RADON DAUGHTERS AND THEIR CONTROL

by

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INTRODUCTION

Union Carbide Corporation has operated mines and mills in the Colorado Plateau for several decades. At the present time it is responsible for the employment of approximately 500 persons in underground uranium mines. About half of these employees are employed by contractors and about half are company personnel. The company operates approximately 50 mines varying in size from those that employ only a few men to larger ones employing 120 men. Production from the company's underground mining operations represents approximately 10% of the nation's total underground uranium production.

In 1956 the company initiated a program for sampling radon daughters in the mines and improving ventilation to reduce the potential radiation hazard in uranium mines. In addition to the underground operations in the Colorado Plateau, the company also has open pit uranium mining operations in the Gas Hills area of Wyoming. Union Carbide operates mills for processing the ore at Uravan and Rifle, Colorado and in the Gas Hills area of Wyoming.

The purpose of this paper is to present to the person unfamiliar with mine radiation problems a review of where the radon daughters originate, how one measures them, their damaging character, how to control them, the cost of control, a review of the regulatory standards, and the progress in control of radon daughters over the last two decades.

For the person who desires more detailed information on the subject, a number of references are cited. Mr. R. L. Rock and Mr. D. K. Walker at the U. S. Bureau of Mines station in Denver, Colorado have prepared an excellent handbook on the subject entitled "Controlling Employee Exposure to Alpha Radiation in Underground Uranium Mines." This handbook, which goes into considerable detail on all phases of the subject, should be available before the end of the year.

ORIGIN OF THE DAUGHTERS

Uranium as it is found in nature consists of 99.3% U-238, which has 92 protons and 146 neutrons in its nucleus. However, these protons and neutrons are not satisfied to remain in this ratio and uranium has been undergoing a continual state of decay, or change, to isotopes and other elements. In so decaying various types of radiation, largely alpha, beta, and gamma, are emitted. Figure 1 shows the decay of uranium through various radionuclides down to the noble gas, radon-222. In uranium mines the original source, or so called parent, of radon is the uranium in the ore. The gas emanates from the ore into the working places and drifts of the mines.

Radon, in turn, decays into several short half-life decay products which are commonly referred to as radon daughters. Figure 2 shows the decay scheme of the parent, radon, through the daughter products. Radon decays through Po-218, Pb-214, Bi-214, Po-214, and eventually to Pb-210 which, because of its 22 year half-life, is not of consequence concerning the problem under discussion. The four short half-life daughters are also frequently referred to as radium A, radium B, radium C, and radium C'. One will note from Figure 2 that the half-life, or the time required for half of the activity to decay, of the four radon daughters is quite short. When separated from the parent radon, almost all of the daughters will decay to lead-210 in approximately three hours. The two problem daughters are the short-lived alpha emitters, radium A and radium C'. For all practical purposes the radon daughters are atomic in size and are normally in an ionized state. As a result, they are easily taken into and retained in the respiratory system as free ions or attached to dust and moisture particles. Their alpha decay in the body can, under adverse conditions, be damaging to the body as will be described later.

MEASUREMENT OF THE DAUGHTERS

To determine the concentration of radon daughters in a mine atmosphere the daughters are collected on membrane filter paper using commonly accepted methods of air sampling. Most uranium mining companies today are using a small battery-operated air sampler with a sampling rate of about two liters per minute. The practice is to take a five minute sample which collects the radon daughters from ten liters of air. Figure 3 shows a technician taking an air sample with the small sampler. After a waiting time of between 40 and 90 minutes the radon daughter alpha activity is counted with a portable alpha scintillation survey instrument. The waiting time minimizes possible errors due to disequilibrium of the daughters at the time of collection. The alpha survey instruments (see Figure 4) are reasonably portable and can be used underground. The concentration of radon daughters is then calculated using the volume of air sampled, the alpha count, and the elapsed time between sampling and counting (1) (2).

The U. S. Atomic Energy Commission recently announced the development of a new instrument designed and built by the Massachusetts

DECAY OF URANIUM TO RADON

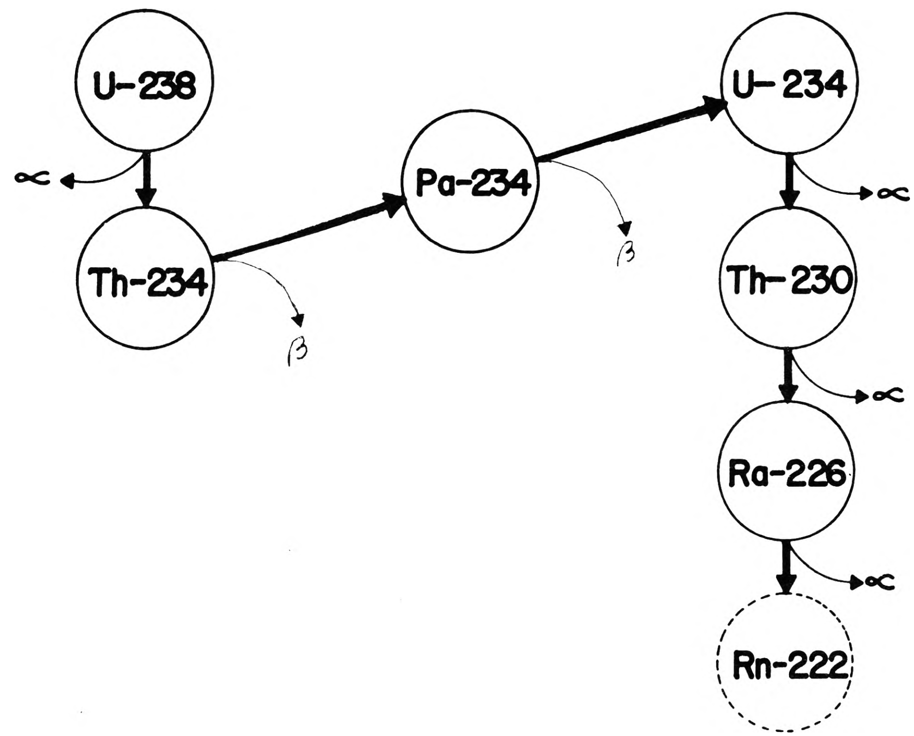


FIGURE 1

RADON DAUGHTERS

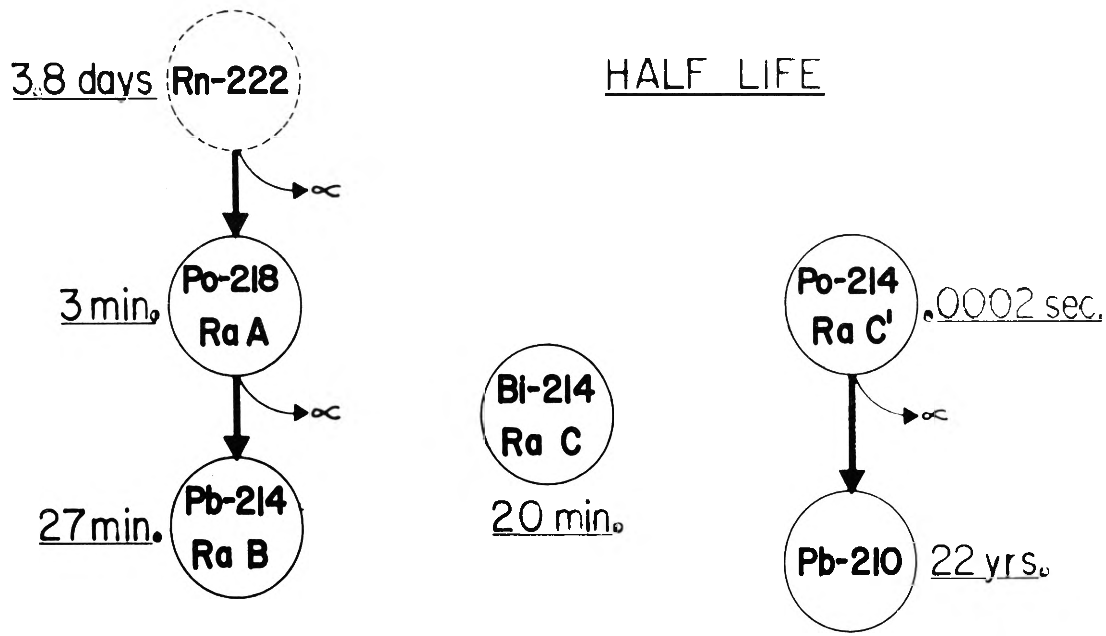
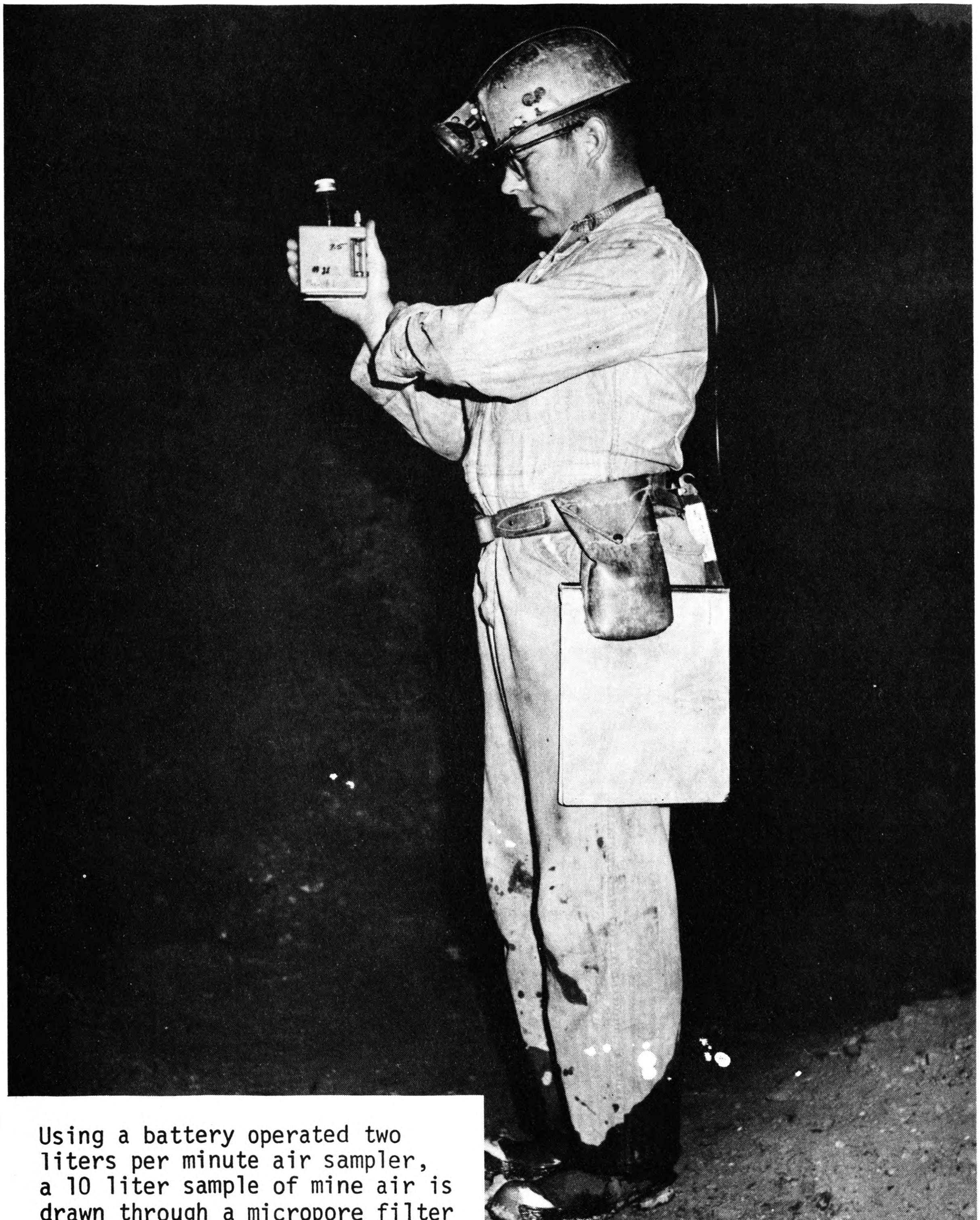


FIGURE 2



Using a battery operated two liters per minute air sampler, a 10 liter sample of mine air is drawn through a micropore filter on which radon daughters are collected.

FIGURE 3

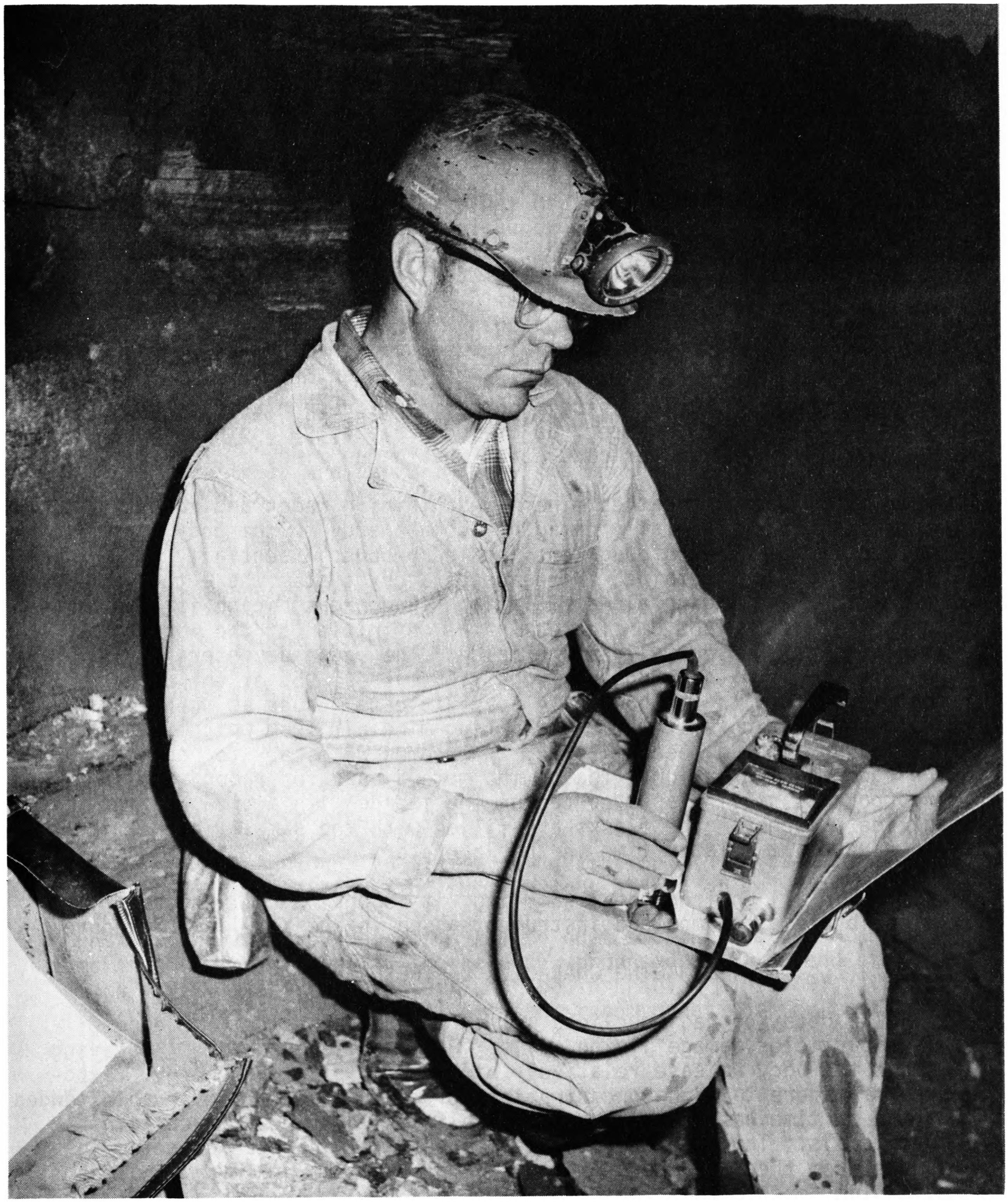


FIGURE 4

Alpha activity from radon daughters collected on filter paper is counted with an alpha survey meter.

Institute of Technology under an AEC contract which will provide instant measurements of the concentration of radon daughters. Five prototypes are to be built within a year.

The unit of measurement for radon daughters has historically been called a "working level" (WL). The working level is defined as any combination of radon daughters in one liter of air that will result in the ultimate release of 1.3×10^5 million-electron-volts (MeV) of potential alpha energy. Exposure of a miner to radon daughters is commonly expressed in terms of Working Level Months (WLM), and is calculated by multiplying the WL by the occupancy time.

During the past two years considerable research has been underway to develop a dosimeter sensitive only to radon daughters which could be used to determine more accurately a miner's exposure over a period of time. Such a device might simplify record keeping procedures but would not, however, be of much use to the engineer attempting to control radon daughter concentrations in the mine.

When a person breathes mine air containing radon and radon daughters, the potentially damaging alpha energy to the body largely results from the radon daughters inhaled because essentially all of the daughters are retained in the respiratory system where they continue to emit damaging alpha radiation. Radon gas, which is also an alpha emitter, is not considered in the definition of the working level as it is essentially all exhaled. The radon daughters if in equilibrium with the radon will contribute about 95% of the alpha energy retained in the body. In specific cases, such as when evaluating ventilation systems or evaluating mine air from which the radon daughters may have been filtered, it becomes necessary to consider the radon concentration. The common method used for radon sampling incorporates small flasks coated on the inside with activated zinc sulfide phosphor. The flasks are filled with the sample in the mine and counted at a later time in the laboratory.

As in all environmental sampling, it is periodically necessary to calibrate air pumps and instruments used in the sampling procedure.

THE DAMAGING CHARACTER OF THE DAUGHTERS

The decay of radionuclides within the body and their release of alpha particles damage living cells. Radium A, and radium C' decaying within the body release relatively high levels of alpha energy. Exposure of miners to high concentrations of radon daughters over an extended period of time has been proven to result in lung cancer in certain individuals. This increase in incidence of lung cancer was noted in miners from the Schneeberg mining region of southern Germany and the adjoining Joachimsthal region of what is now Czechoslovakia. It was reported that 30 to 50% of all the deaths among the miners in these areas were caused by lung cancer. Later tests showed significant levels of radon existed in these mines. A high incidence of lung cancer was also noted in fluorspar miners in Newfoundland. Again, tests showed that significant levels of radon were present in the mines.

Carnotite ores have been mined on the Colorado Plateau for many decades for their radium and vanadium values, and in more recent times, for uranium. It was during the late 1940's and 1950's that a large number of miners were exposed to high concentrations of radon daughters in the uranium mines of the Colorado Plateau. Concentrations from 10 WL to several hundred working levels were measured in these mines (1). During the late 1950's it became apparent that a serious problem could result from this exposure to radon daughters. This awareness was brought into clear focus with the Governor's Conference late in 1960 (3). Action by the mining companies during 1960 and 1961, in the form of greatly improved methods of ventilation, resulted in a great reduction in the radon concentration in the uranium mines. However, the high exposures which some men received during the 1940's and 1950's are now resulting in a greatly increased incidence of lung cancer among the uranium miners (4) (5) (6) (7). At this time there are approximately 180 known cases of lung cancer death among uranium miners which have been attributed to exposure to radiation. In more recent years the medical studies have centered around efforts for early detection of lung cancer. Dr. Geno Saccomanno of St. Mary's Hospital in Grand Junction, Colorado has made great progress in using sputum cytology for the early detection of changes in the lung which may be leading toward lung cancer (8).

An evaluation of the lung cancer deaths, along with medical studies, has shown a definite synergism of smoking and radiation. In other words, the two factors together result in a much higher incidence of lung cancer than either agent by itself. This is demonstrated by the fact that of the approximately 180 cases of lung cancer deaths presently known, only one or possibly two have been non-smokers (the smoking history of one individual has not been verified). If smoking was not a factor in these cases, one would have expected about one-fourth of the deaths or at least 45 to have been non-smokers. Because of this obvious effect of smoking, many companies including Union Carbide Corporation have been making a great effort to encourage employees to quit smoking and have banned smoking in uranium mines. The recently proposed U. S. Bureau of Mines safety standards prohibit smoking in uranium mines (9). The Federal Radiation Council in its recent recommendations for radiation control in uranium mines, "urges that a concerted effort be made by all concerned to discourage cigarette smoking by underground uranium miners."

CONTROL IN THE MINES

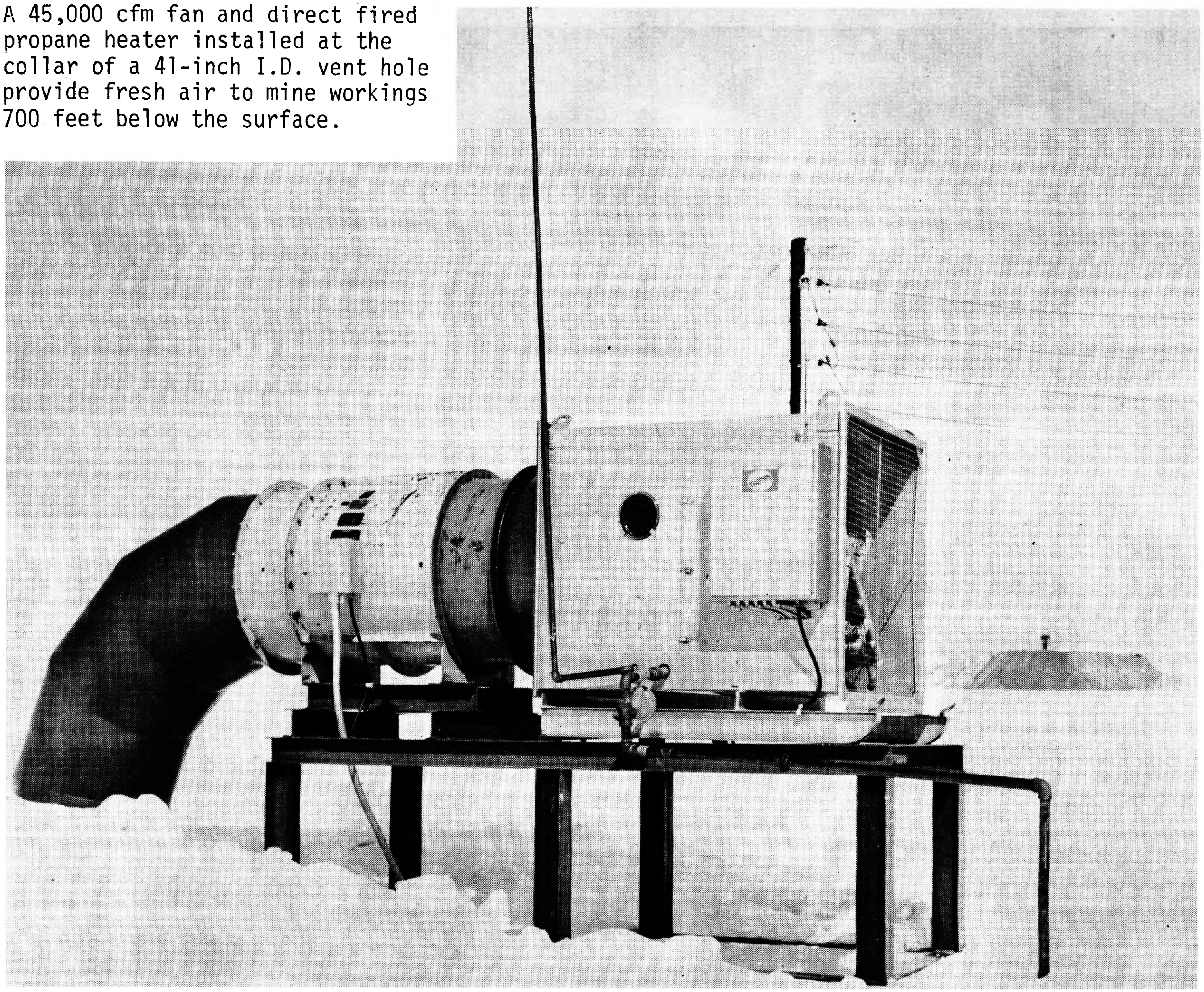
Control of radon daughters in uranium mines has been almost exclusively accomplished by dilution ventilation. Many factors affect the ventilation requirements in uranium mines. Such things as extent of the ore body, depth of the ore, type of mine entry, and eventual size of the mine will affect these systems. Commonly, ventilation is accomplished by primary ventilation systems which introduce fresh air into the mine and by smaller secondary ventilation systems for distributing the fresh air to the working stopes. In some small mines only one ventilation system is used to force air from the surface to dead-end headings.

In Union Carbide mines the primary ventilation systems will include fans as large as 60,000 cfm posered by 75 hp motors. Up to three primary fans have been installed in parallel to deliver 150,000 cfm. The axial flow type of fan is most commonly used (see Figure 5). The primary air may enter the mine by means of large vent holes drilled from the surface or through adits, inclines, or shafts. Shafts may be downcast or upcast or various combinations may be used, depending upon the number of vent holes and entries used. Contamination of primary air from inactive workings of a mine is prevented where possible through the use of air doors and stoppings (see Figure 6). In the Uravan Mineral Belt, where the ore deposits are erratic and discontinuous, connections between the primary air stream and inactive workings are often too large and numerous to effectively seal off.

During winter weather the large quantities of fresh air forced into the mines can cause all manner of freezing problems. This may consist of vent holes being blocked by ice, ice accumulation on the walls of the shafts, and the freezing of water lines near the point of primary air entry. One method of overcoming freezing problems is by reversing air-flow during nighttime periods when no one is in the mine. However, this allows a build up of radon and daughters and results in a decrease in ventilation efficiency. Many larger mines have installed direct fired propane heaters to heat the incoming primary air (see Figure 5).

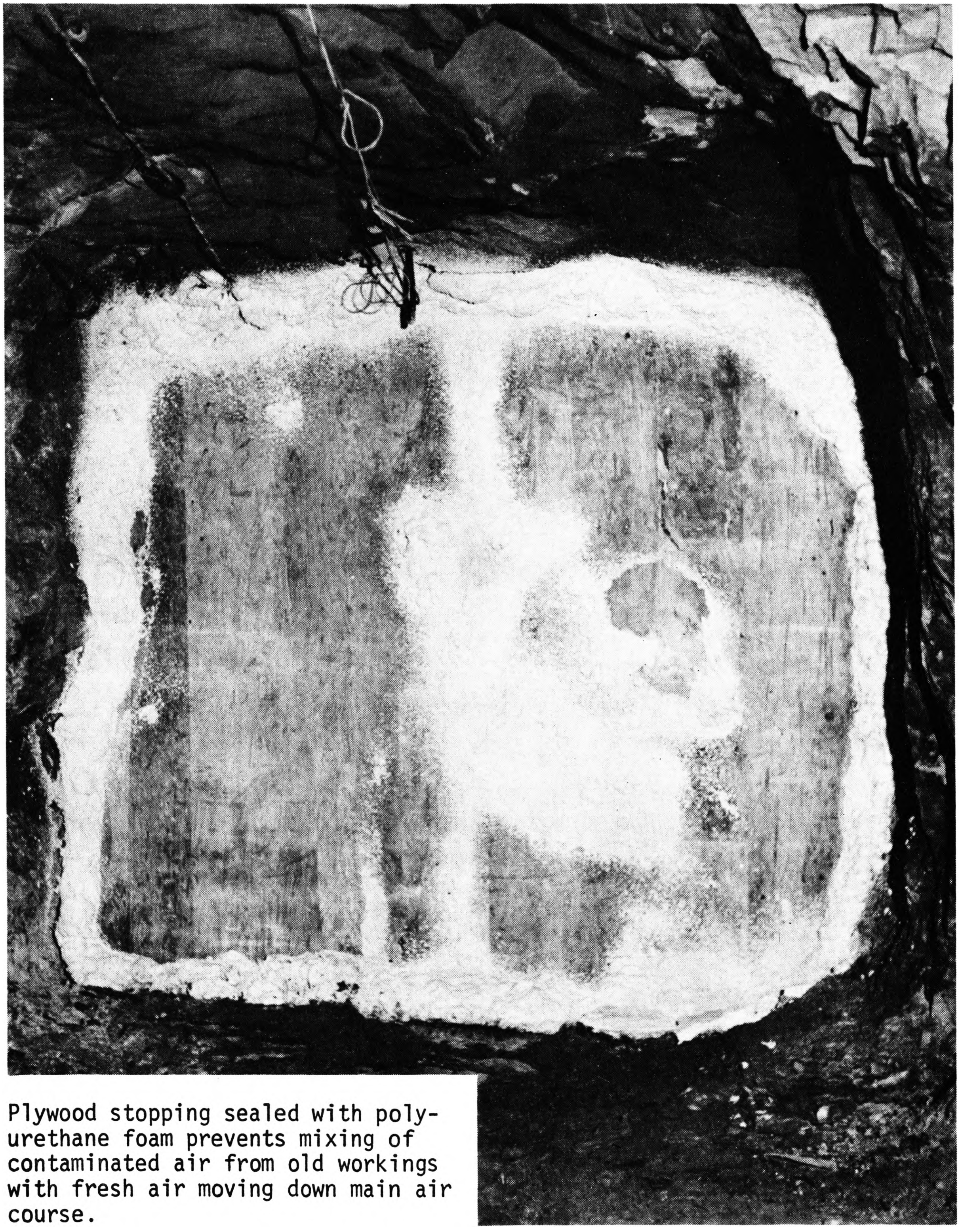
To distribute air to the dead-end working areas of a mine, secondary fans with capacities in the general range of 5,000 to 8,000 cfm are used. Union Carbide uses mostly 20-inch diameter vinyl coated nylon or polyethylene vent tubing hung from the back to carry air to the working places. In some instances tubing as large as 36 inches in diameter has been used where room permitted. It is essential to keep this ventilation tubing in good repair with a minimum of holes. Elbows in the tubing should not be kinked, and where possible metal or fabric elbows are used to reduce the back pressures on secondary fans. One of the most common errors is improper location of secondary fans which causes recirculation of exhaust air. The distance from the end of the ventilation tubing to the working face is also a critical matter. Many mines use a minimum distance of 30 feet between the end of the ventilation tubing and the area where men are working.

Commonly, fans are left on 24 hours a day, 7 days a week, to avoid disruptions in ventilation which may require many hours to regain original control. Where 24-hour operation of the fan is not necessary it is usually common to install timers on the fans so that they will turn on several hours before the men enter the mine.



A 45,000 cfm fan and direct fired propane heater installed at the collar of a 41-inch I.D. vent hole provide fresh air to mine workings 700 feet below the surface.

FIGURE 5



Plywood stopping sealed with polyurethane foam prevents mixing of contaminated air from old workings with fresh air moving down main air course.

FIGURE 6

Education of the miners in good ventilation techniques is an important part of any uranium mine's radiation control program.

The effectiveness of ventilation systems can generally be evaluated by the results of the environmental control sampling. However, it is often necessary to take engineering samples exclusively for the purpose of evaluating ventilation systems and changes in the systems.

Other methods for the control of radon daughters in mine atmospheres have been proposed, and in some cases tested. Union Carbide and some other mining companies have used large filters to remove the radon daughters and permit the reuse of air. Care must be taken in the number of times air is filtered and the length of time between the filtration of the air and the use of the air because filtration does not remove the radon which will continue to decay and produce radon daughters. Continued filtration, therefore, results in the buildup of radon and an increasing rate at which the daughters will be formed. Radon gas samples are helpful in evaluating the application of filters.

Some work has been done in using overpressure to prevent or retard the emanation of radon into mines. However, in this case it must be kept in mind that the radon must flow to some other location and one must avoid this location being another part of the mine or an adjacent mine. Possibilities of using slight underpressure in inactive areas to reduce the flow of contaminated air into main air courses has been studied. Various absorbing materials and sealants have been proposed to retard the emanation of radon from the rock. Dilution ventilation still remains the primary method of control in uranium mines.

A respirator will remove approximately 95% of the potential radiation dose to the lungs. The respirator manufacturers have devoted considerable effort during the past two years toward the development of a low resistant respirator filter for radon daughters. Although it does not appear practical to require a physically active miner to wear a respirator eight hours a day there is definitely a place in the mining operations for the use of respirators. Geologists and surveyors who are required to enter shut-down mines or unventilated areas of active mines for short periods of time should use respirators for protection.

Rotation of men within a mine or between mines can, in certain cases, be used to reduce exposure, but is not a practical long-term method of control for many reasons. The shortage of experienced mining personnel, the specialized training of most personnel, and safety are but a few disadvantages involved with rotation of men.

COST OF VENTILATION

The costs of ventilation systems in a uranium mine will vary according to many factors such as the depth of the ore body, the size of the mine, and probably most important, the characteristics of the ore body. Currently, ventilation costs have been estimated to vary between $.50 and $1.50/ton of ore produced. This compares with uranium mining costs which vary between $10.00 and $20.00/ton. The increased emphasis on mine radiation control over the past two years has resulted in significant increases in ventilation costs, in some instances from $.50 to as much as $1.50/ton. A recent survey by the AEC has shown that capital expenditures are averaging about $4 million per year for the entire uranium industry.

STANDARDS AND REGULATIONS

In 1957 the Public Health Service in its publication number 494 (1) suggested a one working level environment and stated, "On the basis of present information, this level appears to be reasonably safe and not unduly restrictive to mining operations." In 1959 the International Commission of Radiological Protection (10) and the National Committee on Radiation Protection (11) suggested a radon standard which has been interpreted by different persons to be somewhere between a one-third and three working level standard for radon daughters, depending upon the equilibrium ratio of the individual radon daughters. The U. S. Atomic Energy Commission's Rules and Regulations have been interpreted to not apply to the mining of uranium ores but rather to the processing of the ores and further refinement of the products from the mills. In 1960 the American Standards Association, now the United States of America Standards Institute, published Standard N 7.1-1960 "Radiation Protection in Uranium Mines and Mills (Concentrators)" (2). This standard has been the guide for the industry since 1960 and was also adopted by most state mine control agencies in those states in which uranium was mined. Colorado incorporated the ASA standard in its state mining laws (12). The standard is presently being rewritten to incorporate the latest knowledge on the subject.

To obtain background information prior to the enactment of the Metal and Nonmetallic Mine Safety Act (13), the U. S. Bureau of Mines made a study of all uranium mines in 1961 and 1962. The Federal Radiation Council, which was established by executive order in 1959, initiated a study of uranium mines in 1965 as a result of the increasing number of lung cancer deaths among uranium miners, and published a summary report in 1967 (14). The FRC recommended an exposure standard of a maximum of 12 WLM per year, essentially equivalent to a 1 WL environmental standard (15). In January of 1969 the FRC issued a further recommendation which retains the 12 WLM per year standard for a 2-year period and gives consideration to lowering the standard in 1971 if a thorough review of all data available indicates the reduction is necessary.

The Joint Committee on Atomic Energy held extensive hearings during the summer of 1967 on the subject and collected a large amount of testimony and references which make up a very complete story of the entire problem (16).

The U. S. Department of Labor entered the picture in 1967, choosing the jurisdictional route of the Walsh Healy public contracts act. Early in May of 1967 the Department issued a regulation calling for a reduction to 3.6 WLM per year, which is essentially equivalent to a 0.3 WL standard, to become effective in 30 days (17). The complete surprise of this regulation, without any provision for public hearings nor an opportunity to submit comments, resulted in great confusion in the uranium mining industry and other agencies having jurisdiction. In June of the same year the Department of Labor changed the order permitting the 12 WLM per year standard until January 1, 1969, at which time the standard was to be reduced to 3.6 WLM (18). Late in December of 1968, four days before this reduced level standard was to become effective, the Department of Labor issued a standard providing for a variance procedure during 1969 and 1970, if the mine operator submitted a bonified plan for reducing the level of maximum exposure to 4 WLM per year (0.33 WL) by January 1, 1971 (20). The Department has further stated verbally that they will relinquish jurisdiction to the Department of Interior when the U. S. Bureau of Mines' standards become effective.

As provided for in the Metal and Nonmetallic Mine Safety Act (13), the U. S. Bureau of Mines, after consultation with a review committee, issued proposed safety standards in January of 1969 (9). The proposed USBM standards are currently issued for comment. After comments have been reviewed, the standards will be reissued to become effective one year later. At present the USBM standard for uranium mines calls for a 12 WLM per year maximum. It states that the Bureau will follow the recommendations of the Federal Radiation Councin but confuses the issue by adding a section requiring a reduction in the standard to 4 WLM per year on January 1, 1971. The proposed reduction in 1971 may or may not be in agreement with the Federal Radiation Council's forthcoming recommendation after they complete the review of the data. The USBM proposed standard also provides for action levels, whereupon it is recommended that if any concentrations are found in excess of 2 WL the area will be shut down. If levels are found to be between 1 WL and 2 WL, immediate corrective action is to be taken or the men are to be withdrawn from the area.

In March of 1969 the Joint Committee on Atomic Energy held additional hearings to review the matter of mine radiation. Testimony was received from the Federal Radiation Council, the Atomic Energy Commission, the Department of Health, Education, and Welfare, the Department of Labor and representatives of unions and the mining industry. The experts in the field appear to still be divided on what the standard should be. It was repeatedly emphasized during the hearings that the epidemiological data available to date have certain limitations and that it may be many years before data can be developed on the effects of low level exposures on uranium miners. The hearings brought out that there was a conflict within the Federal Radiation Council which spent several months trying to decide on a recommendation to present to the President for approval. It would appear at this time that future standards will hinge upon the review which is to be made by the Federal Radiation Council sometime in 1970 before the proposed reduced standards would become effective.

With the multitude of hearings and conferences held during the past two years and the numerous standards and regulations proposed by various departments of the federal government, it has been difficult for the uranium miner to make even short-range plans on proposed mine ventilation, let alone trying to estimate what mining costs may be two or five years from today. The mining industry believes the U. S. Bureau of Mines is the logical federal agency to have jurisdiction over mining. Also, the Metal and Nonmetallic Mine Safety Act provides that state regulatory bodies can maintain their regulatory control under the watchful guidance of the U. S. Bureau of Mines.

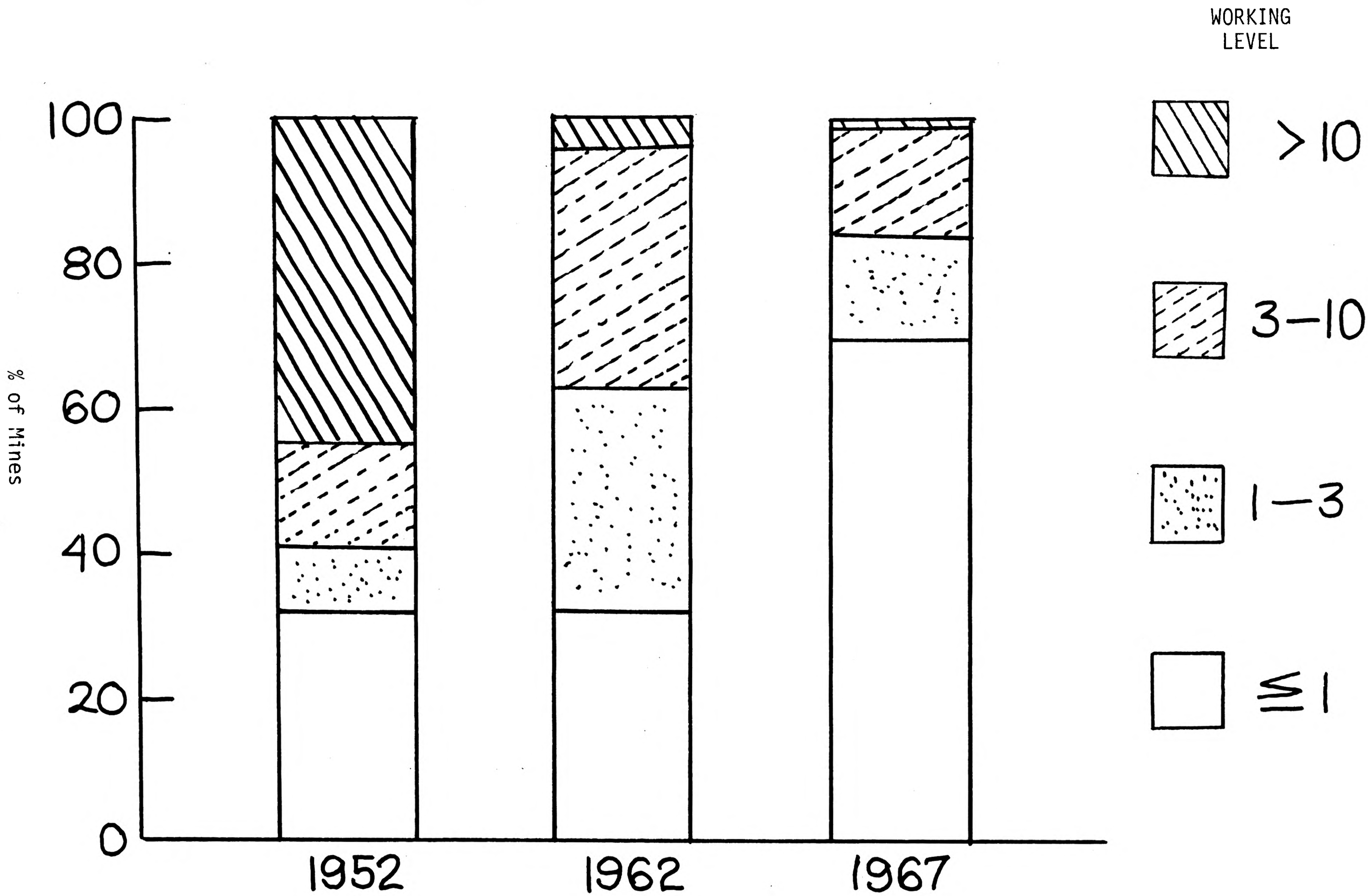
The industry, along with most regulatory agencies, believe that an environmental standard is preferred over an exposure standard. By means of an environmental standard, control is immediate and not after-the-fact. It is easier to enforce an environmental standard and an engineer knows at once whether he is above or below a standard.

PROGRESS IN CONTROL

During the middle 1950's mine operators started installing mechanical ventilation to improve the air conditions in the mines and to reduce the concentrations of radon daughters. As mentioned previously, once the problem was recognized and control measures outlined, industry took significant steps toward lowering the levels, particularly during the 1961-1962 period. Figure 7 is a graph showing the improvement in lowering of the radon daughter concentrations in uranium mines during the period between 1952 and 1967. The data shown in the graph are from data releases by the U. S. Public Health Service.

It will be noted in the graph that as of 1952 in approximately 45% of the mines the average concentration was above 10 WL, and in only 32% of the mines was the working level controlled at or below 1 WL. By 1962 only 4% of the mines had average concentrations over 10 WL, and, although there was not a great increase in the mines in which the concentration was below 1 WL, there was a significant increase in the number of mines in which concentrations were less than 3 WL. By 1967 the number of mines in which the average concentration was over 10 WL had decreased to 1% and the mines in which the concentrations were controlled below 1 WL had increased to 70%. Recent data would show a much greater improvement.

Union Carbide started sampling the mines and accelerated its radon daughter control program in 1956. Following the pattern of the industry, there was a big reduction in working levels in the 1961 period. One effective measure which has produced gratifying results has been the progressive stepwise decrease in the company's self imposed shutdown level. Whereas in 1960 any area over 10 WL


WORKING
LEVEL
>10
3–10
1–3
≤1
100
80
60
40
20
0
% of Mines
1952
1962
1967

was shut down, as recommended in the ASA standard, the shutdown level was decreased to 7.5 WL, then to 5, then to 3, and early in 1967 to 2 WL. By shutting down all areas that are over 2 WL and initiating immediate improvements in ventilation for those areas between 1 and 2 WL, it has been possible to reduce the exposure of the miner so that no miner will receive more than 12 WLM exposure in a year's time.

A continuing program of education of the miner has helped in lowering the levels. Ventilation systems are continually being changed and improved to best fit the current operating plan of the mine. Although we expect to continue lowering the concentrations in some mines, it is difficult at this time with present technology to see how it will be possible to control all exposures of all men below a 4 WLM per year level or control all concentrations below 1/3 WL. For the many persons who might be considered support people in a mine, such as surveyors, geologists, trammers, and hoistmen, control of exposures at this level may be feasible. However, the stope miner, who spends eight hours a day at the working face, is the man whose exposure is most difficult to lower.

In coming years there will no doubt be more standards, more regulation, and more control of radon daughters in uranium mines. The subject has been a popular one and one that has brought about considerable controversy among the experts. As a result of many studies and investigations, somewhat more knowledge is now available on the subject and there has been some improvement in the sampling and counting instruments. However, in the course of the last 10 years, there have been no major breakthroughs on methods of control of radon daughters. It still apparently must be done with more and more air and carefully maintained ventilation systems.

REFERENCES CITED

(1) Holaday, Duncan A., et al, Control of Radon and Daughters in Uranium Mines and Calculations on Biological Effects, Public Health Service Publication No. 494., U. S. Government Printing Office, Washington, D. C. 1957.

(2) Radiation Protection in Uranium Mines and Mills (Concentrators), N 7.1-1960, United States of America Standards Institute, New York, N. Y., October 3, 1960.

(3) "Governors' Conference on Health Hazards in Uranium Mines - A Summary Report", Public Health Service Publication No. 843, U. S. Government Printing Office, Washington, D. C., 1961.

(4) Saccomanno, Geno PH.D., M.D., et al, "Lung Cancer of Uranium Miners on the Colorado Plateau," Health Physics, Vol. 10, pp 1195-1201, 1964.

(5) Wagoner, Joseph K., et al, "Cancer Mortality Patterns Among U. S. Uranium Miners and Millers 1950-1962," Journal of the National Cancer Institute, 32:4, April 1964.

(6) "Federal Metal and Nonmetallic Mine Safety Act," Public Law 89-577, 89th Congress, H. R. 8989, Sept. 16, 1966.

(7) Radiation Exposure of Uranium Miners, Advisory Committee from the Division of Medical Sciences, National Academy of Sciences, Federal Radiation Council, Washington, D. C., Aug. 1968.

(8) Saccomanno, Geno PH.D., M.D., et al, "Cancer of the Lung: the Cytology of Sputum Prior to the Development of Carcinoma," Acta Cytologica, 9:6, Nov.-Dec. 1965.

(9) "Department of Interior Bureau of Mines, Health and Safety Standards," Title 30, Chap. 30, Part 55, Federal Register, 34:11, Jan. 16, 1969.

(10) Report of Committee II on Permissible Dose for Internal Radiation, Recommendations of the International Commission on Radiological Protection, ICRP Publication 2, Pergamon Press, New York, 1959.

(11) Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure, Recommendations of the National Committee on Radiation Protection, National Bureau of Standards Handbook 69, U. S. Government Printing Office, Washington, D. C., June 5, 1959.

(12) Colorado Mining Laws with Safety Rules and Regulations, Bureau of Mines Bulletin No. 19, Denver, Colorado, Jan. 1, 1962.

(13) "Federal Metal and Nonmetallic Mine Safety Act," Public Law 89-577, 89th Congress, H. R. 8989, Sept. 16, 1966.

(14) Guidance for the Control of Radiation Hazards in Uranium Mining, Report No. 8, Revised Staff Report of the Federal Radiation Council, U. S. Government Printing Office, Washington, D. C., Sept. 1967.

(15) "Federal Radiation Council - Radiation Protection Guidance for Federal Agencies, Memorandum for the President," Federal Register, 32:147, Aug. 1, 1967.

(16) Radiation Exposure of Uranium Miners, Hearings Before the Subcommittee on Research, Development, and Radiation of the Joint Committee on Atomic Energy, Congress of the United States, Part 1, U. S. Government Printing Office, Washington, D. C., 1967.

(17) "Safety and Health Standards for Federal Supply Contracts - Radiation Standards for Uranium Mining," Title 41, Chapter 50, Part 50-204, Federal Register, 32:89, May 9, 1967.

(18) Idem, 32:113, June 13, 1967.

(19) Idem, 33:252, Dec. 28, 1968.

(20) "Federal Radiation Council - Radiation Protection Guidance for Federal Agencies, Memorandum for the President," Federal Register, 34:10, Jan. 15, 1969.

COMMENTS

QUESTION: On your last chart there I noticed that you dealt with the percentage of mines. What is thenumber of mines between 1952 and 1967?

ANSWER: Back in 1952 most of the mining had been in western Colorado, and eastern Utah. The Grants area was just being founded and the Wyoming area, which incidently is largely all open-pit mines had not been found yet. I would guess that maybe 200, 300 mines, something like that. Today there would be fewer mines. I would guess probably because they are larger mines; the smaller ones have dropped out of the picture. I would say today it's probably something like 150 to 200 mines in the whole industry. The peak came in about 1961 and 1962 in the AEC stretch-out program where they stretched out their purchase agreements over a longer period of time and they extend to 70.

Mr. Beverly: I forgot to mention that you can find radon daughters in underground mines practically all over the country and particularly in mines where there is some granite formations and the U.S. Bureau of Mines as well as some of the state bureaus has done a lot of sampling to prove this condition exists. You have to meet this 3/10 working level then there's a lot of metal mines that are in the same boat with us.

QUESTION: I want to ask Mr. Beverly a question. What about concentration plants? Do you have this problem there or is the environment such that the emission is very dilute because of all the air?

ANSWER: Yes, we've taken measurements around plants and in a closed area where there's little ventilation. You can sometimes measure a few tenths of a working level. Normally in the mill you have enough natural ventilation. We haven't ever seen it where anybody worked around it enough that it would be any problem at all.

QUESTION: Is there a continuing emission of the radon gas from the walls of the working places? Is there an emission you can measure along the walls in the course of time?

ANSWER: It's pretty difficult. You're almost measuring atoms, and it's pretty difficult to measure it right where it comes out of the face, but it's all the time coming into your mine and being eminated. Uranium has a half life of 4 1/2 billion years. Most people think it was here when the earth was formed so about half of it's decayed away. Another 45 billion years and all the uranium will have decayed away. But it is coming at you all the time and anytime you find uranium ore you'll find radon gas. All other things being equal, the higher the grade of ore the higher the radiation you'll have, but not always, the condition of the ground, the porosity, the permeability and how easy the gas can migrate through the rocks are all important.

QUESTION: My question I think has to do with trying to put impermeable membrane on the walls, spray it on or something like that. This is the total environment, the mine in which these men are working and I've wondered if you've thought of that as a possibility to minimize the emission except in the working face.

ANSWER: Quite a lot of work has been done but this is a noble single atom type gas that would go right through concrete like its a sieve. Certain latent sulfhates, and some asphaltic materials have been tested that tend to absorb this a little bit but getting the material to adhere to the rock is a problem. We haven't found this very practical nor have we found the right material. Something like this or some type of a scrubber that could absorb all the radons would be a great help - something like our filters do. There's quite a lot of research been done on this but nobody's come up with anything yet.

QUESTION: I'd like to address Mr. Beverly and perhaps Mr. Gilliland too. It's a bit unfair, but you're not doctors I guess, but there are two kinds of problems with inhalation. One dealing with high exposure over a short duration. Some attention has now been directed to the problems of long term, low exposure. Do you know of any research or are you doing any research in this area? What kind of conceivable approaches can you have when you deal in these things that are so hard to measure?

ANSWER: I don't know anything about that so I'm going to side step the question. But, in radiation it's long term high exposure that's causing problems. Most of the fellows that have died have received 10 years of exposure at maybe 50 working levels or 30 working levels or something like this. We are very much concerned over low level exposures over long periods. The public health service is making quite a study, actually reinitiating it, where they're going to study miners down in Mexico. They have been studying them at very low levels, something less than a tenth of a working level. We hope they get some information out of S. Africa where down in the gold mines there were levels in the 1/2 to 1 working level. The S. Africans have an extremely complete epithemialogical records and in fact that's why we're waiting on them. They didn't want to give them to us half finished and so they're going over them very thoroughly hoping there might be some clue of what 30 years at one working level means - is it safe? This has been an unanswered question. We think it is. Some people say it can be much higher than that. We don't have enough samples through the early 50's or enough records of where the men worked to really tie these down. The exposures that have been assigned by the public health service to these men are just estimates.

QUESTION: In the mining field, has there been any other underground mines that showed up any problems?

ANSWER: Not on the record to our knowledge. I don't think we have any records of high incidences of lung cancer from other mines. We know that there have been some mines that have had a few tenths of a working level and it's hard to go back and think what it was 10 years ago, 20 years ago. It's hard to get a large enough group together to find out what happened to them, how they died. The public health service is following a group of some 35 hundred that they picked out back in 1957 that had worked prior to that date and are following that group to try to find out what happens to them.

COMMENT FROM THE FLOOR: The Department of Labor has or has had tests run in about all underground mines in the last couple of years, haven't they? I asked that question for the reasons that we did run them in about 20 underground mines in the state of Missouri. We found very light radiation in I believe 3 places. They were old working levels. We put some air in there and it cleared right up.

COMMENT: Yes, the Bureau did some work back in 1961 and 1962 when they were covering all mines and a few of them made radiation measurements in these mines. Most coal mines didn't seem to have any but we found a little bit. But a lot of mines have been looked at. But I don't think we've seen any that are high enough that we think would probably be any problem.

Thursday, April 17 - Afternoon Session

Dr. Scott: Your chairman for the session on Air Problems in the Mineral Industry is Mr. Eugene W. Merry, President, Mine Safety Appliance Company, Pittsburgh, Pennsylvania.

AIR PROBLEMS IN THE MINERAL INDUSTRY

COMMENTS

COMMENTS BY MR. EUGENE MERRY: I might comment paranthetically that at the Pittsburgh meeting of the ASME at least the people in the field of water pollution were rather optimistic. They felt they could solve this problem in 30 years. The people with the air pollution side of it were less optimistic and were inclined to think that things were going to get considerably worse before they got better. You people are also well aware that the magazines and newspapers just abound in articles on air pollution and you are also well aware that the Air Quality Act of 1967 is now a law of the land. So I don't think there is any need for me to emphasize to this audience the importance of the air pollution problems that are currently facing the mineral industry. I think that everyone here is reasonably well familiar with the problems that we are facing today and will face tomorrow. So, frankly, what we're all hunting for is a few sound, practical solutions.