MESA-IR--1001

Informational Report 1001

MESA-IR--1001

DE83 902980

Mine Engineering and Ventilation Problems Unique to the Control of Radon Daughters

By R. L. Rock, Technical Support Center, Denver, Colo.

United States Department of the Interior
mesa
Mining Enforcement and Safety Administration

MASTER

UNITED STATES DEPARTMENT OF THE INTERIOR
Rogers C. B. Morton, Secretary

Mining Enforcement and Safety Administration
James M. Day, Administrator

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

CONTENTS

ILLUSTRATIONS

MINE ENGINEERING AND VENTILATION PROBLEMS UNIQUE TO THE CONTROL OF RADON DAUGHTERS

by

R. L. Rock[1]

ABSTRACT

Quality and quantity of ventilation are the two interrelated but key factors in any radon-daughter control program. The better the intake air quality (little or no contamination from radon and its daughters), the less are the total air requirements for the ventilation of active mining areas. Engineering principles for quantity distribution of air through underground workings are straightforward and the formulae and theories governing forced ventilation are not within the scope of this paper. Rather, this paper discusses the principal methods of utilizing mine planning to facilitate radon-daughter control and also treats the more subtle features of mine ventilation which are especially critical in the ventilation of mines where radon gas constitutes an environmental contamination problem.

INTRODUCTION

Mine design and ore handling methods inevitably affect the relative difficulties encountered in controlling underground radon-daughter concentrations. The reason for this is that these two features influence both the effectiveness of mechanical ventilation and the influx of radioactive contaminants into active mine areas. The generation of radon and its short-lived daughter products cannot be prevented, but concentrations in mine atmospheres can be largely controlled through systematic arrangement of the mining sequence relative to ventilation patterns.

MINE PLANNING

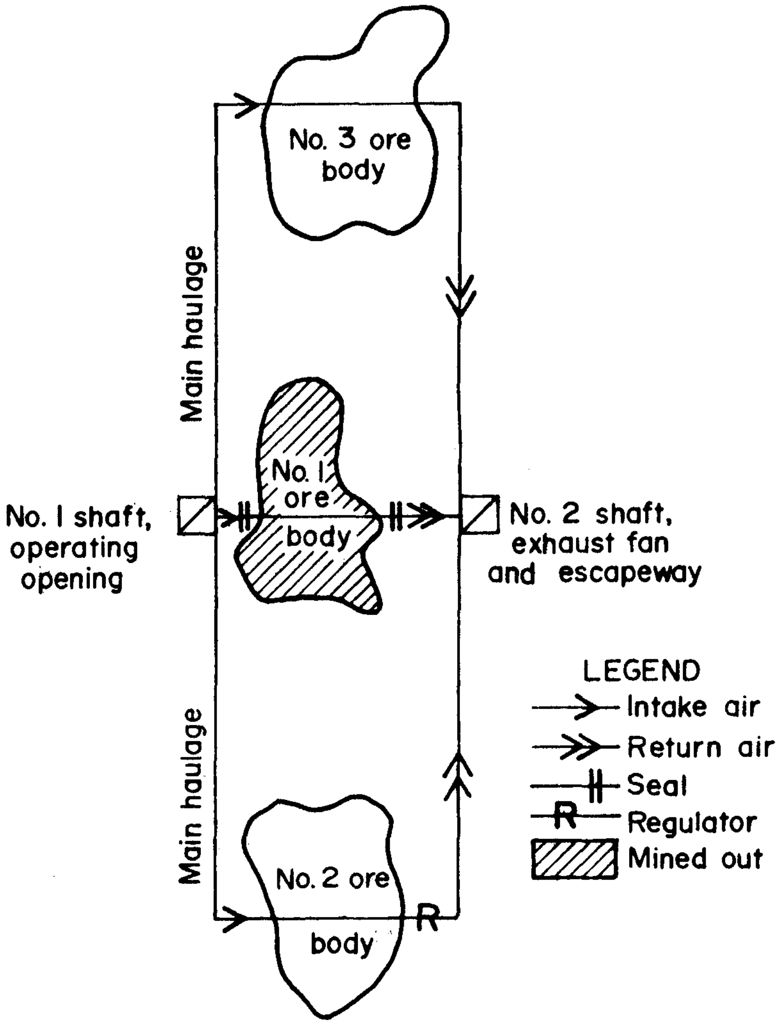
Obviously little successful mine planning can be accomplished without reasonably accurate knowledge of both the spatial orientation and physical characteristics of the ore. Unfortunately uranium mines are notoriously difficult to delineate by drilling. Where the smaller ore deposits are involved, drilling on even 25-feet centers may sometimes yield an inaccurate picture of the orientation, continuity, quality, and quantity of ore to be mined. However, to allow maximum utilization of mine planning for radiation control purposes, ore should be delineated as thoroughly as practical by surface exploration before mining is commenced. Once the extent and configuration of

[1]Chief, Radiation Group.

the ore is known, the best mine layout for efficient ore extraction is usually quite obvious. However, mine layout to obtain maximum radon-daughter control may not be quite so apparent.

To illustrate this point, several years ago there was an exploration-development drilling program in an area in which there was no prior experience regarding ore deposition. As it turned out, the uranium values were concentrated in nearly vertical fractures occurring 5 to 10 feet apart. When drilling for developmental purposes, the drill bit repeatedly intersected one of these closely spaced fractures and, because of relative rock hardness, tended to follow the plane of the fracture. Although the intervening ground between fractures was well mineralized, it was not nearly such high grade uranium as was inferred from radiometric and chemical analyses of the drill cuttings. The mining of this particular deposit was profitable, but not to the extent that it could have been if mining and ventilation had not had to be readapted to accommodate the unanticipated mode of ore occurrence. Later development drilling in the vicinity of the first ore body was designed to transect fracture zones to reveal the true nature of the intervening rock.

Figure 1 shows a simplified and idealistic mine layout for three disconnected ore deposits alined in a somewhat linear fashion. The development openings and mining sequence depicted are



Method advantages

1. Short haulageways and air courses.
2. Production and a second escapeway are achieved quickly.
3. Contamination of intake air is prevented.
4. Air can easily be shunted between No. 2 and No. 3 ore bodies.

FIGURE 1. - Plan drawing of an idealized developmental method for mining multiple uranium deposits to facilitate control over radon daughters.

designed both to enhance ore extraction efficiency and to allow radon-daughter control with a minimum amount of ventilation. Uranium mine designers must not ignore the fact that radon-daughter control is an undeniable mining cost just as are ground control, rock breakage, and ore handling.

Desirable principles of the development system shown in figure 1 are: short haulageways and air courses, the ability to achieve rapid production, and the early provision of a second exit from the mine. Contamination of intake air is precluded and the system is flexible so that available intake air can readily be shunted between ore bodies as air requirements change. Note also that all mined-out areas are kept on the return-air side of the system and that the main operating shaft and haulageway serve as intake airways. The latter feature prevents routine exposure of haulageway workers to high concentrations of radon daughters inherent in return airways.

Many factors other than inadequate ore delineation can detract from the operator's ability to use mine planning for radiation control. Financial pressures sometimes are responsible for mine managers abandoning sound mining plans for expedient methods of achieving increased production. In other instances plain short-sightedness is the apparent cause.

One problem being encountered currently is that a few relatively "low-uranium, high-vanadium" mines are being rehabilitated primarily for mining vanadium, which has become lucrative on today's market. Rehabilitation of old mines nearly always entails special ventilation problems and the potential advantages of mine planning are precluded.

The radiation control problems of newly developed mines almost always arise from mining on the advance without providing a means of diverting the resulting radioactive contaminants from working places in the ventilation currents downwind. Extensive underground exploration drifting may be practiced on the advance in which each and every ore lead is followed diligently. Because such exploration drifts are most often sinuous and explicitly designed to expose as much ore as possible, they not only create contamination problems but also provide very inefficient ventilation openings. Long-hole underground exploration drilling is a better practice than exploration drifting, but ore discovered in this way is also difficult to integrate into a systematic mining plan.

Main development openings and secondary haulageways may be driven in the ore horizon, but sublevel developmental systems are preferable for the primary intake airways and primary haulageways.

United States uranium mines developed within the last few years show evidence that considerable thought is being given to the economics of radon-daughter control. The larger the ore deposit and longer-lived the operation, the more economic advantages there are to be reaped from proper mine planning. Unlike methane, radon gas does not bleed off with time; contamination sources (mineralized rock) exposed in early mine developmental stages creates an added burden on the ventilation system throughout the life of the mine. Where a mine is operated 20 to 30 years, unnecessary contamination burdens on the ventilation system could easily add hundreds of thousands of dollars to composite ventilation costs.

Although all of the principles of mine planning which favor radon-daughter control may not be applicable in any one instance, the principles should be understood so that they can be applied effectively wherever practical.

These principles listed in order of importance are:

(1) Development openings serving as intake airways should be driven in barren ground. If ore or protore is inadvertently penetrated, it should not be mined on the advance.

(2) Mined-out areas should be maintained on the return-air side of the ventilation system insofar as practical. The advantage sought is to avoid having the contamination from nonproductive areas add to the contamination burden of active areas.

(3) Number and size of development openings connecting intake airways to active mining sections should be minimized in order to facilitate later "sealing-off" of mined-out sections.

(4) The mine should be designed so that main haulageways, hoisting stations, and other areas essential to routine production and maintenance (except for facilities which may constitute fire or explosive hazards) are in intake airways.

Mining methods, such as shrinkage stoping, which require the storage of large tonnages of broken ore underground, are not conducive to limiting the amount of radon released into the mine environment. For rock containing a given amount of Ra-266, radon is generated at a constant rate. The amount of radon emanated from the same rock into the mine atmosphere, however, is proportional to, among other things, the surface area of the rock. This explains why the practice of backfilling mined-out areas with protore or mill tailings containing Ra-266 greatly increases the potential radon contamination problem, unless, of course, such filled stopes can be positively isolated from ventilation to active mine areas.

One ore handling problem which is seldom recognized is ore spillage along intake airways. Radon contamination originating from ore spillage is much more of a problem where trackless haulage is employed. Spillage is generally related to roadway conditions, condition of haulage vehicles, travel speeds, and overloading of haulage vehicles. Over a period of time, radon contamination from accumulated ore spillage can become significant.

In one instance where an intake airway was converted from trackless haulage to track haulage, protore was used to fill low spots along the haulageway and to provide the uniform grade needed for track installation. Although the operator knew that "in-place" ore was not exposed by the haulageway, he found that the intake air (about 30,000 cfm) was contaminated to 2.0 working levels before it reached the first active mining area. The problem was very perplexing until the actual source of the contamination was discovered.

Loads of protore are often dumped into low spots along trackless haulageways to improve the drainage of ground water and such protore is capable of providing a continuous radiation contamination source.

Ground water itself carries dissolved radon but, except under unusual conditions, for example, high rates of water flow through rocks of high porosity and relatively low permeability, the added radon contribution due to the presence of ground water is usually quite low. Water under high hydrostatic pressure is capable of transporting much more radon from its point of origin within the rock to mine openings than would otherwise occur through regular diffusion processes. Ground water flowing through open drainage ditches in intake airways can release significant radon into the mine environment unless the water has been previously purged of radon when it first percolated into mine openings. In all likelihood, most dissolved radon is released immediately into the air as the water seeps into mine openings. The percentage of radon released depends on temperatures, pressures, and concentration gradients between radon in water and radon in air. In a few mines, ground water is known to be either the sole transporter or an important contributor of radon to the mine environment. Contamination control in these circumstances should be directed at isolating the flow of water from the primary intake air system.

VENTILATION

The general engineering principles for the design of a well-organized ventilation system are the same for radioactive mines as for mines which extract nonradioactive materials. The main difference is that more discipline must be applied to the more subtle aspects of good ventilating practices. Inefficiencies in ventilation are readily discernible through increased radioactivity. In fact, one investigator[2] has suggested that an improved method for evaluating the ventilation systems of nonradioactive mines might be to inject radon into the systems and use radiation measurements to determine the relative efficacy of air distribution. A more practical application for artificially induced radon might be to inject it behind mine seals to allow radiometric detection and tracing of critical leakage which may be occurring.

The added ventilating-practice disciplines required for efficient radon-daughter control are all related to the fact that the health hazard increases with elapsed time following contamination of the environment by radon because of the increase of radon-daughter concentration with time. Therefore, any factors which disrupt or retard the air-exchange process are to be avoided as much as possible.

General Ventilation Principles

The first engineering feature, which should be sought in the ventilation of radioactive mines, is the provision of adequate cross-sectional area mine

[2] Personal communication, Dr. Eugene Benton, University of San Francisco.

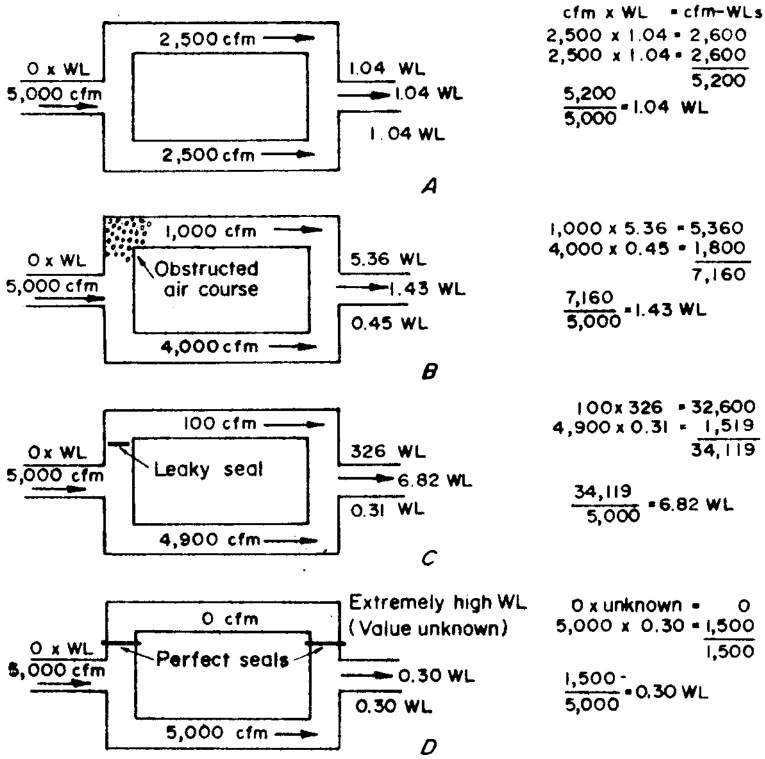
openings suitable to provide for the passage of adequate quantities of intake and return air. Size and uniformity of openings should preclude the need for excessive air velocities and air pressures. This may sound basic, but all too often this simple concept is ignored. High fan pressures require high power costs and usually result in high air velocities. High air velocities can freeze air and water lines, cause much miner discomfort, and, in some cases, increase the silica dust hazard.

Air recirculation is actually pseudoventilation which may not only be ineffectual (depending upon degree) in controlling radon daughters but also sometimes creates worse situations than would arise without mechanically induced ventilation. Air recirculation may take many forms. Probably the most common forms are recirculation within and between secondary systems. The former is usually caused by improper location of the fan inlet relative to the primary air supply. If the fan inlet is not located well upstream in the primary air supply, recirculation frequently occurs. Recirculation between secondary systems is tolerable only where the primary air quantity is great enough to dilute the contaminated air from the first system sufficiently to allow the air to be usable by the second system. Of course, the primary air supply must exceed the capacity of the auxiliary fan or fans, or recirculation is inevitable.

Recirculation within the primary system is most often caused by leaky booster fan bulkheads or by leaky stoppings installed to separate intake airways from return airways. More subtle primary recirculation occurs where intake airways are, in part, large open stopes having large cross-sectional areas. In this instance, air velocities become so low, due to lack of airflow confinement, that convection currents and natural draft pressures cause a portion of the air to move aimlessly.

This same thing can happen where large active stopes are ventilated without the provision of adequate air-control corridors to distribute the air unidirectionally and uniformly through the stoping area. Sometimes, due to marked density differences, a distinct channeling of the intake air will occur through such large open stopes. When this happens, peripheral stope areas undergo a very slow air-exchange process allowing high radon-daughter concentrations to develop outside the main channel of airflow. Due to air entrainment, these high radon-daughter concentrations are gradually drawn into the main airflow causing higher overall radon-daughter concentrations to prevail than if the total airflow were more uniformly distributed throughout the entire stope.

An interesting aspect of ventilating mines for the control of radon daughters is that dead-end barren side drifts and similar openings connected to intake airways can have a decidely harmful effect on radiation control even though the side openings themselves do not emanate radon. The effect of such side openings is to provide a delay-volume which is filled with the radon-contaminated air from the connecting airway by diffusion and convection processes. The resulting radon-daughter growth time within the side opening allows the development of near equilibrium between radon and its daughters. This relatively high contamination is then gradually fed back into the main ventilating system by convection and diffusion processes. Such side openings



Figures illustrate the importance of uniform ventilation and non-leaking seals. If seals are not designed to preclude the entrance of contaminated air into intake air, they are actually detrimental to radon-daughter control. All calculations assume uniform radon emanation throughout exposed mine surface areas and are based on the equation $V_2 = V_1 (WL_1/WL_2)^{0.56}$ where: V_2 = Ventilation in cubic feet per minute (cfm) after quantity changes have been made

V_1 = Initial ventilation in cfm

WL_1 = Measured WL in V_1

WL_2 = Measured WL in V_2

FIGURE 2. - Influence on radon-daughter concentrations due to proper and improper sealing.

are seldom sealed, but under some circumstances, sealing would be advisable.

Sealing of mined-out areas is a common practice to attempt to prevent radon and its daughters generated therein from contaminating active mine areas. Unfortunately most sealing projects are not very effective and some even add to the control problem. Figure 2 shows the relative effects of a perfect seal versus imperfect sealing. In reality, the radon permeability of the coating material used on seals is not nearly so important as the need to make the seal as airtight as practical. Because seals cannot be made absolutely airtight, they must be provided with a negative pressure behind them to assure that the leakage which invariably occurs is "into" and not "out from" the sealed area. Negative pressure behind seals is usually provided by high-pressure low-volume fans mounted on the surface exhausting from boreholes penetrating the sealed area.

All radioactive mines should be ventilated with a mechanical system even though, during certain periods of the year, natural draft pressures may provide more ventilation than is provided solely by the mechanical system. Both directional and quantitative control over ventilation are absolutely essential to the continuity of any radon-daughter control program. Natural ventilation cannot be relied upon for either directional or quantitative control over airflow, and does not provide an acceptable method of ventilating. Natural draft pressures can, however, sometimes be integrated advantageously into the total system.

Uranium mines and other radioactive mines having ventilation systems of any complexity should avoid discontinuing ventilation between active shifts. The growth of daughters underground over an 8- to 16-hour period without ventilation can require a considerable amount of time to be nullified after ventilation is resumed. High worker exposures can, therefore, occur over an indefinite interim period after ventilation is restored. The amount of time required for environmental control over radon daughters to be reestablished depends upon how quickly ventilation causes a complete change of underground air to occur.

Ventilation engineers presently make extensive use of boreholes for ventilation of U.S. uranium mines. Usually the main intake airway is the operating shaft, and return airways are boreholes dispersed throughout the ore body so that major mining sections are each provided with a separate split of intake air. This system has generally worked quite well. If a mining section presents a particularly difficult ventilation problem, that particular section is sometimes isolated from the rest of the ventilation system by providing the section with its own intake- and return-air boreholes. A distinct advantage of the split system of ventilating is that only that volume of air required to ventilate each mining section need be passed through it. This is in direct contrast to a series ventilation system in which the quantity of air required to ventilate the most difficult working place must be passed through the entire system. Another obvious advantage of the split system of ventilation is that radioactive contaminants are not cumulative throughout the system. Instances where ventilation requirements have become prohibitive, are usually the result of the mine operator's reliance upon extensive series ventilation.

Air Quantities Required

Air quantities required for radon-daughter control usually exceed air requirements for the control of conventional contaminants such as blasting gases, diesel exhaust gases, and dusts; but air quantity requirements need not be excessive if excessive series ventilation is not practiced. Formulas are available for calculating air quantities necessary to control specific radiation-ventilation conditions, but the data needed to make these formulas valuable are often elusive. So long as the intake air can be delivered to the mining faces relatively free of contamination, 2,000 cfm of air will ventilate adequately a 10- x 10-foot face of high-grade ore. As the intake air becomes contaminated above 0.1 working level, however, air quantities required for control increase rapidly. Figure 3 shows the factors by which air quantities needed for control increase as the intake air becomes contaminated.

Maintenance

Maintenance of ventilation systems plays an important part in determining the radiation exposures that underground workers ultimately experience. No matter how well planned and installed the ventilation system is initially, the system must be maintained or efficiency rapidly deteriorates. Maintenance is often badly neglected, unless a ventilation engineer or some other knowledgeable person familiar with the radiation hazard is assigned direct responsibility for maintaining adequate ventilation. Persons assigned this responsibility must be willing to apply themselves fully to the problem and must have authority to make the corrections or repairs to the ventilation system necessary to maintain healthful conditions.

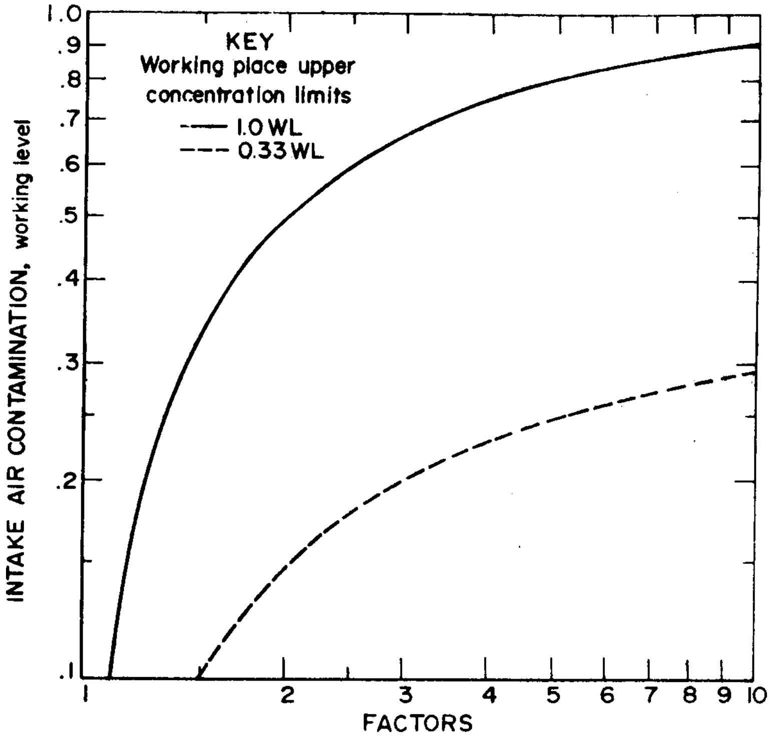


FIGURE 3. - Factors by which air volume must be increased when contaminated air is used for ventilation.

CONCLUSION

Control of radon daughters in radioactive mines is sometimes considered to be basically a ventilation problem. The problem is, however, of such a nature that control over the amount of contamination released into the mine environment plus control over the manner in which that contamination is removed from the mine environment relative to occupied mine areas are of major importance in determining the difficulty of ventilation.

In many respects, radon-daughter control involves different considerations than are involved in more conventional mine contaminants. One reason this is true is because of the rapid growth of the hazard (radon daughters) following contamination of the air with the parent radon. Another reason is that so few atoms of radon emanating from so many different sources can be involved in total mine contamination difficulties.

Having worked on ventilation problems involving dust, blasting gases, diesel exhaust gases, and methane, the author can state that solutions to high radon-daughter concentrations often require more finesse than the aforementioned problems.

The best method for providing practical solutions to radon-daughter control difficulties is to first make a detailed assessment of contamination sources relative to existing air distribution. Detection of subtle contamination causes may require highly trained personnel using specialized equipment. Usually the mine must be considered in its entirety during the contamination assessment program. Answers sought are:

(1) Where and why major contamination problems are occurring.

(2) How beneficial changes may be affected without causing harmful effects in other active mine areas.

(3) What major changes, such as increased primary airflow, are necessary to assure long-range environmental control over radon-daughter concentrations.

Far too many mine operators try to solve their radiation problems by the indescriminate addition of more primary ventilation. Increased air quantity is often necessary, but, for maximum effectiveness, additional air must be integrated appropriately into the ventilation system. The only way this integration can be accomplished with any degree of certainty of success is through utilization of information gathered in preliminary detailed radiation-ventilation surveys. Such surveys are time-consuming in that they require measuring air quantities and associated radiation in all the separate branches of the ventilation system.

The author has found from the radiation-ventilation surveys conducted by the radiation group that, in a surprising number of instances, satisfactory radon-daughter control is attainable merely by containment and/or diversion of contamination emanating from inactive mine areas.

BIBLIOGRAPHY

1. Little, Arthur D., Inc. An Assessment of the Economic Effects of Radiation Exposure Standards for Uranium Miners. A report to Federal Radiation Council, 1970, 250 pp. plus appendixes.

2. Rock, R. L. Radiation-Ventilation Relationships in Six Underground Uranium Mines. BuMines IC 8413, 1969, 17 pp.

3. _____. Radiation Monitoring Section of Metal and Nonmetal Mine Inspector's Training Manual. BuMines, 1970, 60 pp.

4. Rock, R. L., and D. K. Walker. Controlling Employee Exposure to Alpha Radiation in Underground Uranium Mines. BuMines Handbook, v. 1, 1970, 72 pp.

5. U.S. Bureau of Mines. Training Film, "Protection Against Radioactivity in Underground Uranium Mines," a 30-minute film produced in 1969. Available from film libraries of Education and Training Divisions, MESA, Pittsburgh, Pa., and Denver, Colo.