lung)

Element	Mean concentration		Ratio
	Miner's lung (M)	Normal lung (N)	
Al	9 535	205	47
Ba	283	2,5	113
Be	4,0	—	—
B	7,7	0,28	27,5
Cr	11,6	3,02	3,8
Ge	1,1	—	—
Fe	1 595	2 410	0,66
Pb	23,7	13,9	1,7
Mg	98,8	495	0,20
Mn	8,1	4,38	1,8
Ni	37,0	20,2	1,9
Ag	1,1	0,01	110
Sn	20,0	23,13	0,87
Ti	215	50,1	4,3
V	45,2	1,73	26

The critical factors in the development of pneumoconiosis are the average concentration of coal mine dust to which the miner is exposed and the number of years of exposure. The product of these two factors is called the 'dose'. On the basis of the data of the National Coal Board, it would appear that the critical dose for the development of simple pneumoconiosis is in the vicinity of 70 mg/m³ years. (35 years × 2,0 mg/m³.) If the dose concept is valid, new cases can be expected to develop for a number of years despite preventive engineering measures. For example, a miner exposed for 20 years to an average dust concentration of 5 mg/m³ of coal mine dust would have attained a dose of 100 mg/m³ years; thus, a large number of individuals with this exposure would be expected to develop pneumoconiosis even though they were removed from the exposure. On the other hand, a miner with 10 years' exposure to an average concentration of 5 mg/m³ would have accumulated a dose of 50 mg/m³ years. Therefore, another 10 years of exposure at an average concentration of

2 mg/m^3 would give a total dose of 70 mg/m^3 years and provide some chance of an individual developing simple pneumoconiosis. Miners entering the industry at this time should work in an environment in which the total dose accumulated during a 30-year working lifetime would not exceed 60 mg/m^3; therefore, his risk of developing pneumoconiosis should be minimal.

Between 1963 and 1965, the Public Health Service conducted a study of the prevalence of pneumoconiosis among active and non-working miners.[10] Of the 3 862 miners selected to participate in the study, 93,5 per cent were actually examined. Of these, 85,5 per cent had no X-ray evidence of pneumoconiosis; 6,1 per cent were in the suspect category; 5,9 per cent were diagnosed as having simple pneumoconiosis; and 2,4 per cent had complicated pneumoconiosis. Of 1 191 non-working miners under the age of 65 examined in the same study, 74,9 per cent had no X-ray evidence of pneumoconiosis, 6,9 per cent were in the suspect category, 9,2 per cent had simple pneumoconiosis, and 9,0 per cent had complicated pneumoconiosis.

Since the study did not include dust evaluations, it was not possible to correlate prevalence with dust concentrations; however, it was evident that prevalence increased according to number of years in the mines and increasing age (Fig. 5).

Smoking histories were considered as a factor in prevalence rates. Although marked and severe dyspnoea and persistent productive cough occurred with much greater frequency among smokers as compared to non-smokers and past smokers, the prevalence of pneumoconiosis was slightly greater among non-smokers. These relationships are shown in Fig. 6 and Table VI. However, if one assumes that past smokers discontinued the habit because of pneumoconiosis, there is no great difference in prevalence between the smokers and non-smokers.

In 1969 the National Institute for Occupational Safety and Health began a study of pneumoconiosis in 31 mines, including two anthracite mines, located in 20 states. In this study 8 553 bituminous miners were examined.[27] This study showed an increase in prevalence of simple pneumoconiosis when compared to the 1963-65 study. Of those examined, 72,0 per cent did not have X-ray evidence of pneumoconiosis, 26,3 per cent had simple pneumoconiosis, and 1,7 per cent demonstrated X-ray evidence of complicated pneumoconiosis. Whether this is an actual prevalence increase was not discussed. It is reasonable to assume that for health reasons and because they were able to qualify for compensation, those miners with complicated pneumoconiosis in the 1963-65 study had left the industry by the time of the new study. If this assumption is valid, then all complicated cases found in the 1969-72 study were new cases. It is also known that many miners with simple pneumoconiosis and disability had left the industry and accepted compensation. However, an increase in prevalence could be expected because of the additional six to eight years of exposure since the 1963-65 study. In the latter investigation radiologists reading the films discontinued the classification of suspect pneumo-

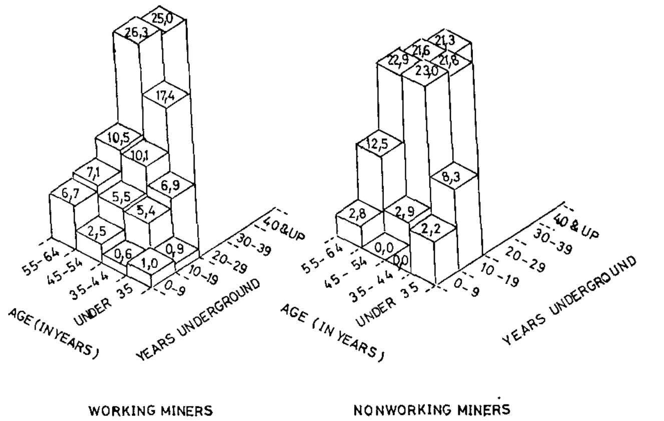

Fig. 5. Roentgenographic findings of definite pneumoconiosis by age and years underground among working and non-working miners.

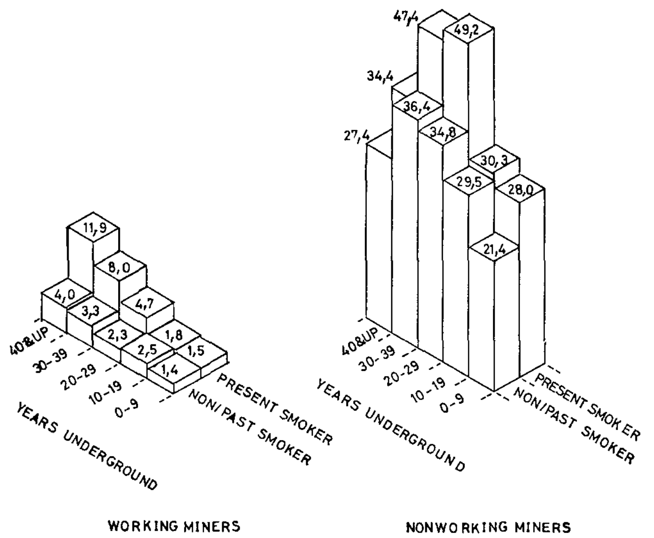

Fig. 6. Marked and severe dyspnoea by years underground and cigarette smoking habits among working and non-working miners

TABLE VI

ROENTGENOGRAPHIC FINDINGS RELATED TO SMOKING HISTORY AMONG WORKING MINERS

Degree of pneumoconiosis	Present smokers	Past smokers	Non-smokers	Total
None	1 334 (87,1%)	379 (77,9%)	423 (85,2%)	2 136
Suspect	74 (4,8%)	44 (9,0%)	16 (3,2%)	134
Simple	89 (5,8%)	45 (9,2%)	38 (7,6%)	172
Complicated	35 (2,3%)	19 (3,9%)	20 (4,0%)	74
Total	1 532 (100,0%)	487 (100,0%)	497 (100,0%)	2 516
Mean age	45,1	48,1	46,9	

Unknown smoking history or no roentogram: 33.

coniosis. Since some of these films would have been read as simple pneumoconiosis, this fact would account in part for an increased prevalence rate of simple pneumoconiosis.

A second round of medical examinations being made since 1972 by the National Institute for Occupational Safety and Health is showing a decreased prevalence rate when compared with the 1972 findings.[27] Since the study is not yet complete, and the collected data are in the process of analysis, it would be improper at this time to compare rates with either of the two previous studies. However, because of compensation benefits, large numbers of miners, especially in the greater age group, have left the mining industry. This fact would of course lead to a decrease in the prevalence of the disease.

The data reported in this Section are based entirely on roentgenographic findings and therefore do not reflect other occupationally-related health conditions of miners. According to Morgan,[28] there is some evidence that non-specific obstructive airway disease occurs more frequently in coal miners. While there is little doubt that cigarette smoking is pre-eminent in the etiology of this disease, studies of the prevalence of bronchitis in working miners have shown that in non-smokers there is a clearcut relationship between bronchitis and dust exposure.

TRANSFER RIGHTS OF MINERS

The Act provided that a miner with evidence of pneumoconiosis could, at his request, be transferred to a position with a dust exposure of 2,0 mg/m^3 or less and after December 30, 1972, to a position of 1 mg/m^3 or less. In his regulations, the Secretary of Health, Education and Welfare defined the points at which coal miners show sufficient evidence of pneumoconiosis to be eligible to exercise this transfer option. The established criteria were:

(a) Any miner who shows X-ray evidence of category 2 or 3 simple pneumoconiosis, complicated pneumoconiosis, or

(b) any miner who shows X-ray evidence of category 1 simple pneumoconiosis in less than 10 years in coal mining.

Table VII shows the numbers of miners who in September of 1972, were eligible for transfer because of X-ray findings.[27]

TABLE VII

NUMBER OF MINERS ELIGIBLE FOR TRANSFER BECAUSE OF X-RAY FINDINGS

Category of pneumoconiosis	Number of miners eligible	Per cent of miners examined
Category 1 in less than 10 years	678	1,0
Category 2	2 259	3,4
Category 3	190	0,3
Complicated	887	1,3
Total	4 014	6,0

Miners who decide to request transfer apply directly to the Mine Enforcement and Safety Administration. If the worker meets the established medical criteria, the Administration notifies the operator to make the transfer, unless the miner is already employed in an area where the respirable dust level does not exceed 1,0 mg/m^3. By September 1972 a total of 567 applications from working miners had been approved. This number amounts to less than 1 per cent of the 65 807 men examined at that time and slightly over 14 per cent of the 4 014 men in the same group eligible for transfer because of X-ray findings. By late 1974 approximately 1 000 miners had exercised their transfer options.[29] The relatively large number of workers who have exercised this transfer option probably reflects an increasing concern on the part of miners about their personal health.

COMPENSATION

In the United States workmen's compensation for accidents and occupational diseases has always been a responsibility of the various states, resulting in a great disparity in compensation plans. In 1969, when congressional hearings were held on coal mine health and safety, only two coal mining states, Pennsylvania and West Virginia, provided benefits for coal worker's pneumoconiosis. In Pennsylvania, the disease was recognized by statute, but in West Virginia it was compensated through the silicosis plan. Pennsylvania was quite liberal in its interpretation of disability, while West Virginia was quite restrictive in terms of disability requirements and benefits. This situation created great inequities in the coal mining industry; compensation for coal worker's pneumoconiosis was dependent on where one lived. Since it would be impossible to standardize benefits among the states in a reasonable time, if ever, the Congress had no alternative other than a federal compensation plan. The development of an equitable plan proved to be a very difficult problem. Primary problems were criteria for disability and the effective date of eligibility.

Criteria for disability were deemed to be X-ray evidence of pneumoconiosis together with some degree of respiratory disability. Once these parameters were defined, it was a matter of establishing criteria for a classification of pneumoconiosis[10] and procedures for defining disability.[30] This concept disqualified the miner with pulmonary impairment but without X-ray evidence of pneumoconiosis. In the future, pulmonary impairment may be included in the compensation scheme as there is evidence that non-specific obstructive airways disease occurs more frequently in coal miners than in the general population.

The eligibility date for compensation proved to be even more difficult to specify. Any arbitrary date of eligibility would be unfair to those who may have developed the disease prior to that date. In addition, there was the matter of social responsibility to be considered, since pneumoconiosis was in part present among coal miners because of inactivity by the federal government.

Eligibility for compensation benefits established in the Act included:[30]

(i) Any present or former miner with X-ray evidence of complicated pneumoconiosis.

(ii) Any present or former miner with X-ray evidence of simple pneumoconiosis accompanied by sufficient respiratory impairment.

(iii) Widows or dependant children of miners employed at the time of the Act and thereafter, whose deaths were caused or complicated by pneumoconiosis.

(iv) Widows or dependant children of former miners whose deaths were due to pneumoconiosis or complications of pneumoconiosis.

The inclusion of former miners in the compensation plan increased the financial liability by a tremendous factor and this concern caused the President to consider vetoing the entire Coal Mine Health and Safety Act. The magnitude of the problem is reflected in the fact that in 1952 there were 500 000 coal miners in the United States. Because of mechanization, when the Act became effective in 1970, employment had decreased to 100 000. In addition to those among the 400 000 employed in 1962 who were still living in 1970 (or their widows or dependant children), there was also an undetermined group who had been in and out of the industry between 1952 and 1970, many of whom were still living or had dependant survivors.

The United Mine Workers estimates that there are currently 4 000 deaths from pneumoconiosis per year among present and former coal miners; this estimate looms large indeed when compared to the 100 to 200 fatalities each year from mine accidents for various causes.[20] One must consider, however, the fact that mortality from pneumoconiosis occurs in the latter decades of life expectancy, whereas accidents occur irrespective of age.

In the report of the Secretary of the Interior for 1973,[20] it was estimated that an average of one billion (US) dollars per year will be required from federal and state governments to provide death and disability payments to some 600 000 coal mine workers and their dependent families through 1980. The astronomical size of these compensation payments, paid from public funds, is the equivalent of $12 500 each year for each presently-employed miner or $1,63 per ton of coal produced.

Further efforts are being made to liberalize eligibility requirements. For example, in October 1974, a bill introduced into the House of Representatives but not acted upon provided 'if a miner was employed for 15 years or more in one or more underground coal mines, there shall be an irrebuttable presumption that he is totally disabled due to pneumoconiosis or that at the time of his death he was totally disabled by pneumoconiosis.'[31] This means that any miner, with 15 years of coal mining experience who dies of natural causes will be eligible for pneumoconiosis benefits. Another bill[32] of the same date requires rebuttable presumption of coal pneumoconiosis after 25 years of underground coal mining and irrebuttable evidence after 35 years.

CONCLUSIONS

Discovery of coal worker's pneumoconiosis in American bituminous workers brought significant changes in legislative concepts which may have substantial future influence on protective legislation in the United States and other mining countries. These legislative changes were motivated, to a great extent, by an aroused and informed public and reflects a growing interest on the part of the public in matters affecting health and safety of workers. Passage of the Federal Coal Mine Health and Safety Act established many legislative and social precedents and led to enactment of the Federal Occupational Safety and Health Act of 1970. This Act relates to conditions of employment in all work places.

Despite fears by qualified technical personnel that the industry could not meet the required stringent dust standards with existing technology, experience has shown that improved use of ventilation and water suppression procedures will permit most mines to comply with these standards. However, this requirement has motivated government and private industry to undertake research directed to methods of preventing dust generation. Significant progress has been made in this direction by altering certain design characteristics of mining machines. This fact reinforces the concept that machines can be designed to meet human requirements without sacrificing production goals.

Through delay in recognizing an occupational disease among coal miners a tremendous compensation debt, estimated to be approximately 10 billion (US) dollars, will be incurred. However, this large debt may also have side benefits in that studies are now being made to modernize workmen's compensation plans so that they are more responsive to the needs of workers.

In the United States, as in other mining countries of the world, dust diseases, from all types of mining, have caused many more premature deaths than mining accidents. The Federal Coal Mine Health and Safety Act is one more milestone on the road to total prevention, a necessary human and economic goal.

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