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Mining Sessions

MINING SAFETY AND THE INDIVIDUAL AT THE BICENTENNIAL JUNCTURE

By T. H. PATE, Jr.
General Mgr. of Operations, Duval Corp., Tucson, AZ

To me, the accident prevention and safety functions are rather unique. When the program is working effectively, there is very little notice or notoriety. Everyone takes the position that management, unions, supervision, safety personnel and the employees are just doing their job. However, when a serious accident occurs, the reverse is true. The notoriety can become intense.

In my opinion, the hard work and sincere effort by all segments of industry that has been put into industrial accident prevention and safety down through the years should not be overlooked. If you review the record for the past 50 years, it is obvious that progress has been steady and certainly worthy of comment. This progress started long before most of the present laws and regulatory agencies were brought into being.

For example, here is a circumstance that is little known or recognized. In the State of Arizona, mining is one of the most significant basic industries. Mining is considered to be one of the more hazardous occupations. Yet there are statistics to prove that a person is less susceptible to disabling injury at work on a mining job in Arizona than they would be driving or riding on Arizona streets or highways. Mining safety in Arizona did not reach this position without a tremendous effort on the part of a lot of people. This effort should be a matter of pride for all those who participated.

So where does safety go from here? We are a long way from the ultimate goal of zero frequency. Obviously, there is much to be done. I believe the appropriate question is: What approach should we take?

First, industry and the regulatory groups must set common goals. There must be a spirit of good will and sincere

purpose. While it may not be the intent, it often appears that there is an adversary and punitive attitude as regulatory policy interfaces with operating properties. It is appropriate to mention that in the states and provinces where Duval has operations—Texas, New Mexico, Arizona, Nevada, and Saskatchewan—there has been good cooperation from the individuals of regulatory groups with whom we have had contact. These individuals are always dedicated to the ideals of good industrial safety.

The principal thrust of safety by regulatory agencies many times is directed to the physical or inanimate side of safety. I do not wish to imply that safety guards on equipment and the elimination of physical hazards are not an important consideration. Rather, what I wish to convey is that there are the means available through existing technology and practices to eliminate a significant portion of physical hazards. The installation of mechanical safeguards are an important engineering consideration in the design of all new facilities. Follow-up to determine that adequate safeguards are in place and being utilized should be the perfunctory side of a safety program.

This brings to mind the most important point that I feel should be stressed. Long ago, it was recognized by those associated with accident prevention and safety that the major effort should be in the training, education, and development of the proper attitude and safety awareness in the individual employee. This might be called the human side of safety, or safety from within. This is by far more difficult than mechanical safeguards because you are dealing with people, their attitudes, their feelings, and their interests. While realizing that this phase of safety is most

difficult, we have learned also that it is the most important.

If safety and accident prevention are not a constant consideration, there will be accidents caused by human error. At all times, supervision must be supplied with and required to utilize proper techniques, practices, and procedures as standards for the indoctrination and training process. The chance for human error must be reduced to the absolute minimum.

Let me use an oversimplification: I am of the opinion that a well trained employee or group of employees can work safely in an environment that has significant physical hazards present. On the other hand, an individual or group that does not have a good safety attitude will be subject to accidents and injury even if all apparent physical hazards have been eliminated.

In reviewing the safety records of Duval Corporation, it appears that the most dramatic illustration of this premise occurred in 1967 at Duval's Carlsbad potash property. During the first 15 years of operation at this mine, there had been a formalized safety program based on many of the proven standard safety techniques including training, safety committees, job analysis, safety statistics, and incentive awards. During the prior 15 years of operation the accident frequency averaged 18, but appeared to reach a plateau and was not improving.

By 1967, the only ore remaining in the original mine was in pillars left in panels in which the first ten years of mining had taken place. During the intervening years, subsidence had created dangerous roof and rib conditions. As a result, mining of the pillars in these areas would most certainly be accompanied by increased accident and injury potential. At this point, it was recognized that the job ahead would require a more effective safety program. In an effort to cope with this situation, all face equipment was modified by the installation of cabs to protect the operators from rib and roof falls. The effectiveness of these cabs in providing protection to the operators was soon demonstrated and, as a result, all face equipment in normal-height mining areas is now equipped with protective cabs.

With the installation of the protective

cabs, every reasonable mechanical safeguard had been provided. Roof bolting, barring down, and rib slab removal programs were stepped up. The only remaining avenue of improvement in the program was the strengthening of the human side of safety. This phase of the program was subjected to close examination, but very few new ideas were developed. In the final analysis, it was concluded that the proper practices and procedures were set forth adequately in the existing safety program and that further improvement could come only from a renewed emphasis on safety education and development of the best possible attitude toward safety among individual employees. The added emphasis consisted primarily of more training and involvement in an intensified program to involve every single employee. The basic responsibility for follow-through was, as usual, delegated to the various levels of supervision. Although special emphasis was placed on the underground operation because of its inherent hazards, a similar program was conducted in the surface operations.

The effectiveness of what can be accomplished when the human side of safety is emphasized is demonstrated by the notable safety record established by the Carlsbad potash employees of Duval Corporation. The most significant recognition came on July 12, 1971, when these employees were presented their third consecutive Sentinels of Safety Award by the U.S. Bureau of Mines and the American Mining Congress. The three awards were given in recognition of the safety record: three years—1968, 1969, and 1970—and 2.3 million man hours worked without a single disabling injury.

After the human-individual involvement approach to safety proved to be effective at Carlsbad, its implementation was applied more and more at the open pit copper operations in Arizona and Nevada. The frequency in the open pit operations was 26.5 in 1969. This figure for the first six months of 1975 was 1.4. To achieve this reduction represents the efforts of more people than I could name. The most notable achievements have been made at the Mineral Park property near Kingman, Arizona and the Battle Mountain property in Nevada. These operations employ upwards of 800 persons and

senior superintendent who has been around for several decades.

This brings to mind the special importance that goes with seniority or rank. Seniority and rank often signifies privilege. However, the important responsibility of setting a good example should never be overlooked. The impression that the average employee has of supervisor's attitude toward safety is most important. If that impression is positive, it will reflect an attitude that management recognizes that its first duty is to employee safety. The goal of job safety must not be impaired by the short term desire to increase profits or reduce costs. Senior management must exert leadership and insist that the only acceptable safety effort must be an effective effort.

Hopefully, at Duval we will not fall into the common trap of assuming that the safety and accident prevention program can be a special project for a few weeks or months and then allowed to coast thereafter. Accident prevention and safety is the one program that must be started again each day and emphasized just as much or more today than it was at any time in the past.

The past 200 years of this country's history has been based on recognition of the dignity of the individual. In my opinion, this can be the basis of improved safety in the mining industry from now forward by practicing what we preach: importance of the individual. Without exception, this program will require the best efforts of all involved—management, the work force, and regulatory agencies, and with these efforts we will continue to make progress.

work close to 1.6 million man hours per year. Mineral Park had only one minor three-day sprained ankle during 1974 and has been accident-free thus far in 1975. The Battle Mountain property has operated over 1100 days, a little over three years, without a disabling injury. The Battle Mountain property won the intra-company awards in 1973 and 1974 and is going strong in 1975.

To me, these examples are absolute proof that the goal of improved safety can be achieved if the necessary effort is expended.

There are two significant anomalies that surface when viewing the Carlsbad and Battle Mountain records. When Carlsbad had its lowest disabling frequency rate, it is noted that they also had a productivity record that was about 10 percent above average. Currently, the Battle Mountain property is the open pit operation within the Duval organization that is operating at the most efficient level compared to budgeted production levels.

The only conclusion that can be drawn from these examples is that, besides being its own reward, the effective safety program results in a more efficient operation overall. Development and administration of a successful safety program demands the best efforts of all employees; however, the rewards more than justify the effort.

Duval is currently embarked on an intensified program at all of its operating properties to further develop the safety attitude in the individual. The program is designed to continually involve every employee with the safety awareness theme. This includes the most junior person from the standpoint of seniority and the most

THE ERIE MINING COMPANY HEARING CONSERVATION PROGRAM

By ROBERT L. GIULIANI
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Erie Mining Company and Pickands Mather and Company, the managing agent for Erie, have always maintained a comprehensive safety program. The desire to eliminate all potential causes of occupational diseases led to the inclusion of noise abatement and hearing conservation as a vital part of Erie's overall safety program when the commercial plant began operations in 1957.

In 1971, significant progress was made in our hearing conservation program. However, I cannot adequately discuss the success of our program without relating how the groundwork was laid and how the many factors pioneered years previously were linked in the progress that bore fruitful accomplishments in 1971.

The present Erie plant, located at Hoyt Lakes, Minnesota, is owned by Bethlehem Steel Corporation, Lykes-Youngstown Corporation, the Steel Company of Canada, Limited, and Interlake Incorporated. Erie produces 10.3 million dry tons of high grade taconite pellets annually and employs approximately 2800 persons.

All industries utilizing modern heavy equipment have areas of high noise levels. Erie is no exception, and when operations began the fact was recognized that hearing impairment of a permanent nature can occur as a result of prolonged exposure to high noise levels.

The first step in establishing a noise abatement and hearing conservation program is that of conducting audiometric examinations or hearing tests for employees and applicants for employment. The initial test serves as a baseline for future tests. This examination, which determines the individual's threshold of hearing, requires a pure-tone audiometer, test room, a trained technician, and qualified medical interpretation.

We utilize a manually operated pure-tone audiometer for preemployment examinations and the follow-up tests when indicated, and an automatic audiometer for the majority of repeat tests, which include an annual test for all employees. Both units allow a range of frequencies from 125 cycles per second to and including 8,000 cps, and the intensity of tone can be varied from minus ten to 100 decibels when calibrated to ASA standards. The test results are plotted on a graph called an audiogram. The audiogram graphically demonstrates the decibel loss in the specified frequency, and the questionnaire portion of the form aids the doctor in his interpretation. The test is conducted by a qualified technician who is well versed in the many peculiarities associated with hearing tests.

The automatic audiometer requires a minimum of attention from the Technician and greatly reduces the number of instructions which must be given to the subject.

Hearing tests, by necessity, are conducted in a quiet room treated with sound-absorbing materials. We selected a prefabricated audiometric testing room. This room is located in the plant dispensary in our administration building, removed from plant and mining activities. The background noise levels within our room meet USASI standards. The background noise level within the room is monitored and the records filed periodically. These records may be needed at some future time to prove the validity of an audiometric test.

The active participation and interest of the medical advisor is a must if the program is to be successful.

The next step in our hearing conservation program was to know how much noise our employees were being subjected to. Soon after plant startup in 1957, surveys were conducted with sound level meters in all areas, to record overall noise levels. This was an early start in the noise measurement program, but was not considered adequate because of the many types of noises encountered; however, it

served as a guide in future studies.

A noise analyzer was then used early in 1958, and a complete analysis was made of the entire operation, beginning with the areas of highest overall readings that had been previously determined. With this complete coverage, it was decided to repeat the surveys annually, using the results not only for hearing conservation but also to study the correlation between noise levels and equipment wear.

Included in this phase was the testing of various types of ear protection in our own audiometric booth, so that we had a high level of confidence that the ear protectors, properly inserted, would provide adequate attenuation for any noise level and exposure intervals that our employees might be subjected to.

Early in 1958, it was decided to familiarize our employees with the hazards connected with noise. All plant employees were required to attend a scheduled hearing conservation meeting. The number of employees in attendance was limited and was composed of individuals assigned to approximately the same work areas. Noise levels of all areas frequented by the group were displayed and discussed. A question and answer period followed, and finally each individual was fitted with ear plugs by the medical advisor who, for the most part, conducted the meeting.

Follow-up noise programs with supervisory personnel were scheduled periodically to keep them abreast of new developments. They, in turn, were expected to relay this information to the employees under their jurisdiction.

The wearing of ear protection was on a voluntary basis. In general, the employee acceptance was good. We know that the program was successful from the annual review of the audiometric tests.

We have recently computerized the hearing records of all employees. This includes those who have terminated as well as all active employees. As of January 1, 1975, the run contains slightly over 87,000 audiograms taken on 4,100 people. One thousand six hundred fifty of these people have been with us since 1960, representing a control group with 15 or more years of records. This information and the noise surveys previously discussed will be used to correlate noise exposure with threshold shift, if this proves

to be the case. The effects of noise exposure or the effectiveness of noise abatement cannot be determined without a combination of sound level studies, which identifies the problem, and a medical program with audiograms to evaluate the effectiveness of protection devices and noise abatement activities.

In 1971, with so much publicity being given to industrial noise and to the exposure limitations provided in the Walsh-Healy Act, it was decided that a more controlled hearing conservation program would be beneficial at Erie. All areas and equipment were resurveyed and the "A" weighted scale reading was included with each survey which was not taken for our records in the past. The results were plotted, using the Walsh-Healy time exposure limitations.

In April 1971 a hearing conservation program was presented to all supervisory personnel. In this program we gave some basic information on noise and noise measurement, demonstrated loudness and frequency, showed how the damage to hearing from loud noise occurs, and the attenuation provided from properly worn ear plugs. Representative noise surveys were shown and time was allowed for questions. The success of this program was due to several factors: (1) we kept it simple—technical terms and big words were avoided; (2) the program kept moving; and (3) it left everyone with a challenge to protect his hearing when in areas of loud noise. The feedback from this program was so enthusiastic that it was decided by our management to present a similar program to each one of our 2200 hourly employees and to make ear protection mandatory wherever the noise levels were 90 dbA or above.

This appeared to be a formidable assignment, but actually it progressed very smoothly. An organizational charter was drawn up outlining the scope and objectives desired. A project manager and assistant were named and a representative from each department was selected. A timetable was agreed on, with September 15 as the date when ear protection would be compulsory. The first announcement was to the Mine Safety Committee of the union at the regular May meeting. The format of the program was explained to them, including the timetable and target

date. They were enthusiastic in their response.

Scheduling was worked out so that the men would receive a one-half hour program at the beginning of their shift whenever possible, or taken off the job during the first half of the shift, where they could be rotated. We avoided any programs at the end of a shift when the men might be more interested in leaving for home. We also avoided overtime. Three members of the Industrial Hygiene Section of the Safety Department conducted the sessions, using overhead projectors, blackboards, and displays.

In searching for a positive and unique way to identify the areas where ear protection would be mandatory, an ear symbol, showing an ear plug inserted in the ear channel, was suggested and adopted. We had them made up in two sizes—9"×9" and 3"×3"—with adhesive backing. The nine-inch decals are displayed in the operational buildings or on equipment where that size would be appropriate; the three-inch decals are posted on the instrument panels of tractors, dozers, trucks, etc. where noise surveys have shown ear protection to be necessary. They both carry the same message. Control of our program thus has become simplified; where you see the decal displayed, you must wear ear protection—if you do not see the ear, ear protection is not required. Since the original program began, we also have 24"×24" decals in some areas, such as hanging in the center of the repair bay, etc.

We have also supplemented our sign program to warn that hearing protection is necessary whenever air-operated tools such as chipping hammers or impact wrenches are used, or when arc air burning is done.

The one-half-hour program, given at the reporting areas, often under less than ideal conditions, had to have enough impact to get and hold the men's attention. It started by showing by illustration the total amount of noise most people are subjected to, including recreational activities of snowmobiles, motor bikes, chain saws, outboard motors, rifles, shotguns, rock music, etc. We told the men that we can protect their hearing while on the job, but we wanted them to be concerned with their exposure to noise off the job—and to

consider their family's exposure also. It put hearing loss and noise exposure on a very personal basis. We had their attention. Then a diagram of the human ear was displayed with an explanation of how hearing losses originate. We explained loudness and frequency and showed how noise surveys were taken; actual surveys of the areas or equipment where these men worked were shown along with the exposure limitations without ear protection and the attenuation afforded by properly fitted ear plugs. We wound up our presentation showing them the ear decal and explaining the mandatory hearing conservation program—that this was June and they had until September 15 to become accustomed to wearing ear protection—and left them with a challenge: they must protect their hearing or be in danger of losing something that could never be regained. During June, we put on 163 separate programs for the hourly personnel and three for salaried personnel; 1926 hourly employees received this program. At times, three simultaneous sessions were in progress. Each instructor was fully equipped with all the program materials.

I have mentioned ear protection and ear plugs. I have not mentioned ear muffs. You might be interested in our approach to the use of muffs.

Early in our hearing conservation program, when various ear protectors were tested in our audiometric booth, muffs were tested as well as plugs. It was found that ear plugs would afford as much protection as the ear muffs for the frequencies that our employees were exposed to in most cases. Ear plugs were adopted as standard ear protection on the recommendation of the medical advisor because of their convenience, comfort, and effectiveness. A selection of five types were available, and Erie has tried to remain consistent in that choice up to the present.

Some exceptions are recognized. In a few instances, the doctor will find an individual whose ear plugs irritate or infect the ear canal, while some people feel that they just cannot wear them. An ear muff was furnished to these few. We also supplied muffs to the railroad trainmen who were required to go into the power units for servicing and trouble shooting while on a run. A policy was adopted to satisfy

those who thought that they would prefer to wear the muffs rather than the ear plugs. The name of the individual wanting to try muffs was forwarded to the supervisor of safety—it was placed on a list, and a pair was issued to the employee for a two-week trial period. He was allowed to return them at any time, but at the end of the two weeks, he had to make a choice—to keep the muffs permanently for his ear protection, or return them and resume wearing ear plugs.

There has not been an abnormal demand or rush for ear muffs. An industrial survey of workers' preference between ear muffs and ear plugs has shown that, when given a choice, 85 percent of the persons wearing ear protection prefer the ear plugs because of the convenience and comfort. At Erie, until about a year ago, only five percent were using ear muffs. In the past year we discontinued our previous trial program and we now issue them to all individuals who want them. We have issued muffs to approximately 30 percent of our people. We have not conducted a survey to determine actual use, however.

Although noise abatement was mentioned only briefly early in this paper, it is a vital part of our program. In fact, noise abatement is the ultimate objective, where possible. All authorities agree that to reduce the noise is the primary goal; to block the path of sound or screen the employees would be the next objective.

Where these are not possible, personal protection is the most feasible alternative. In reality, a noise abatement solution in an industrial plant is very complex. Most machinery manufactured even in recent years was not built to conform to acoustical specifications. Some equipment, such as compressors or heavy mine equipment, if given a specific noise rating when new will show a marked increase in noise level in time because of normal wear.

During the hearing conservation programs, we asked for suggestions as to where we could reduce or eliminate noises that would be within the scope of a noise abatement committee; areas where an acoustical curtain would be effective or where installing or improving a muffler system would reduce equipment noise. Many good and valid suggestions were submitted, and it is surprising how many

irritating and disturbing noises were identified which might be reduced to acceptable levels. There is no promise that a satisfactory solution can be found for each suggestion, but the fact that we made a sincere effort does promote better morale and cooperation among our employees.

New materials now being developed for noise absorption and vibration dampening will definitely be a factor in how successful and how far we can go in noise abatement.

Hearing conservation and noise abatement programs are primarily aimed at personal protection and noise reduction. However, having the sound survey equipment has resulted in additional benefits. Several years ago, we were called upon to assist our electrical maintenance department in attempting to prove to a manufacturer that we had been supplied with a faulty piece of equipment. The general foreman in charge suspected a problem with one of three identical units that had been purchased during an expansion period. By using a small sound level meter, slightly modified at the microphone, we were able to determine that the problem unit was five decibels noisier than the other two or, for that matter, than several older units where readings were taken against the unit housing. This information was relayed to the manufacturer, who in turn sent one of their engineers to Erie for the purpose of proving our data. The tests were repeated in his presence, and he agreed the tests were valid and proceeded to recommend to his company that the machine, valued at approximately \$20,000, be replaced. The value of the unit was not the only factor involved, but production loss and downtime had to be considered should an unsuspected total failure occur. We were later informed by the manufacturer that the machine had faulty parts and would have failed had we continued to operate it.

Several years ago, we had occasion to conduct a study dealing with background noise and an alarm in a production truck. Our 85-ton trucks are equipped with an audible alarm to alert the driver in the event an oil pressure loss occurs. An engine with some 20 hours of operating time was ruined because of an oil pres-

sure loss that was not detected by the driver. The alarm system was tested and found to be operating properly, yet the driver claimed that he did not hear it. The alarm was monitored with a noise analyzer and found to be in the neighborhood of 4800 Hertz and 90 decibels in intensity. The background noise under full power at 4800 cycles per second was 75 decibels, or 15 decibels lower than the alarm. A review of the employee's audiogram showed that he had a bilateral hearing loss in this frequency range in excess of 90 decibels and, therefore, was not able to hear the alarm.

To prevent similar occurrences in the future, we attempted to purchase, through equipment manufacturers, a suitable alarm with a frequency of 2,000 cycles per second or lower, but were not able to find one that was compact enough to install in a truck cab. Our electrical maintenance department at Erie accepted the challenge and did develop a unit that produces a pure-tone signal of 85 db at 500 cycles per second and is well within the desired size dimensions. After an adequate testing period, the alarm has been declared satisfactory, and all 85-ton trucks were equipped with this protection.

For years, Erie has used sound level meters coupled with impact analyzers to monitor the over-pressure of our production blasts. The results read from these instruments placed in strategic locations have had significant benefits. As blasting techniques have improved, the steadily reduced over-pressures resulting from the blasts are a matter of record. Also, by monitoring and recording the intensity of the blasts, false blast damage claims have been denied and valid claims have been substantiated and accepted.

Progress in these areas mentioned, which are unrelated to our hearing conservation program, would not have been possible without the sound survey equipment and a comprehensive approach to all the problems relating to noise.

In conclusion, I do not want to suggest

that our hearing conservation program is in any way complete. We have had success, but employee education is a continuing process—the degree of employee acceptance is, and will be, directly related to the educational effort that is put into the program. A review of hearing conservation programs undertaken in industry shows that more programs have failed than have succeeded.

It has been four years since our program has become mandatory. So far, Erie's program appears to be an unqualified success. Perhaps the most significant reason for success would be that we put hearing protection on a personal basis: each employee could consider his own involvement and risk. At the conclusion of each training session, we asked our employees: "What is it worth to you to be able to hear the good sounds of life; the chatter of your children, the splash of a fish, the cry of a loon, the lapping of waves?" As I said previously, we had their attention, and they took it seriously.

The whole program of hearing conservation is timely. Erie's position on mandatory hearing protection is bolstered by the many articles appearing in the news media, TV, and publications. It could never have been successful without the backing of management and the full cooperation of all the departments involved. The union, through the Mine Safety Committee, has been kept well informed, and in 1971 they designated two of their members to attend quarterly meetings where hearing conservation and noise abatement projects and problems are reviewed, and this participation will have its own healthy effects.

My own personal involvement in helping prepare and present the hearing conservation programs to both the supervisory and hourly personnel has been fully rewarded. I have witnessed a high degree of acceptance by both groups without the customary resistance which usually attends the adoption of a mandatory program.

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PLAN FOR SURVIVAL— FIRE PROCEDURE UNDERGROUND

By G. G. McPHAIL

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I am going to summarize three subjects, all of which when blended together at the time of fire underground, should result in the safe evacuation of miners, the bringing about of an efficient system of organizing the work force, and the prevention of potential chaos.

1. Fire Procedure. The procedure to be followed in the event of a mine fire, outlining the duties and movements of all personnel, including those of the person discovering the fire.

2. Fire Organization. The organizational plan to specify the duties and responsibilities of department chiefs to coordinate all the mine services toward efficient rescue of men, extinguishing of fires, and getting the mine back into operation again.

3. Fire Control. The Nerve Center of operations, where decisions are made on policy and plans of procedure.

The worst disaster in North American metal mining history occurred at the Sunshine Mine, Kellogg, Idaho, on May 2nd, 1972. Ninety-one men died as a result of a fire believed to have started by the spontaneous heating of flammable refuse.

It is known that many varieties of refuse, paper, rags, oil containers, and scrap timber were dumped into waste rock used for backfill in mined-out stopes. History repeated itself after 44 years, as the deaths of thirty-nine men at Hollinger in 1928 resulted from a fire underground caused in exactly the same manner. While this poor practice of disposing of flammable material underground was the prime cause of the fire, it was only one factor in the death of the ninety-one men. Other factors, possibly a result of complacency, were:

1. A 20-minute delay in injecting the stench warning, while supervision tried to ascertain the exact condition of the fire.
2. Ineffectiveness of the stench warning system. Subsequent testing of the sys-

tem during investigation revealed the system contained about 20 percent of the necessary amount of ethyl mercaptan for the quantity of air entering the mine.

3. Failure to conduct evacuation drills. No drill had ever been conducted, and employees were not trained in emergency procedures.

4. Inadequacy of the emergency fire plan and the emergency escapeway system.

5. No provisions for breathing protection of underground hoistmen so the hoists could still be operated to bring men up from the lower levels. The death of the hoistman on 3100 level of No. 10 Shaft condemned every man still to be hoisted from below 3100.

6. Inadequate telephone system. The single circuit, connecting hoistroom, shops and shaft stations was ineffective because so many persons attempted to use it simultaneously.

7. No management official was designated to be in charge of the entire operation in the absence of top mine officials at a stock-holders meeting.

8. No check-in, check-out system was in effect. Miners were checked into the mine in shift bosses' time books, and the books taken underground. Some were lost with the shift bosses. Mechanics and electricians entered the mine without any control. Cap lamps missing from the charging racks were the only means of indicating who might be underground, and then too, extra lamps had been sent underground to replace defective ones.

9. Refuge stations were not provided on levels of the mine from where there were no second exits.

These are only nine of 30 factors existing on May 2nd, 1972 which contributed to the deaths of ninety-one men underground from suffocation by carbon monoxide and smoke.

Sunshine is now history. It was a disaster.

ter that should not have occurred. What has been learned from it that may prevent its recurring right in your own mine? Ask yourself, "Are you satisfied with your fire procedure?" "Has it been reviewed and revised since 1972?" "Do your new employees know what ethyl mercaptan smells like, and what it signifies?"

Fire Procedure

Clearcut instructions should be given to and be thoroughly understood by the general force underground by means of posters and notices displayed conspicuously in changehouses, shaft houses, underground shops, lunch rooms etc., by booklets and cards on safety, by serious lectures to new employees, and in lunchtime talks to everyone. As men move to new working places, they should be made aware of any change in their evacuation route of travel. As ventilation patterns are altered, what effect will they have on emergency movement of men?

As a general rule, any fire with the exception of one started by an explosion or massive spontaneous combustion begins small and can often be extinguished by the person who discovers it. A quick decision must be made on the spot. "Do I try to put it out, or do I spread the alarm?" If the fire is visible, is small and with little smoke, the person who first sees it might decide to try to extinguish it. If however, the first indication is the sight of smoke in a roadway, the alarm should be given immediate precedence, and the stench injected without delay. That precious 20 minutes at Sunshine would have given the hoistman time to raise three or four more cage loads of men to safety.

All available facts should be given to, and be understood by, the person on surface who is to receive the first report of a fire underground. Depending on the time of day, he may be the topman, the first aid man, the hoistman, the safety director, the superintendent, or a deck man.

Company policy should be carefully reviewed to decide who has the authority to activate the stench injector, but remember: a false alarm is a lot better than the loss of one man or a disaster. A false alarm is not a total loss, as it could take the place of a later fire drill, as required

by the Mining Act of Ontario, or a similar act in the U.S.

Within five minutes of the stench being injected in sufficient quantity into both the compressed air lines and the ventilation air, movement of men should begin underground. The difference between orderly evacuation and panic will depend on the effectiveness of your plan for survival and how well it has been communicated.

Do your men just write down the time they smell the rotten onions, and keep on working? Do they head for the refuge station or lunch room? Or do they take-off individually for the shaft or the ladders to surface?

The inauguration or review of a mine fire procedure might well be undertaken by a small group consisting of the underground superintendent, the safety director, the chief engineer, and the ventilation engineer. The mine manager should be included to decide on matters involving the policy of the company. The services of the engineer of mines, the mine rescue station superintendent, or the inspector of mine rescue training are available if we can be of assistance. To begin with, two charts should be made up: Notification, and Supervision.

The Notification Chart should show first the mechanism to call for and spread the alarm by stench gas, followed by the method of propagating the alarm underground. Printed instructions should tell each person receiving the alarm what to do.

This chart indicates the officials and others to be notified, the order of doing so, and by whom. Telephone numbers should be shown, together with names and numbers of alternates in case the person called cannot be reached. Every possibility of omission should be eliminated. Brevity and speed in action are essential.

Clear and brief printed instructions should be given to each person listed on the Notification Chart and a copy posted at or near the individual's place of work.

These lists should be revised frequently, as supervisory personnel change or rotate. It's bad enough to be faced with a fire call at 3:00 A.M. Sunday morning even with an up-to-date chart.

There should be maintained, preferably by the safety department, an up-to-date

list of the trained mine rescue men available at the mine, their addresses and phone numbers, and a record of their shift and work location.

The Supervision Chart shows at a glance who is to supervise each phase of the fire procedure, and may give their home and office phone numbers. It should be set up in such a manner as to leave no doubt who is responsible for what, and who is alternate or second in command.

Now is the time to list the many jobs that may need to be done, to establish priorities, review them, revise them, and finally test them. Things will go wrong but now is the time to find out the mistakes and correct them. Here are some of the duties that must be performed. Some or all of them may be required, depending on the size and duration of the operation.

1. Immediate notification of supervisors and men underground by stench gas, or other alarms, followed by prompt removal of men in the mine to a place of safety, and then to surface in an organized manner.

2. Establish a check system to account for each man as he reports to the assembly points and to surface. Roving mechanics, electricians, machine doctors, etc. need special instructions.

3. Advise the mine rescue station superintendent, or send a reliable man to open the mine rescue sub-station. Breathing apparatus should be available if and when needed.

4. Assemble mine rescue teams from surface, home, or as the members become available from underground.

5. Establish headquarters, working place, and facilities for rescue teams to prepare apparatus and to rest after a tour of duty.

6. Notify adjacent or adjoining mines, especially if there are interconnected mine workings. You may also need additional rescue teams from them.

7. Notify all department heads whether on shift or at home; they should each be aware of their individual responsibilities as outlined in the Supervision Chart.

8. Notify the provincial, state or federal Department of Mines.

9. Assemble mine plans, including ventilation systems, compressed air and water lines, pumping systems, electrical systems, refuge stations, and fire equipment

locations.

10. Assemble staff to provide supplies, stretchers, blankets, tools, fire equipment, etc. Arrange for meals and possibly sleeping accommodation for rescue teams and others.

11. Appoint a responsible person to handle communication with the news media and families of missing men.

12. Prepare a plan to rotate tours of duty of mine rescue teams. Provide clerical staff to maintain complete records of events with exact times and dates of directives, reports, and the dispatch and return of teams.

13. Tighten security to prevent unauthorized persons from entering the property or from going underground. It is not the intention of this paper to discuss the details of fighting mine fires. Few fires are similar; most can be attacked by direct action with water, fog, or high expansion foam. Some have to be scaled and/or brought under control by the introduction of water-borne sand or tailings. Some general plans may be prepared in advance where possible known hazards exist, for example where heating conditions exist in some sulphide ore zones, or in diesel fueling stations, but generally confusion will reign for a short time after the first announcement. The efficiency of your fire procedure plan will determine how long it takes to eliminate this confusion.

Fire Organization

The purpose of a Fire Organization Chart is to outline the chain of command and the sub-sections or services for which each department chief is responsible. This chart should be an important part of any mine's Plan for Survival.

The briefing officer should be the underground foreman or the underground superintendent and he should have been active in mine rescue training and be familiar with the ideals of training. Rescue teams must have confidence in his direction. The briefing officer will pass on to the team the directives or work orders compiled from progress reports from previous teams, or by discussion with the Control group. Reports should be made to this same person or his alternate by the team captain.

The briefing officer should be made

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THE FUTURE NEEDS OF MINE RESPIRATION EQUIPMENT

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aware of every person going underground, where he is going, what he is going to do, and when he is due back up. Very careful consideration must be given before permitting anything less than a five-man team to go underground during a fire.

Although it may not be necessary to have a doctor at the mine around the clock, unless men are missing, arrangements should be made for daily or twice-daily visits by the doctor. Close watch should be kept on the physical and mental condition of rescue team members after periods of strenuous exhaustive work in extreme heat or humidity.

Fire Control

This is the "nerve center" of the operation. The mine manager, who is legally responsible for the entire operation, should be the head of this group. Here, policy as it relates to the evacuation of men (and women) from underground, requests for outside assistance of men or equipment, security, release of information to the public, notification of families of deceased or injured workmen, and the general program of fire control would be formulated. Key persons in the control group would be the chief engineer, the ventilation engineer, the underground superintendent and, depending on the subject discussed, other department heads. Department of Mines engineers and mine rescue officers would be available for consultation in respect to the Mining Act or mine rescue practices.

Fire Drills

The only way to prove the adequacy of your plan for survival is to test it. Some fire drills conducted by some mines have confirmed the efficient planning of a good fire procedure; some others (and in some instances, experience at an actual fire) resulted in utter confusion through not

knowing what to do.

Knowledge that a fire drill is to be conducted must be confined to only a few top officials. No part of the procedure, including calling the rescue station, should be omitted. Observations made during the tests can help correct errors or inadequacies.

Particular attention should be paid to the stench signal, that is, the time required to receive it and the extent to which it reaches all working places, and to the use of mine rescue crews to reach those who did not receive the warning. Severe reprimand should be given to any workman who ignores the signal. The manner and the order in which men are brought to surface or arrive at refuge stations should be observed carefully. A complete report of the drill should be prepared and thoroughly discussed by all supervisors soon after the test to see if it can be improved, or if further education is necessary.

The Ontario Mining Act requires that a test of the effectiveness of each mine's fire procedure be conducted at least once a year. This test may in effect be during an actual fire, or during a false alarm, or simply as a planned test. A trend has developed where most mines hold off their fire drills until November or December, not in the hope they may have a fire before then, but in case they do, and so won't have to tie up the mine a second time.

I can't quarrel too much with this as it fulfills the Act, but every employee is expecting it at that time of year and is planning for it. Posted fire procedures are reprinted, and the exercise loses some of its value. On the other hand, with the large turn-over of men in some mines, some preparation is necessary to remind the newer men what to do. An ideal would be to have two drills, one planned and one unannounced.

In covering the subject of the future needs of mine respiration equipment, I will be discussing respirators. Thus, it is important that we all understand what a respirator is. A respirator is defined as a device which has been designed to be worn by a person to protect him against inhalation of harmful atmospheres.

Next, let us briefly consider the matter of harmful atmospheres. There are two major classes of harmful atmospheres: (1) oxygen deficiency; (2) air contaminants—airborne particles, vapors and gases, and combinations of airborne particles, vapors, and gases. Depending upon the mining operation, a mine worker may be exposed to any of these harmful atmospheres.

Next, let us briefly review the various types of respirators available. There are three major classes of respirators: air purifying; atmosphere-supplying; and combination air-purifying and atmosphere-supplying.

Air-Purifying Respirators. An air-purifying respirator contains an element that removes contaminants from air prior to the inhalation of air. Since an air-purifying respirator cleanses the ambient air prior to inhalation of air, the ambient air must contain adequate oxygen to support life. Therefore, an air-purifying respirator cannot be used in an atmosphere that is deficient in oxygen.

Both non-powered and powered air-purifying respirators are available. It is the breathing action of the wearer that operates a non-powered air-purifying respirator. During the inhalation phase of breathing, air is pulled through an element that removes contaminants. During the exhalation phase of breathing, air coming from the lungs of the respirator wearer is expelled from the respirator.

A powered air-purifying respirator contains an air pump, which may be carried by the respirator wearer or which

may be separated from the respirator wearer and be located at some convenient place, that pulls air through an element which removes contaminants from the air. The air pump pushes the cleansed air to the respiratory inlet covering of the respirator.

The air inside the respiratory inlet covering of a non-powered air-purifying respirator during inhalation will be at a negative pressure, a pressure lower than that of the ambient atmosphere. Thus, if a poor seal exists between the respiratory inlet covering and the respirator wearer's face, contaminated air may penetrate into the interior of the respiratory inlet covering during inhalation.

The air inside the respiratory inlet covering of a powered air-purifying respirator always is at a positive pressure, a pressure higher than that of the ambient atmosphere. Thus, any leakage of air between the respiratory inlet covering and the respirator wearer's face always is outward from the respiratory inlet covering.

The existence of a negative air pressure inside the respiratory inlet covering of a non-powered air-purifying respirator during inhalation and the existence at all times of a positive air pressure inside the respiratory inlet covering of a powered air-purifying respirator means that the powered device offers a much higher degree of protection than the non-powered device.

Air-purifying respirators are available for protection against inhalation of airborne particles, vapors and gases, and combinations of vapors and gases.

Atmosphere-Supplying Respirators. A respirable atmosphere from a source which is independent of the ambient atmosphere is supplied to the wearer of an atmosphere-supplying respirator. There are three major classes of atmosphere-supplying respirators, with severe-

al sub-classes: (1) Supplied-air—airline, hose mask without blower; hose mask with blower; (2) self-contained breathing apparatus—open-circuit, closed-circuit; (3) combination supplied-air and self-contained.

Airline Respirators. In an airline respirator, compressed respirable air from a stationary source (an air compressor or a tank of compressed air) is supplied through a small-diameter hose to the respiratory inlet covering of the respirator. Airline respirators may have three modes of operation: Continuous flow; Demand flow; and Pressure demand flow.

Respirable air is supplied continuously at a steady rate to the respiratory inlet covering of a continuous-flow airline respirator, and the pressure of the air inside the respiratory inlet covering is positive, above that of the ambient atmosphere, during both inhalation and exhalation. The demand-flow airline respirator is equipped with an air-flow control valve that supplies respirable air to the respiratory inlet covering only during inhalation, and the pressure of the air inside the respiratory-inlet covering becomes negative, below that of the ambient atmosphere, during inhalation. The pressure-demand-flow airline respirator is equipped with an air-flow control valve and a special exhalation valve that supplies respirable air to the respiratory inlet covering during inhalation slightly in excess of that needed by the respirator wearer to insure that the pressure of the air inside the respiratory inlet covering remains positive during inhalation. Since the pressure of the air inside the respiratory inlet covering of the continuous-flow airline respirator and inside the respiratory inlet covering of the pressure-demand-flow airline respirator is positive during both inhalation and exhalation, while the pressure of the air inside the respiratory inlet covering of the demand-flow airline respirator drops from positive during exhalation to negative during inhalation, the degree of protection offered by both the continuous-flow airline respirator and the pressure-demand-flow airline respirator is much greater than that offered by the demand-flow airline respirator.

Hose Masks. The respiratory inlet covering of a hose mask without blower is

connected to a large diameter hose which has its open end located in an area where the air is respirable. During the inhalation phase of breathing, air is pulled through the large diameter hose into the respiratory inlet covering.

In a hose mask with blower, the respiratory-inlet covering is connected to a large-diameter hose which in turn is connected to an air pump, motor-operated or hand-operated, which is located in an area where the air is respirable. The air pump pushes respirable air through the large diameter hose to the respiratory inlet covering. If for some reason the air pump fails to operate, the respirator wearer's breathing action pulls respirable air through the large diameter hose and air pump.

Self-Contained Breathing Apparatus. The wearer of a self-contained breathing apparatus carries a source of respirable air on his body. In the open-circuit self-contained breathing device, the source of the respirable air may be a tank of compressed air, liquid air, compressed oxygen, liquid oxygen, or a solid state oxygen generator. There are three modes of operation of the open-circuit device: Continuous flow, Demand flow, and Pressure demand flow. The operational characteristics of these three types of self-contained breathing devices are similar to those of the three types of airline respirators previously described.

There are two types of closed-circuit self-contained breathing devices: recirculating, and oxygen generating. In the recirculating type self-contained breathing device, the moisture and the carbon dioxide gas in the exhaled breath is removed by a chemical housed in a canister, and oxygen gas from a tank of compressed oxygen gas or from a tank of liquid oxygen is added to the air of the exhaled breath to make up for the oxygen consumed by the respirator wearer.

In the oxygen-generating type device, the moisture and the carbon dioxide gas in the exhaled breath reacts with a chemical housed in a canister to result in the production of oxygen gas which is added to the exhaled breath to make up for the oxygen consumed by the respirator wearer.

Atmosphere-supplying respirators may be used for protection of workers against

inhalation of harmful airborne particles, vapors, and gases. Inasmuch as it is possible that the source of the respirable air supplied to the respiratory inlet covering of a supplied-air type atmosphere-supplying respirator may fail, this type of respirator should not be used for protection of workers against inhalation of atmospheres that are immediately dangerous to life or health, including atmospheres that are deficient in oxygen.

Since a self-contained breathing type atmosphere-supplying respirator includes a source of respirable air carried by the respirator wearer, this type of respirator can be used for protection of workers against inhalation of atmospheres that are immediately dangerous to life or health, including atmospheres that are deficient in oxygen.

Respirators should not be considered as the primary means of protecting workers against inhalation of harmful atmospheres. The primary means of protecting workers against inhalation of hazardous atmospheres is engineering control of these atmospheres. Engineering control should be used to prevent harmful atmospheres in workplaces or to reduce dangerous atmospheres to safe levels in workplaces. Respirators should be used only when engineering control of harmful atmospheres is impossible, not feasible, not adequate, or is being installed.

Health and safety standards issued under the provisions of the Federal Coal Mine Health and Safety Act and under the provisions of the Federal Metal and Non-Metallic Mine Health and Safety Act require the use of respirators when engineering control of harmful atmospheres is impossible, not feasible, or is being installed. These standards require the use of specific types of respirators for emergency escape and for rescue operations. Each underground miner is required to carry, for self-rescue purposes, an air-purifying respirator designed to provide an hour of protection against a concentration of 10,000 ppm carbon monoxide gas in air. Self-contained breathing devices which offer a useful service life of at least one hour are required for mine rescue operations.

Respirators used to protect workers in mining operations must be approved either by the Bureau of Mines or jointly

by the Mining Enforcement and Safety Administration and the National Institute for Occupational Safety and Health.

From 1919 and until May 1972, respirators were tested and approved by the Bureau of Mines. Since May 1972, respirators have been tested and approved jointly by the Mining Enforcement and Safety Administration and the National Institute for Occupational Safety and Health. The actual testing of respirators is carried out in a laboratory located in Morgantown, West Virginia which is operated by the National Institute for Occupational Safety and Health.

An amendment of the respirator test and approval document, Part 11 of the Title 30 of the Code of Federal Regulations, states that the approvals of the various types of respirators granted by the Bureau of Mines will be recognized as valid until the following dates: March 31, 1976 — particulate-filter respirators; March 31, 1976—chemical cartridge respirators; March 31, 1979—self-contained breathing apparatus; March 31, 1980—supplied-air respirators; no definite date—gas masks. After these dates, only respirators approved jointly by the Mining Enforcement and Safety Administration and the National Institute for Occupational Safety and Health will be recognized as approved.

The philosophy of both the Mining Enforcement and Safety Administration and the Bureau of Mines is to eliminate occupational safety and health hazards in mining operations by means of engineering control. These government agencies feel that respirators designed to protect workers against the inhalation of harmful atmospheres should be used only as a last resort. However, both of these government agencies are realistic and are aware that engineering control of harmful mine atmospheres may not always be possible, feasible, or adequate, and when this is the situation, the use of respirators is encouraged.

Mining involves more than 4,000 substances and more than 12,000 operations. Since the available manpower and funds for carrying out research and development work in mine safety and health is limited, research and development can cover only major safety and health problems. Recent projects funded by the Bu-

reau of Mines have resulted in the development of two new self-contained breathing respirators for self-rescue use and the development of a new powered air-purifying respirator for use in dusty atmospheres.

New Self-Contained Breathing Respirators for Self-Rescue. Current government regulations require each underground miner to carry an air-purifying respirator that offers one hour of protection against a concentration of 10,000 ppm carbon monoxide gas in air. This device is used as a self-rescue respirator to permit miners to escape from an area in a mine which suddenly may become contaminated with carbon monoxide gas generated by a fire or explosion. This respirator utilizes a granular substance, hopcalite, to catalyze a reaction between the carbon dioxide gas and the oxygen gas in the air to convert the toxic carbon monoxide gas to carbon dioxide gas prior to inhalation of the air. The air-purifying type self-rescue respirator weighs about 2½ pounds, has dimensions approximately 3 by 4 by 6 inches, and is priced at about \$40. At the present time, two firms market this type of respirator in the United States. Unfortunately, this type of respirator does not provide respiratory protection against an oxygen deficient atmosphere which sometime occurs in mine areas, and it does not protect workers against inhalation of various toxic gases which may be generated by fires in mining equipment.

The Mining Enforcement and Safety Administration and the Bureau of Mines decided that a self-contained breathing apparatus that is light-weight and compact is needed for use as a self-rescue respirator by mine workers, since such a respirator would provide the mine workers with protection against an atmosphere deficient in oxygen and an atmosphere containing toxic airborne particles and toxic vapors and gases. The Bureau of Mines funded two development projects pertaining to self-contained breathing type self-rescue respirators. One project involved the development of a respirator which would provide a 10-minute service life, and the other project involved the development of a respirator which would offer a 60-minute service life.

The development projects included studies of all potential systems for self-contained breathing apparatus. Studies involved sources of respirable air, including ultra-high pressure compressed air, compressed oxygen gas, liquid air, liquid oxygen, solid state oxygen-generating materials, and metallic superoxides which utilize the moisture and carbon dioxide gas in the exhaled air to generate oxygen gas. Studies also involved flow systems for self-contained breathing apparatus, including open-circuit, pendulum closed-circuit, and loop closed-circuit. Tradeoff factors considered in the studies included weight, size, reliability, thermal aspects, maintenance requirements, and flexibility in accommodating various breathing rates. As a result of these studies, a pendulum closed-circuit flow system and a metallic superoxide respirable air source were selected for the 10-minute service respirator, and a loop closed-circuit flow system and a metallic superoxide rescue respirator were selected for the 60-minute service respirator.

The 10-minute service self-contained breathing apparatus developed weighs about 2½ pounds, has dimensions approximately 6½ by 5½ by 3½ inches, and has an estimated price of \$125. The 60-minute service self-contained breathing apparatus developed weighs about 4½ pounds, has dimensions approximately 7½ by 6½ by 3½ inches, and has an estimated price of \$150. Both respirators have performance characteristics which meet the approval criteria for self-contained breathing apparatus listed in the respirator test and approval document, Part 11 of Title 30 of the Code of Federal Regulations. Neither of the respirators is commercially available at this time.

The Mining Enforcement and Safety Administration is considering a revision of occupational safety and health regulations for the mining industry which would require that each underground miner carry a self-contained breathing type self-rescue respirator. The revised regulations would permit the application of a 10-minute service device only for use in escaping from a hazardous area to a nearby area where a 60-minute service device is stored.

New Powered Air-Purifying Respirator for Dusty Atmospheres. The Bureau of

Mines funded a project to develop a powered-type air-purifying respirator for use in dusty atmospheres which utilizes an air-curtain helmet as the respiratory inlet covering. The new respirator consists of an air pump (operated by a battery or by an external source of electricity) which pulls air through a filter element that retains dust particles and pushes the cleansed air to an air distribution system attached to a protective helmet worn by a mine worker. The air distribution system produces two curtains of air, an inner curtain and an outer curtain, which pass in front of the mine worker's face and prevent dust particles in the mine atmosphere from reaching the mine worker's nose and mouth. Performance tests carried out on this respirator indicates that it will permit the penetration of only 10 per cent of the dust particles present in the mine atmosphere into the breathing zone of the respirator wearer. Thus, the respirator is 90 per cent efficient in protecting a mine worker against inhalation of dust particulate matter. It is estimated that the price of this respirator would be \$250. The newly developed powered air-purifying respirator is not commercially available at this time.

Respirator Protection Factors

A respirator protection factor is a measure of the level of protection provided by a respirator to the respirator wearer. It is defined as the number equal to the ratio of the concentration of a contaminant in the ambient atmospheric air to the concentration of the contaminant in the air in the respirator wearer's breathing zone inside the respiratory inlet covering of the respirator. To determine the protection factor for a respirator of a given design, it is necessary to conduct quantitative performance tests of the respirator worn by workers carrying out their usual tasks in contaminated work areas, or to conduct quantitative performance tests of the respirator worn by human test subjects in a test atmosphere who carry out exercises simulating those carried out by workers. A reasonable basis for assigning a protection factor to a respirator of a given design, which has been agreed to by many respirator experts, is to use a panel of human test subjects having anthropometric

characteristics representing 95 per cent of the adult working population and to determine the protection factor achieved by 95 per cent of these human test subjects while wearing the respirator. After tabulating all of the protection factors for the various respirators of a single type of respirator, it is possible to select a protection factor for this particular type of respirator. This protection factor is the lowest value assigned to any of the various respirators of the particular type.

Multiplying the established breathing time weighted average concentration for a specific air contaminant by the respirator protection factor for a particular type of respirator gives the value of the maximum concentration of the contaminant for which the particular type of respirator may be used. The value of the maximum concentration of a specific contaminant in air for which a particular type of respirator can be utilized is known as the "maximum use concentration." If the actual concentration of the contaminant in the ambient atmospheric air of the work area is less than the calculated maximum use concentration, then the particular type of respirator can be used to protect workers in the contaminated work area.

A problem exists at this time in assigning protection factors for particular types of respirators. Under the provisions of the Standards Completion Program being carried out jointly by the Occupational Safety and Health Administration and the National Institute for Occupational Safety and Health to develop so-called "mini" standards covering exposure of workers to the somewhat more than 400 toxic substances listed in Section 1910.98 of the Occupational Safety and Health Standards for Industry promulgated by the Occupational Safety and Health Administration, the National Institute for Occupational Safety and Health engaged a contractor to develop a document on respirator protection factors which would list protection factors assigned to particular types of respirators and which would justify these protection factors. The two government agencies intended to use these protection factors in selecting respirators for listing in the mini standards. The contractor engaged the services of a consultant to write the

document. The consultant was employed previously by the contractor as the leader of the contractor's section engaged in carrying out respirator research and development and was in charge of respirator performance testing which resulted in the test data used to assign protection factors for particular types of respirators. The validity of the protection factors assigned to various types of respirators listed in the document prepared by the consultant now is being questioned for several reasons.

The respirator performance test data used by the consultant to determine respirator protection factors was not obtained for this purpose, but instead this data was obtained in the development of new respirator test equipment and procedures. A significant portion of the respirator performance test data is for tests classified as "terminated," and the reasons for terminating tests either are vague or unknown. However, the consultant interpreted data for terminated tests in developing respirator protection factors. A significant lack of reproducibility of respirator performance test results is shown by the large number of tests carried out wherein the same human test subject tested the same respirator several times, achieving protection factors which vary over an extremely wide range. An analysis of the anthropometric data for the human test subjects used in the respirator performance tests shows that the panels of human test subjects were not anthropometrically based upon the adult working population, although the consultant's document infers that anthropometrically representative panels were used. The results of many respirator tests carried out using a certain aerosol as the test agent are of questionable value, because after the tests were carried out it was discovered that the instrument used to measure the performance of the respirators was producing incorrect results. A recent study of the respirator performance test results carried out by the Industrial Safety Equipment Association which eliminated use of questionable data has resulted in respirator protection factors for various types of respirators that differ from those assigned by the consultant. The Association has stated that the respirator protection factors being used

by the Occupational Safety and Health Administration and the National Institute for Occupational Health and Safety are not justified by the test data employed by the consultant to develop these respirator protection factors, and this is an important problem that must be solved in the near future.

Quantitative Respirator Fit Tests

The respirator test and approval document, Part 11 of Title 80 of the Code of Federal Regulations, does not include quantitative respirator fit test criteria. This means that it is possible for respirators equipped with respiratory inlet coverings which seal poorly on respirator wearers' faces to be approved.

For several years, the National Institute for Occupational Safety and Health, the Division of Occupational Safety of the Atomic Energy Commission (now the Division of Occupational Safety of the Energy Research and Development Administration), and the Directorate of Regulatory Standards of the Atomic Energy Commission (now the Office of Standards Development of the Nuclear Regulator Division) have sponsored work at the Los Alamos Scientific Laboratory aimed at developing equipment and procedures for carrying out quantitative respirator fit tests and aimed at developing quantitative respirator fit criteria. The purpose of this work was the development of tests and criteria which would insure that approved respirators would be equipped with respiratory inlet coverings that would give satisfactory seals on the faces of 95 per cent of the adult working population both male and female.

The Los Alamos Scientific Laboratory has succeeded in developing equipment and procedures for use in carrying out quantitative respirator fit tests. This laboratory has recommended to the Mining Enforcement and Safety Administration and the National Institute for Occupational Safety and Health that these two agencies consider an amendment to the respirator test and approval document, Part 11 of Title 80 of the Code of Federal Regulations, which would require that quantitative respirator fit tests be established as part of the respirator approval procedures. The work carried out by the Los Alamos Scientific Laboratory indi-

cates that new respiratory inlet coverings of several sizes may be needed to insure that approved respirators are equipped with respiratory inlet coverings that would give satisfactory seals on the faces of 95 per cent of the adult working population, both male and female. Since the respirator manufacturers would have to develop new respiratory inlet coverings of several sizes and would have to construct new tools for use in producing these new respiratory inlet coverings, the

Los Alamos Scientific Laboratory has recommended to the Mining Enforcement and Safety Administration and the National Institute for Occupational Safety and Health that the respirator manufacturers be given at least three years to comply with new quantitative respirator fit test criteria. It is not known at this time what action the two government agencies will take on the proposed quantitative respirator fit test criteria.

MINE SHAFT FIRE AND SMOKE PROTECTION PROTOTYPE SYSTEM

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As metal and nonmetal mines become deeper, larger, and more mechanized, the fire danger increases because of the increased fuel loading in the mines and the restricted miner egress. This fact was unfortunately illustrated in May 1972 by the Sunshine mine fire at Wallace, Idaho, in the Coeur d'Alene lead-zinc-silver mining district. Ninety-one miners lost their lives in the disaster.

To help solve this health and safety problem, and better protect the production capability of our nation's mines, the Bureau of Mines proposed development of a mine shaft fire and smoke protection system for metal and nonmetal mines through contract research. The methodology for hardware development and in-mine testing was to follow that used in the Bureau's successful development of automatic fire protection systems for large mobile mining equipment.

FMC Corporation, San Jose, Calif., was awarded a contract (HO242016, May 1974 to June 1975) to (1) evaluate non-coal mine shaft fire and smoke hazard problems and (2) develop and demonstrate a reliable mine shaft fire and smoke control system. This system was to be flexible in design so that with modifications it would be applicable to the majority of metal and nonmetal mine shafts and adjoining shaft stations. Following the system's in-mine fire test at the Silver Summit shaft near Wallace, Idaho, the contract was extended for an additional 15 months (July 1975 to September 1976) for long-term validation testing and detailed evaluation of the cost-effectiveness of the system's hardware.

Definition of the Hazard

The greatest causes of noncoal mine fires in or near shafts are electrical in nature. Welding and torch cutting are also major causes. Other causes are spontaneous combustion and friction. As

mines become deeper, ventilation systems can become more complex, thus spontaneous combustion hazard will probably also increase. The Bureau has taken this into consideration in its planning for future research on improved fire protection system.

Smoke control is an important requirement of the system because air contamination (i.e., smoke, toxic products, etc.) in underground fires is the most dangerous hazard. Most miners die from inhalation of toxic gases produced from combustion rather than being burned to death in underground metal and nonmetal fires.

System Design and Mockup Testing

As a result of the fire and smoke problem analysis portion of the contract, the design criteria for a mine shaft fire and smoke protection system were developed. From such criteria the first system design was generated. It utilizes thermal, carbon monoxide, and ionized-particle smoke detectors and remotely controlled smoke doors and sprinklers. The system protects both the shaft and shaft station areas. The system's surface control unit receives the fire warning signal via multiplex wiring through two separate routings. The system's underground control units are then activated from the surface to warn the miners at each shaft station. A stench system would then be activated by surface personnel to warn other miners.

The sprinklers and doors can be opened or closed from either their local control unit or the master control unit on the surface. Fire warning horns and lights and mine evacuation signals at the underground units can also be controlled from the surface control unit. Automatic sprinkler actuation is currently not a feature of the system, but such a design alternative could be easily added if a user wanted such an option.

System Selection and User Manual" in the fall of 1976. The user manual will also be made available through the National Technical Information Service.

Advantages and Cost of the System

This first-generation, mine shaft fire and smoke protection system has a very fast response to fire situations. Also, having sprinklers in the shaft and shaft station area is much more effective in extinguishing fires than the commonly-used shaft-collar water rings. The cost of the system is estimated to be from \$10,000 to \$40,000 per shaft station level, depending on the degree of sophistication desired of the system. This is a large investment, but compared with the millions of dollars a shaft fire can cost and the increased protection provided the miner, the system will be a significant contribution to the improved safety of underground mines.

Summary

This project involved efforts by FMC and the Bureau to define the mine shaft fire and smoke hazard problem, then design, fabricate, and in-mine test prototype hardware for a system that better protects miners and the mine than the shaft-collar rings now commonly used. The resulting mine shaft fire and smoke protection system involves both thermal and smoke detectors, remotely controlled smoke doors at the shaft station, and remotely controlled sprinklers. The system was successfully demonstrated by an actual fire test set in the Silver Summit shaft near Wallace, Idaho in the spring of 1975. Long-term, in-mine testing of alternative system designs is currently being conducted to show that the system has credibility as a reasonably-priced, reliable piece of improved mining health and safety hardware.

A shaft and shaft station mockup was built at FMC's plant in San Jose, and system component tests were conducted during the winter of 1975. Mockup testing was highlighted March 20, 1975 when the system's hardware was demonstrated to Bureau, MESA, and industry representatives with actual fire tests.

In-Mine Fire Testing

After the mockup testing, the final design for the mine shaft fire and smoke protection system prototype was developed to be installed in the 3,000 level of Consolidated Silver Corporation's Silver Summit shaft near Wallace, Idaho. The Hecla Mining Company operates the facility. To maintain timeliness of this preliminary test of the first generation hardware, the north drift sprinklers and smoke door, and one-half of the shaft sprinklers were not installed.

The first in-mine testing of the system took place in April 1975. The hardware was successfully demonstrated to Bureau, MESA, and Hecla personnel by actual in-mine fire testing. A smoke test of the mine's ventilation was made prior to the actual fire testing. A final report on the system design and testing will soon be available through the National Technical Information Service in Springfield, Va.

The objectives of the follow-up work with FMC are to (1) reinstall the mine shaft fire and smoke protection prototype system in at least two operating mine shafts for long-term, reliability testing, and (2) conduct cost-effectiveness evaluations of optional system designs and uses. This follow-up will help analyze the reliability of the system and demonstrate how it can be modified for other underground fire protection situations.

The follow-up work will produce a "Mine Shaft Fire and Smoke Protection

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