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ACCOMPLISHMENTS IN DESIGN OF ROOF-BOLT MATERIALS AND INSTALLATION EQUIPMENT

By J. ROBERT FLETCHER
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(Part of a panel discussion, aided by slides.)

Since the conception of roof-bolting in the late 1940's by C. C. "Jim" Conway in the mines of southern Illinois, there has been a continuous history of mechanical advancement and safety.

Over the years rotary drilling machines have become more powerful, better able to install bolts rapidly and penetrate harder strata.

There have been advances in tools such as bits and steels.

The bolts themselves have been upgraded, and a new generation of anchoring materials is under test. However, two lines of development are receiving particular attention at this time: automation and operator safety.

To date, success has been achieved in automatic drilling of the hole. In practice, the operator positions the drillhead, places the drill steel between the chuck and roof while aligning with the drillguide, actuates the feed and rotation controls, and is then free to move from the drilling area.

The automatic controls, through change in hydraulic pressure, sense variations in roof structure, as from shale to sandstone. In shale the drill may rotate at 500 rpm with 3000 lbs. thrust. With internal dust collection, rate of penetration should approach six fpm. On encountering sandstone, rotation immediately drops to 250 rpm and thrust increases to as much as 10,000 lbs. If desired, impacting will commence. In sandstone, penetration is a function of hardness, and will probably average three fpm. Once the hard layer is drilled and the bit is again in shale, the rotation, thrust, and rate of penetration return automatically to the original setting.

Manual reaction is too slow to make instantaneous changes in rotation and thrust before damage to the bit. Automatic control increases bit life by as much as 25 per cent, as the bit is not dulled by high speed rotation and low thrust while in abrasive rock. A sharp bit drills more rapidly, demands less power from the machine, and reduces maintenance.

While the hole is being drilled, the operator can move from the drilling area, preferably toward the outby end of the machine under bolted roof. His free time may be used in making up bolts, changing bits, or in other work procedure.

In the last 12 months, protection of the bolting machine operator has been emphasized. Many safety devices have been added to the machine, not to mention supports for unbolted roof between the last row of bolts and the face.

A cab that will support 18,000 lbs. or 15 psi must be installed over the tramming control location to protect the operator from spalling roof and ribbing as he drives from place to place.

At the drilling location, de-energizing bars cover hydraulic controls so electrical circuits will drop out, should the man be squeezed between the controls and the rib; or to permit manual control if he is endangered by any of the drill movements. To overcome hydraulic lag due to inertia, a solenoid-operated dumping valve by-passes all hydraulic oil at the pump.

Another device is a latch to hold the drill steel or extension wrench.

A safety canopy at the drill location may be a hydraulic jack wedging between the floor and roof, or a pivoted arm between the machine and roof for protection from minor falls.

A study of roof-fall fatalities shows the majority occur under unbolted roofs. For many

years the roof bolt operator has been exposed beyond the last row of bolts with a minimum of roof support in the drilling area. Though many approved plans require temporary roof jacks or posts in the unbolted span, it is evident the setting of the temporary support has been without protection from possible falls. A corollary to the setting of a temporary support is that it must be taken down. Too often the post is inadequate or improperly placed, creating a false sense of security.

Recently a Temporary Roof Support system (TRS) has been developed for various style machines. The TRS is either carried on, or extended from the front of the roof drill. Tramming and TRS controls are in the cab of the machine, far enough outby so the operator is always under bolted roof.

Procedure is to drive the machine to the unbolted area and properly locate the TRS to protect the drilling position with the wedged arms. The TRS will support a 15 to 30-ton load. With the addition of a canopy support, the driller has protection while installing as many as three rows of bolts with an extending boom.

In the case of machines which position by moving the body of the drill, the TRS is carried astraddle the forward part of the unit. Once placed, it is cut off by means of hydraulic quick-disconnects, and either two or three rows of bolts may be installed before moving.

Drills capable of installing only one row of bolts per machine-setting use a single TRS bar.

The TRS has been approved as part of the bolting system in a number of mines. It replaces the temporary jacks. This increases bolting capacity, as setting and taking down the jacks can consume as much as 20 per cent of the working time.

Summarizing, experience has shown that automatic controls and TRS are well-accepted at the working face. Proof is the positive attitude of the operator, which is the most important factor in the effective use of any safety equipment.

CLEAN-UP PROGRAM AND EQUIPMENT IN UNDERGROUND MINES

By DENNIS FRAILEY
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Since enactment of the Federal Coal Mine Health and Safety Act, the mining industry has been faced with many problems because of the lack of technical knowledge to comply. In the past, when the industry has been faced with wage increases, they have attempted with some degree of success to absorb these increases by increasing the efficiency of the operation. Since the enactment and rigid enforcement of the Act, it has become necessary that industry add additional non-productive equipment and labor, contributing to increasing costs. As a result, many mines in the country have had productivity reduced to a point where they are now marginal operations.

In order to have an adequate and acceptable clean-up program, and in an effort to comply with section 304(a) of the Federal Coal Mine Health and Safety Act, additional equipment has been purchased and additional men employed.

The one sentence in the Act which states, "Coal dust including 'float dust' deposited on rock-dusted surfaces, loose coal and other combustible materials shall be cleaned up and not permitted to accumulate in active workings or on equipment therein," has probably caused more uncertainty and disagreements than any other one thing pertaining to the Act.

Soon after the register was published, we, like other companies, composed a program that we were to institute, and posted it at each of our mines to comply with 75.400-2 of the *Federal Register*. It read something like this, "After a mining sequence has been completed and the roof supported, the miningmachine would be used to clean the loose material from the floor." We realized this program would not be accepted as adequate, since the mining machines in our Illinois mines are, for a large part, boring type. This machine's maneuverability and stiffness did not lend it to be a practical clean-up unit. In addition, the loading time lost at the face was prohibitive. In the meantime, we were looking for equipment that would best fit our situation. During this same period, a special effort was made to keep other combustibles out of the mine.

Late in 1970, for the Illinois mines, we purchased an electrically-operated, rubber-tired Melroe "Bobcat" M-600 mining machine. This machine is a front-end bucket-type loader. The machine is 60 inches wide X 105 inches long, and weighs 3,740 pounds. The bucket has a capacity of .41 cubic yards and the machine has a turning radius of half its length. This machine is used to push loose material to the face, where it is loaded by the continuous miner. After some modifications on the bucket to fit the kerf made by the bottom sprocket of the continuous miner, we thought that an acceptable job of clean-up could be done. The quality of clean-up depends on the dexterity of the operator, but the job-bidding provision of the National Bituminous Coal Wage Agreement of 1971 intensifies the problem of keeping good operators on the machine.

The machine will do an acceptable job. However, we have encountered other problems in our clean-up: First, the conveyor of the continuous mining machine is designed with a slot in the conveyor on the return of the conveyor chain, which by necessity allows the coal fines to fall out, preventing the foot shaft from clogging. Consequently, fine coal falls on the mine floor. This material is then carried back, by the drag on the shuttle car, to the area that the "Bobcat" had previously cleaned. The second problem we have

encountered is the mining plan, especially in panels.

The mining plan for a panel is a three-entry system, one entry of which is an intake and one a return, with the belt in the middle entry. After the panel is developed and pillaring is ready to begin, two rooms are developed through a 400-foot block. Then, 45° lifts are driven on 27-foot centers off the room center through a 40-foot block. The present mining plan has been successful from the standpoint of safety and production since 1954; therefore, we have been hesitant to make a change. However, with the addition of the clean-up machine, two working places are not compatible to three pieces of face equipment. Therefore, it almost becomes a "must" to change our plan, especially in rooms to facilitate coal loading, roof support and clean-up. At present, we are in the process of studying a new plan. At the King's mine, in Indiana, an articulated battery tractor with a front-end loader was purchased. This mine has all ripper-type machines and, except for the slightly uneven floor, clean-up is easier because of the 90° angle of the rib to the floor.

I do not want to imply that, since we have started using the clean-up equipment, we have been free of violations. Either machine is capable of doing the job but, as aforementioned, some problems will have to be eliminated.

HOW THE FEDERAL COAL MINE ACT AFFECTS MINE VENTILATION DESIGN

By JOHN E. CAFFREY
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William J. Montgomery in his book "Theory and Practice on Mine Ventilation"[1] stated:

"Ventilation is vitally important to underground mining for three reasons: First, it sweeps all workings with a plentiful supply of air and drives to the outside the smoke, gases, and contaminated air which would be injurious to the miners; Second, it dilutes and renders harmless the explosive gases emitted from the strata, thus eliminating the dangerous conditions caused by the accumulation of these gases; Third, it keeps the mine air as nearly as possible of the same composition as the outside air, thus giving to the miner the healthiest possible condition in which to work . . . ."

Specific methods to achieve the above basic reasons for mine ventilation were established in the Federal Coal Mine Health and Safety Act of 1969. Sections 303(y)(1); (y)(2), and Section 317(f)(4) of the Act, which can be broadly described as entrapment features, are controversial and debatable in the minds of many mining engineers in their intent and method for effecting.

303(y)(1) in certain cases prohibits the use of belt haulage entries as an intake for face ventilation. This is to say that air traveling in a belt entry will be placed into the returns and not used for face ventilation.

303(y)(2) limits the velocity of the air on trolley haulage entries. The regulations, as published in the Federal Register, have set this limit at 250 feet per minute unless a higher velocity is approved by the District Manager.

317(f)(4) provides that escapeways be separate from belt and haulage ways, and ventilated with intake air for the entire length to the beginning of each working section.

The above provisions are applicable to all new mines. It is the intention of the authors of this article to evaluate the effects of these provisions on a large mine with multiple fans and complex ventilation networks. The design of a fairly big mine on an exhausting ventilation system, with which the authors are associated, will be used for illustrating the principles. The allocated property is intended to form a full size mine of 4 million tons of clean coal annually. Consideration of the ventilation in this mine is based on dividing it into three production zones. consistent with geology, geographic orientation and management.

In this property in two production zones, coal is loaded into shuttle cars, onto belts, into mine cars, and the loaded cars are then pulled by electric locomotives for transportation to the tipple. Supplies are handled by trolley wire-track system. Each production zone is served by a main haulage and the area is subdivided by submains into blocks of roughly 5 million tons of raw coal. A positive bleeder system is intended for each block before pillaring starts in the block.

In order to ascertain some effects of the Act, a comparative computer simulation was developed by Kevi Rao, mining engineer with us and formerly a ventilation engineer, safety officer, and mine manager of a large coal company in India. Mr. Rao used the Penn State University Department of Mining computer program. In the computer simulation program, one case presumes full application of the cited sections of the Law, and a second case removed the restrictions occasioned by the law. An attempt to isolate each section of the Act and to simulate its effect proved to be beyond our computer time limitations.

The overall layout of the simulator program was based on a conceptual block design consistent with our planning. Eleven entries branch off from the intake shaft, six on one side with load and empty tracks and the remaining five from the other side which serve as smoke free intake escapeways. The 240 feet of solid barrier left between the two sets of intakes gives better roof control in the entries and helps, reasonably, in getting multiple intakes. If we exceed a developed span of over 400 feet, serious roof control problems will be encountered during the life of these entries; and further, they pose bump hazards during final extraction since the pillars could build high stress energy. So, as a policy, we try not to exceed six entries in one set.

Sub-mains are intakes and start from the main haulage with six entries. The inby three entries in each set serve as haulage intakes and the outby three serve as smoke free intakes up to the point where the first flat branches off. Beyond this point the outby entries of the sub-mains will be utilized to conduct return air from the section to the sub-returns. Each flat or section is intended to have five entries and will be driven to a length of 5,000 feet using double-split face ventilation. The flat will be pillared, driving rooms on retreat. It is our intention that we should be able to provide at least 50,000 cfm to each working section to dilute the anticipated methane and to effect good ventilation at the face.

In all input data for the two cases parameters applied were:

1. Leakage resistances are generated through the program by trial runs for known leakage values and these values were used consistently in both simulations.

2. All leakage was dumped through a particular leakage path.

3. 10 ft. diameter Joy Axivane fan characteristics were used as input data in both simulations.

Quantitative effects of the cited three provisions of the law show the following:

(1) In Case 1, where the three sections of the law are applied, the bulk of the air flows in smoke-free intake mains (256,700 cfm in five entries vs 152.300 cfm in six entries of haulage intakes). This is due to compliance of the velocity restrictions on trolley entries. Similar conditions prevail in sub-mains and flats. Both the intake systems are isolated one from the other all along, and the only place they mix is at the working face. Regulation of haulage intakes at the shaft bottom is required to comply with velocity standards in the haulage entries. Additional haulage intake regulators in nearby Flats (No. 1 and No. 2) are required in the simulation to obtain better distribution of haulage intake air in the system.

On Flats No. 3 and No. 4, sub-marginal quantities flow on the trolley track entries (7,000 to 7,500 cfm) and marginal quantities flow on belt entries in No. 3 and No. 4 Flats (approximately 9,000 cfm).

From past experience in Gary District, methane liberations of 800 to 900 cubic feet per ton of coal mined are not unusual. Further, it is noted that quite an appreciable quantity of methane will be liberated outside the active face from the fractured coal. The estimate of air needed on the belt split to keep methane diluted to 1 per cent is made on the basis of the above quoted liberations. On a 4,500 ft.-long belt line, during peak loading, the gas liberation in the belt entry from the coal on the belt alone will call for 9,500 to 10,000 cfm of air. As such, on belt entries in No. 3 and No. 4 Flats, the quantities are just marginal. The air quantities on track entries No. 3 and No. 4 are inadequate. In the interest of safety alone, it is not desirable to live with such sub-marginal quantities of 7,000 to 7,500 cfm on trolley wire entries where trolley pole sparking is not uncommon. Since the mainline haulage intake is already at maximum allowed velocity, no more air can be obtained to help this situation.

(2) The system in Case 1 is operating at a water gauge of 5.8" versus 4.6" in Case 2. The detrimental effects of high water gauge in mine ventilation systems cannot be overstressed.

(3) The system of Case 1 kills the merits of an open ventilation system and the benefits of equalization. In a complex network system with multiple fans, there will certainly be some critical spots at the interface on the rail haulage intake. It is not feasible from a practical standpoint to find workable solutions for those critical spots without adversely affecting ventilation on the track entries elsewhere, or without violating the velocity limit in the track entries.

(4) Case 1 is only capable of delivering approximately 78 per cent of the system's capacity. For the same shaft, roadway size and fan, Case 2 will give about 256,000 cfm at the working faces whereas Case 1 will give only 199,000 cfm (77.6% of Case 2) at the working faces.

(5) Case 1 needs 1.9 air horsepower for every 1,000 cfm delivered at the working face, whereas Case 2 needs 1.2 horsepower. This means Case 1 needs 58 per cent more air horsepower for the same effective ventilation.

(6) The system of Case 1 reduces the built-in ventilation capacity of the mine design. The design which was originally intended for 5 mining units is reduced to 3 units.

(7) Case 1 requires 54 overcasts and Case 2 requires 34.

In summarizing, the following can be stated:

A. Reducing the velocity in the trolley entries to 250 feet per minute will have a negative effect on safety since it introduces intake regulation and limits the air on the inby trolley entries, thereby increasing the hazard of ignition. *Solution:* Good ventilation practices limit velocity. The limits should be self-setting in a reasonably efficient system.

B. Provision of a smoke free-intake, continuous from the section to the surface, cannot be faulted on its intent. Negative results lie in (1) possible over-development to provide the smoke-free intake, and (2) the exposure of labor while constructing the necessary additional overcast. U. S. Steel has come up with a scheme which in our two-split face ventilation system could permit the establishment of smoke-free intake from the section to the surface by the remote opening and closing of doors. The system is feasible but is in need of hardware.

(C) Prohibiting the use of belt air at the face has the following negative effects on our conditions and systems:

(1) Reduction of escapeways from the section

(2) Crew training is made more difficult

(3) Potential for airborne dust is increased

(4) Ventilation is maintained at a critical level along the belt

(5) It is economically unsound

(6) Early detection of hot spots by odor is precluded.

(7) In any case vulnerable points to firing–head and tailpiece–remain in the air stream which is used to ventilate the working areas.

(8) The tailpiece cannot be adequately ventilated in a religious application of Section 303(y)(1).

Solution: A system utilizing belt air at the face is one that had been in use in our Gary District for over ten years prior to the implementation of the Act. It does take care of the above listed negative effects.

In conclusion, objective evaluation of the cited three sections of the Act must take into consideration the many provisions in the Act which provide for minimization of fire opportunity, early detection of fire, and tools for fighting fire.

It is the opinion of the authors that in our operations, letter of the Law application of Sections 303(y)(1); (y)(2); and Section 317(f)(4) will introduce hazards and confusion for which no immediate solutions are visible. If possible, these three sections should be modified to permit an in depth study of the ramifications of the provisions. This paper is intended to show some of the problems and to give direction. Objective analysis by interested persons is invited.

REFERENCE

[1] Montgomery, William J. "Theory and Practice of Mine Ventilation"- Page 11, Paragraph 2 - Introduction.

DEVELOPING A TRAINING PROGRAM THROUGH JOB SAFETY ANALYSIS

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Public Law 91-173, better known as the Coal Mine Health and Safety Act was passed December 30, 1969. Upon passage of the act, Allied Chemical Corporation management started immediately to study the act and implement procedures that would acquaint key personnel at corporate, division, and local levels with its contents and take action that appeared necessary to effect compliance without undue delay.

Realizing that the act itself was structured in broad and sometimes general coverage, it was evident that most sections would be subject to additional criteria and detailed interpretation by the U. S. Bureau of Mines.

The first briefing on the new law was held in Washington, D. C. on February 19 and 20, 1970. Allied personnel attending this briefing included the Semet-Solvay Division president, director of mining operations, director of services for mining operations, chief safety supervisor of mines and mine superintendents.

Following the briefing in Washington, D. C., subsequent briefings at other locations were attended by assistant mine superintendents, mine foremen, safety supervisors, industrial engineers, mining engineers and master mechanics.

Upon publication of Part 75 of the Federal Register on March 28, 1970, a complete review of the published regulations was held with the mine superintendents. Following this review, members of the local mine management and mine headquarters staff were assigned responsibility for submitting required plans to the Bureau of Mines for approval. Specific sections of the Law were assigned to individual staff members, and training classes were held for all supervisory personnel down through the section foreman level. Funds were appropriated and orders placed for required equipment and instruments. Additional personnel was hired on both the supervisory and hourly level.

With inspections starting under the new Law on March 30, 1970, it soon became evident that the purchase of improved equipment and instruments, and the use of additional supervisors and hourly workers (all of which involved huge expenditures of capital) would not achieve the desired goals. Training programs of a general nature were proving less effective than anticipated. We felt it was imperative to develop a program for systematically training individual workmen and supervisors to carry out the provisions of the mine law, and that the program selected would have to meet the following standards:

1. Upgrade the performance of individual workmen and supervisors by developing safe, systematic work procedures that would allow the production of coal safely with the least possible interruption.
2. Show immediate progress while generating the ingredients for additional progress as the program was developed over a continuing period of time.
3. Be flexible enough to continue through changes in mining methods and equipment.
4. Be a personalized program requiring involvement by the individual in developing each step.

After reviewing numerous programs developed by our own company and many other companies in the coal industry as well as other industries, it was decided that a Job Safety Analysis program, developed and followed up by developing safe job procedures—with the results combined as a "sound-on-slide" presentation—would serve to meet the requirements previously mentioned. The program was projected as a three phase project:

1. Prepare job safety analyses.
2. Prepare safe job procedures.
3. Develop 1 and 2 into sound-on-slide programs for individual job classifications.

Formal training classes were scheduled for all supervisors on how to make a job safety analysis; how to break a job down into the different steps or segments, identify the hazards, and then outline proper precautions that would eliminate these hazards or prevent them from causing injury. The position of Job Safety Analysis Co-ordinator was established for assisting the supervisors and monitoring progress of the program.

At the end of the training classes each supervisor was asked to submit a list of 12 job steps that he would analyze in the following 12 months. Each supervisor would observe closely the job step he chose to analyze for the current month. This would continue through the first week of the month. The second week he would discuss the job with the individual workman, covering his observations and soliciting the workman's opinion on the safest way to perform the job. He would make notes as necessary. The third week he would begin to list his analysis in rough form with the continued participation of the workman. The fourth week the analysis would be completed and submitted to the Safety Department. Here, it would be reviewed and presented to the superintendent, mine foreman and Industrial Engineering for approval.

Upon final approval of a Job Safety Analysis as the accepted way to perform a particular job step, additional copies were prepared and presented to each supervisor. This then became the standard procedure for performing that part of the job. Each supervisor then discussed the accepted Job Safety Analysis with his crew member who performed the job, and presented him with a typed copy.

After approximately one year, sufficient Job Safety Analyses had been prepared to begin Phase II of the project: the preparation of Safe Job Procedures. As with Phase I, formal training classes were scheduled for all supervisors. The different job steps analyzed for a specific occupation were grouped together and from these a safe job procedure was prepared. This procedure covered the entire shift from the time the workman reached his work site until he completed the working shift. Selected groups of supervisors prepared the safe job procedures, using the Job Safety Analysis that had been prepared by the entire supervisory force and the individual workmen performing the jobs being analyzed.

The safe job procedures for operating a shuttle car were used to develop the initial sound-on-slide program which inaugurated Phase III of the program.

In developing the sound-on-slide program, considerable thought was given to hiring outside people to utilize their expertise in narration and to photographing new equipment on a set-up location. However, it was felt that an artificial or unrealistic atmosphere would surround the program if this was done. While the advantages of professional photography and staged performance was fully recognized, the decision was made to "do our own thing" and try to personalize the entire program. Considerable time elapsed while acceptable photographic equipment was being purchased and our people were trained in its use.

At present, we have completed programs on "Operating a Roof Bolting Machine" and "Operating a Continuous Miner." This initial program was put into use shortly after its completion. While developed specifically for the shuttle car operator, it has been presented to complete crews underground. Underground it is shown to the entire crew at a location. An adapter is used to provide 110-volt AC power from the normal section power source. It is shown on a windowshade-type screen attached to either timber or roof bolts. It has also been presented to crews on the surface prior to entering the mine.

By presenting this type program to the entire crew we not only hope to reach the employee who is performing the job covered by the program; we also hope other employees will apply the safe practices shown to their own work procedures.

We have developed the program by using our own people, in our own coal mine, with

the equipment they are personally operating. The narration is done by a company official.

Sufficient time has not elapsed to make an honest evaluation of this type program. However, the program has been well received by the work force and we are confident that this type of training will prove to be a valuable supplement to other training programs required under the Federal Coal Mine Health and Safety Act.

COORDINATING BETHLEHEM MINES SAFETY PROGRAM WITH THE FEDERAL COAL MINE ACT

By THOMAS E. KOBRICK
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The Federal Coal Mine Health and Safety Act of 1969 is one of the most far-reaching pieces of legislation ever enacted toward providing a safe and healthful environment for employees of the coal mining industry.

Congress declared that the first priority and concern of all in the coal mining industry must be the health and safety of its most precious resource—the miner. It also declared there is urgent need to provide more effective means and measures for improving working conditions and practices in the nation's coal mines in order to prevent death, serious physical harm and occupational disease.

Following is a brief review of Bethlehem's attempts to coordinate the new requirements of the Act into our existing safety program. Two principal aims were to minimize confusion and insure compliance to the greatest degree possible. Because many of the provisions of the Act deal with conditions rather than people, we also decided to continue emphasis on our existing safety program which is more people-oriented.

Bethlehem Steel Corporation's supervisory safety training program, known as "Our Next Step to Zero", was established in 1962. This program grew out of an awareness by top management that there was need to train supervisors in the basic fundamentals of accident prevention.

At the moment, Bethlehem's supervisory safety training program is being revised and expanded to include an audio-visual presentation. The new program will be implemented at all Bethlehem operations early in 1973.

The "Next Step To Zero" program has three major objectives. The first is to strengthen the supervisor's awareness of his responsibilities for accident prevention.

The second objective is to strengthen the supervisor's safety know-how. In addition to knowing what his responsibilities are, the supervisor must also be capable of carrying out his assigned responsibilities effectively. This requires a thorough knowledge of principles and procedures of accident prevention.

The third objective is to strengthen the supervisor's motivation in the overall safety program so that he will be more enthusiastic and conscientious in his application of safety knowledge.

Bethlehem's supervisory safety training program is a continuing one with no end as long as there are new supervisors who need instruction and supervisors who need refresher courses. Direction of the program is the responsibility of line management, and each department superintendent is responsible for administration of the program. Line management personnel serve as discussion leaders to place responsibility for the program in the hands of those responsible for safety of employees.

The supervisory safety training manual is divided into 10 chapters, which are presented in a training course of 40 one-hour sessions.

Chapter One covers the history, policy and responsibility of accident prevention. Bethlehem's policy is that safety is an integral part of production, and that the two cannot be separated. Because organized accident prevention requires the efforts of all levels of management, responsibility is divided with each level of management doing what it can best do to promote accident prevention.

Six major duties of the manager, outlined in Chapter One, include:

1. Communication of safety policy.

2. Stimulation of earnest effort.
3. Establishment of safety objectives.
4. Formulation of program.
5. Provision of necessary means.
6. Evaluation of progress made.

The 12 duties of superintendents include organization, meetings, training, analysis of accident data, job safety analyses, inspections, and the development of standards. Similar duties are defined for the mine foreman.

The responsibilities of the first-line supervisor include the following 15 major areas:

1. Assigned personnel.
2. Nonassigned personnel working in his areas.
3. Employee know-how.
4. Employee safety attitudes.
5. Employee fitness to work.
6. Planned personal safety contacts.
7. Planned safety observations.
8. Planned safety inspections.
9. Job safety analyses.
10. Accident investigations.
11. Chronic "problem employees."
12. General housekeeping.
13. Employee medical care.
14. Safety development.
15. Safety recommendations.

Chapter Two reviews the nature of accidents, accident causes, and the major kinds of causes. It includes a discussion of the 12 basic types of unsafe acts and the personal factors which relate to them. In addition, the unsafe condition, which is a direct environment cause, and the results of accidents are also included.

Basic principles of accident prevention are covered in Chapter Three with emphasis on establishing and eliminating both the potential and actual causes of accidents. Basic types of accidents are reviewed in Chapter Four.

One of the most important tools of the program, Job Safety Analysis, is covered in Chapter Five. A job safety analysis is a procedure that identifies the hazards or potential accidents associated with each step of a job, and develops solutions that will either eliminate or guard against such hazards. The analysis consists of 1) the steps of the job in the order in which they occur; 2) the hazards or potential accidents associated with each job step; and 3) the safe procedure that should be followed to avoid the identified potential accidents.

A job safety analysis program is an organized effort to develop an up-to-date job safety analysis for every hazardous job: to use the finished job safety analysis for training purposes, and to develop standard safe job procedures.

Another major accident prevention procedure, covered in Chapter Six, is detecting and correcting unsafe practices by the use of planned and incidental observations.

In a planned observation, the supervisor decides which man and job he will observe, and decides the most appropriate time. If possible, he will observe the man from start to finish of the job. If he observes an unsafe practice of any kind, he will correct the man and make a record of his observation. If an unsafe practice is observed, the man is reinstructed and a follow-up re-observation is in order, and should be done within one week.

One more invaluable accident prevention tool is accident investigation, reporting, and followup, covered in Chapter Seven of "Our Next Step to Zero." The investigation of accidents involving men reporting to him is a primary responsibility of the first-line supervisor. By participating in all accident investigations involving his men, the supervisor learns about the causes of the accident and takes or recommends corrective action to prevent future occurrences.

A standard report form is used to cover all accidents. It includes basic information about the accident, the man, the job he was doing, the environment, the causes to the accident, and recommendations for preventing a similar occurrence. Each lost-time injury accident report is reviewed by higher management prior to its final approval, with particular emphasis placed on preventing future similar accidents.

Accident reports are reviewed by first-line supervisors with their personnel.

Bethlehem Mines Corporation operates mines in three states: Pennsylvania, West Virginia and Kentucky. These operations are represented by five divisions—Central Pennsylvania, Western Pennsylvania, Northern West Virginia, Southern West Virginia, and Eastern Kentucky. To insure rapid transmittal of information, a telegram system is used to send immediate notification to all operations of any lost-time accident. Upon completion of the accident investigation, copies of the accident report are sent to each operation, where they are discussed with mine employees.

In addition, reports of fatal accidents throughout the mining industry are sent to all operations for review.

Investigating committees comprised of management personnel from the division investigate all potentially serious accidents. In the event of a fatality or serious accident, representatives of Bethlehem's home office participate in a second investigation and review their findings with local management.

Job safety training is an integral and essential part of any effective accident-prevention program. This accident-prevention tool is covered in Chapter Eight of Bethlehem's supervisory safety manual. A basic tool in job safety training is the personal contact—a short safety talk by the supervisor with from one to three men.

Planned and correctional contacts play an important role in providing the job safety training. Correctional contacts are those in which the supervisor sees men working unsafely and corrects them on the spot.

The planned safety contact is used to train new employees and to retrain personnel who are temporarily assigned or transferred to new jobs. A planned safety contact may be either a personal or group contact. Topics for contacts include general safety rules, Federal and state regulations, job safety analyses, review of accidents, and other selected topics.

All planned personal safety contacts covering rules and regulations and job safety analyses are recorded on employee records. This helps the supervisor plan topics for future safety contacts. If a man had an accident as a result of violating a safety rule or deviating from a Job Safety Analysis procedure, the record shows whether he was instructed previously, and how long ago. The records also help higher supervision control the planned safety contact program.

Instruction in the material covered by the manual began in 1962. Forty hours of training were given to all levels of management, from manager to first-line supervisor.

An essential part of any effective accident prevention program is qualified safety personnel to coordinate the application of all phases of the program. In 1965 Bethlehem Mines realigned its safety personnel and added additional support.

The Safety and Environmental Health Department of Bethlehem Mines Corporation includes a Director of Safety and Environmental Health, who reports to the manager of the coal mines, an assistant director who is primarily concerned with fire protection, and a chief inspector who spends the majority of his time at the mines reviewing conditions, work practices, systems and standards, and application of the safety program. In addition, an Environmental Health Laboratory was set up in 1965 to seek new and improved means of respirable dust control.

Each of the five operating divisions has a division inspector reporting to the division superintendent. His duties are similar to those of the chief inspector. A mine inspector is assigned to each mine, and in many instances, an assistant mine inspector, primarily concerned with fire protection, is also part of the safety staff of each mine.

As a result of the Act's requirements for respirable dust sampling, we have added approximately 15 persons to our staff. Special training was given these people in company-conducted sessions to insure qualification and proper know-how.

The total safety environmental health staff includes approximately 60 people.

To evaluate application of the accident prevention tools of our program, planned safety audits are held at selected mines each year. The audit determines to what extent the mine is using the program tools, also the quality of the program. Three or four audits are conducted annually, usually at those operations where an audit would be most beneficial. The audit team consists of representatives from the mine being audited, supervisory personnel from other mines, representatives of the manager's office, and a representative of the Safety and Workmen's Compensation Division of Bethlehem Steel

Corporation. The audit system is useful to the operation being audited, as well as to those persons participating from other operations.

Continued application of these concepts has produced results, even though it has not resulted in our goal of "zero disabling injuries." The disabling-injury frequency per million man-hours for Bethlehem Mines Corporation was 30.95 in 1941, 23.93 in 1951, 8.53 in 1961, and 5.10 in 1971, thereby indicating that the goal of a continuing downward trend is being achieved.

We use another indication of accident performance evaluation—the Serious Injury Index, which includes all disabling injuries in addition to any injuries that resulted in temporary assignment to other than an employee's regularly assigned job. The Serious Injury Index frequency for Bethlehem Mines Corporation was 19.81 in 1963, and 7.05 in 1971, an all-time record low for any calendar year.

Passage of the Act posed many serious problems to our operations, since many of the provisions were not fully understood, or could not be complied with due to unavailability of equipment, or technology. Further confusion was created by the publication of mandatory regulations on March 28, 1970, effective immediately upon publication. These, too, were not fully understood and, for the most part, allowed no lead time to determine what was necessary for compliance.

Initial inspections by Federal inspectors resulted in issuance of Notices of Violations for such unavailable material as automatic brakes on locomotives, approved methane monitors, approved sanitary toilets, approved potable water, one-hour self-rescuer devices, and others. Needless to say, this created even greater confusion. As a result of this type of inspection, mine personnel could become overly concerned with trying to abate or prevent violations which did not concern major accident potentials, resulting in a serious neglect of other accident prevention responsibilities.

To offset this possibility, a Mine Law Coordinator was designated at each of our five divisions to devote full time to coordination of the mine law into our existing mining practices. These coordinators worked in close conjunction with the home office of the corporation, through which all information was distributed. The purpose of this move was to implement the mine law uniformly for all operations with a minimum of confusion. Due to the many decisions which had to be made, frequent conference telephone calls were made. Participants included the coordinators, as well as operating personnel from all levels of management. This provided a rapid means to pass along information, discuss problems, and decide on a rapid and uniform method for achieving compliance. Each coordinator was responsible for timely submission of plans and other information which had to be submitted within specified dates.

Even with these added precautions, our accident performance experienced an upward trend shortly after enforcement began in March, 1970, and then again after the mandatory regulations became effective on November 29, 1970. A review of the monthly experience during 1970 and 1971 indicates unusually high frequencies during April, May and June of 1970, the months immediately following the initiation of inspections under the new Act which became effective March 30, 1970. A similar experience was noted in December, 1970, and January, February and March, 1971, immediately following the November 20, 1970 effective date of the new mandatory regulations which were adopted by the Bureau.

A review of the 12-month cumulative and calendar frequencies indicates the same general trends, resulting in higher frequencies shortly after enforcement of the Act, and again, after the mandatory regulations.

One of the most directly-related provisions of the Act to our safety program is the requirement for training. The Act requires each operator to submit training plans for certified persons in roof and rib, ventilation, methane measurement, oxygen deficiency testing, principles of mine rescue, first aid, and provisions of the mandatory regulations. It also requires training for qualified persons in the duties performed as qualified persons, as well as the use of the self-rescuer, and the availability of first-aid training.

It has been, and continues to be, our practice that all supervisors receive annual training in first aid, and this training has always been made available to all employees.

Each of our operations has historically maintained trained mine rescue teams, regularly trained to insure readiness in the event of their need.

In submitting our plans for training, we indicated that either the Bureau's training programs, our own programs, or a combination of both would be used as they became available. The Bureau has recently conducted sessions in roof and rib control at each of our divisions, and to date the response has been very favorable. Much of the material which is contained in the Bureau program is encompassed within our existing program in the form of job safety analysis, planned safety contacts, and observations.

Of all levels of management, the first-line supervisor has the most day-in, day-out contact with employees, and with the employees' work area, and therefore he has the best opportunity to train, guide, and influence employees to work safely. Accordingly, in consistency with our existing program, it is our intent that all training programs directed toward mine personnel will be conducted to the greatest degree possible by the first-line supervisor. We are currently in the process of combining the material contained in the Bureau training on roof and rib with out own existing Job Safety Analyses. This training program will be submitted to the Bureau as the training proposal for Bethlehem Mines Corporation. It will be an extension of what is presently being covered. It is felt that the approach of providing continuous instruction throughout the year is more effective than a single course given annually. The same basic approach will be used for all required training.

In recognition of the need for training, not only training required by the Act, or our safety training, but all training including management development and job-skill training, our operations are presently in the process of assigning Training Coordinators at each division. These coordinators will combine all requirements of training into a single comprehensive approach. Our accident experience during the past two years indicates that men with relatively short experience on their assigned jobs experience the greatest percentage of lost-time accidents. While our experience may not be indicative of the industry, approximately 40 per cent of the accidents occur to men with less than one year of experience on the job (not total mining experience) and 60 per cent with less than three years on the job. Such a study must be accompanied by a population study to determine if this is disproportionate, but in any event it does point to the need for a continuing training approach rather than any short-term single-shot program, regardless of the quality of its contents.

There can be little question that safety is the responsibility of all levels of management, and that it must be continuous, but it should also be noted that the miners must share in this attitude. If safety is truly to be achieved, they too must face up to their responsibilities in the acceptance of safe operating procedures and practices.

The Bureau of Mines also has a lion's share of the responsibility in making the mines safer. The recent emphasis on roof control, utilizing roof control specialists to work with local mine management in observing and instructing adherence with safe roof control practices, is certainly a step in the right direction.

Our experience indicates that the answer does not lie in merely citing more violations, or issuing more closure orders, but must come through proper motivation and training of all personnel, from the mine manager to the men at the face.

RESEARCH IN UNDERGROUND ILLUMINATION

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An experimental program is underway to develop illumination systems for underground coal mines that will provide area illumination inby the last open crosscut while men are working in these places. Research is directed toward several areas simultaneously: Determination of the minimum luminance levels for the various visual tasks in underground mines; development of prototype hardware including machine-mounted, rib-supported, battery-powered task lamp and an improved cap lamp. Additionally, techniques have been developed to assess the performance of lighting systems via computer analysis. The prototype hardware is being evaluated in operating coal mines as it becomes available.

The Coal Mine Health and Safety Act of 1969, Public Law 91-173, specifies in section 317(e) that within 18 months "the Secretary (of the Interior) shall prepare standards under which all working places in an underground mine shall be illuminated by permissible light while persons are working in such places." The Act further defines working places as that area inby the last open crosscut. Standards proposed for underground illumination were published in the *Federal Register* on December 31, 1970, and a revised proposal was published on October 27, 1971 (*Federal Register* v. 30, no. 207). The statutory provisions of the Act require that within 18 months after promulgation of such standards all working places shall be illuminated. The proposed standards specify the illumination level required, the area to be illuminated, requirements of the lighting fixtures, methods of measuring light levels, and miscellaneous requirements for mining machines, hard hats, and cap lamps. Regarding the level of illumination, the proposed requirements state that the luminous intensity (reflected light) of surfaces of working places in the direction of miners relative to their normal visual field shall be no less than 0.06 foot-lamberts.* This brightness is required within the normal visual fields of miners on rib, floor, exposed equipment, and task surfaces where equipment is employed during the cutting, mining, and loading of coal up to and including the inby end of shuttle cars and other conveying equipment during the actual loading of coal.

Today, face area illumination in underground coal mines consists of the cap lamp and machine head lamps. A miner's cap lamp is a very efficient, reliable form of light that will penetrate 150 to 200 feet down an entry, but it provides a very narrow beam with essentially no peripheral illumination. Other industrial standards, based on the recommendations of the Illuminating Engineering Society, are as follows: Automobile manufacturing—frame assembly, 50 foot-candles; Final assembly line inspection—200 foot-candles; Chemical works—furnaces, generators, stills, driers, etc., 30 foot-candles; Elevators—20 foot-candles; Offices—on desk tops, 100 foot-candles.

Notice that these levels are specified in foot-candles, a measure of incident light, whereas the minimum level for areas in the proposed standard is specified in foot-lamberts, a measure of reflected light. Most surfaces absorb some light and reflect the rest, depending on the color and finish of the surface. This characteristic is known as surface reflectivity, and ranges from 0 per cent (reflection) for a very flat black to 100 per cent (reflection) for a block of magnesium carbonate. The reflectivity of coal is typically in the range of one to four per cent, whereas the industrial examples given above have surface reflectivities of 20 to 50 per cent. People see by reflected light, not incident light, and comparing the recommended minimum surface brightness of face areas, 0.06 foot-lamberts in a coal mine to five to 30 foot-lamberts for industrial applications, we see that the proposed levels are substantially lower than we are typically accustomed to.

Another important point is that of adaptation levels: Only the face area is to be provided with general area illumination and justifiably so, as this is where much of the concentrated action is and where many of the accidents occur. Men must enter and exit this illuminated area frequently and temporary loss of, or reduction in, vision while going from "light" to "dark" and vice versa is certainly not acceptable. The specified level of 0.06 foot-lamberts is approximately the same as that provided by the cap lamp for close visual tasks, so that when leaving an illuminated face area all the miner suffers is a loss in peripheral vision, and not adaptation problems.

An intensive research program is underway to develop various types of permissible hardware to implement the proposed standards, and as the hardware becomes available commercial mine evaluations are being conducted.

The development and evaluation of illumination techniques and hardware is underway, both in-house and by contract. Illumination can be implemented with either machine-mounted luminaires or portable luminaire fixtures; depending on the type of mining and operation conditions, one system or the other may be more suitable. Although both types of systems are being investigated, machine-mounted lighting seems to have some advantages.

Past American mining experience with area illumination has been unsatisfactory, primarily because of the lack of miner acceptance because of glare and adaptation problems. In fact, present-day experience with cap lamps, as when someone inadvertently shines it in another's eyes, is also unsatisfactory. Hence there is justifiable concern that if additional lights are put in a mine to "light it up like Broadway," more problems are going to be created than solved. In the proposed standards there are requirements that when the surface brightness of lighting devices are brighter than 90 foot-lamberts they should be enclosed or have cutoff devices so that one cannot directly see the light bulb. While this requirement is proper, one may ask how this effect is achieved? The headlamps on the continuous miner meet this requirement in that the intensity at the lens of the fixture is greater than 90 foot-lamberts, but they are positioned on the machine so that they are directed toward the face and personnel cannot see the light bulbs during most operations. However, such a lighting device only provides illumination on the face and not in the rest of the area required to be illuminated. One could put headlamps on the rear of the continuous miner, direct them toward the face, and for personnel behind this point the required levels could be achieved. However, as we all know, there are personnel ahead of this point, operator and helper included.

While the use of existing permissible headlamps to provide additional illumination in the working place is attractive, especially because the hardware is readily available and may be routinely serviced underground, the present vintage of headlamps is not optimum. Several alternative approaches are under investigation, including some modified headlamps.

With a multitude of possible approaches to illuminate a working place, including variations in entry dimensions, in types of machinery, and in type, number, and placement of lighting fixtures, the need is apparent for techniques to rapidly assess the performance of a candidate system. The Bureau has developed a technique with the Mathematical Applications Group, Inc. (MAGI) to provide a computer analysis of a candidate system. From basic data such as the intensity of the light, distribution pattern, entry and machine dimensions, and fixture placement, a computer-generated photograph is furnished. This particular figure is only qualitative but gives a general feeling of the performance of a system. However, in order to quantitatively assess the performance of a

Guidelines for Mine Lighting, by John F. Halldane. Institute of Applied Technology, National Bureau of Standards, Washington, D. C., October 1970.

system, another step is necessary.

The same scene is reproduced on a color photograph wherein red denotes less than 0.06 foot-lambert; green, 0.06 to 16 foot-lamberts; and yellow, greater than 16 foot-lamberts; hence the actual intensity ranges can be shown in a simulated photograph. This technique is helpful to our present development program, and it will also be available to operators and consultants in the installation of actual operation systems.

Instrumentation is another area that is essential to the evaluation of illumination systems. While several illumination meters (incident light) are available to measure the low light levels involved, the preferred method of measurement is luminance (a measure of reflected light). The use of luminance has several advantages: (1) Measurement of levels in confined spaces is easier with a telephotometer, and (2) luminance is possibly less restrictive in terms of the number of lighting fixtures required because of the range of reflectivities of coal and machinery surfaces. There have recently been announced several portable luminance photometers, which are potentially intrinsically safe, that could be used underground.

In discussing an illumination problem, lighting experts talk about the reflectivity of the walls, floor, ceiling, the position and angle of the bulbs relative to the workers, and the height of the fixtures above the task surface as controllable parameters. However, as a general rule, in the face areas of underground coal mines these parameters are fixed, usually to the disadvantage of the light engineer.

In the area of hardware development to implement the proposed standards, several efforts are underway with the general categories of interest being machine-mounted fixtures, rib supported fixtures, battery-powered task lamps, and an improved cap lamp. The latter two areas are under development through contracts with Ocean Energy Inc. and Gould Laboratories, respectively. The task lamp is intended to provide the required illumination for tasks such as machine repair, roof drilling, etc. The cap lamp is intended to provide peripheral illumination while still providing some beam or spot intensity at the center of the distribution. Prototypes will be forthcoming in the near future for evaluation.

In the area of machine-mounted light systems, several approaches are under investigation. A system developed by Crouse-Hinds Co. under a Bureau contract employs a 250-watt Lucalox bulb in each fixture; four fixtures are required to illuminate around the sides of a continuous miner, with face illumination provided by four machine headlamps. One of the prototype fixtures has completed Bureau of Mines permissibility tests. The lighting system uses a polarizing filter to eliminate any glare; by placement of a right circular polarizing filter on the lens of the lighting fixture and a left circular polarizing filter on a miner's safety glasses, the direct light from the bulb (source of glare) is essentially reduced to zero, while the reflected light from the mine and machine surfaces loses its polarization and can be seen by the observer. While this hardware is available for in-mine evaluation, revisions to the system are underway to reduce the size of the fixtures and the ballasts so that machine placement will be easier.

Another machine-mounted system under development by the Control Products Co. employs mercury vapor lamps for both the headlamps and the fixtures to be mounted on the side of the machine. The durability and long life (10,000 hours) of the discharge lamps offer a new era of performance in mine lighting.

In addition to the above machine-mounted systems, Pittsburgh Mining and Safety Research Center (PMSRC) is investigating some other alternatives, including some experimental wide-beam PAR lamps developed by the General Electric Co. and several fluorescent fixtures, including a U-tube, 40-watt fixture that offers a high packing density so necessary for machine mounting. Facilities are available at Bruceton for in-mine evaluation of candidate lighting systems in both high and low coal conditions—the high coal in the Safety Research coal mine and the low coal, up to 36 inches, in a simulated entry.

Concurrently with the machine-mounted development is the investigation of lighting systems which could be suspended from the ribs or roof and moved with the advancing mining operation. In 400-watt Lucalox fixture, developed for the Bureau by Crouse-Hinds, the reflector system projects a uniform light in the entry and the color is slightly amber but pleasingly warm. The polarizing system described above is also used with this fixture. Two such luminaires were designed to illuminate a working place by hanging them from the roof. One light is to be placed 20 feet from the face against the rib, while the other will be placed 30 feet from the face against the opposite rib.

Additionally, several fluorescent fixtures and a mercury vapor system are under development for this type of mine lighting.

In terms of the actual performance of the hardware in operating mines, a joint program by the Bituminous Coal Operators Association, the United Mine Workers, and the Bureau of Mines is underway to determine if satisfactory illumination systems can be implemented. The portable roof-mounted hardware developed by Crouse-hinds was installed at the Franklin No. 25 mine, Hanna Coal Div. of Consolidation Coal Co. Using two of the luminaires, a uniform illumination in a conventional section was obtained. During each blasting cycle a thin metal cover was placed around each luminaire as protection against flying debris. Luminance levels on the roof and rib were 0.6 to 0.8 foot-lamberts. Photometrically speaking, the system was a success. Problems encountered with the prototype system included the time necessary to advance the lights and cables and the necessity to cover the fixtures when blasting. The blast covers reduced the heat transfer around the polarized filters, resulting in loss of polarization, hence glare. Additional problems were that in the present design the ballast is not an integral part of the light, hence more cables are required, and the men lost their polarizing glasses so that glare was a problem to those who had to look into the lights.

Recently the lights were moved to a continuous miner section in the same mine with improved results. Without the need for blast shields on the lights, the filters lasted more than a month without needing replacement. The mine was well illuminated and the men did not wear glasses or complain of glare. They had learned to work without looking at the light although their glasses would have eliminated any glare. Several miners stated that they liked the system. Throughout these field evaluations, the cooperation of the miners and management was excellent.

The Crouse-Hinds machine-mounted lights are being installed on a Lee-Norse 48Y-1E continuous miner for evaluation in the Mount Braddock mine of the U. S. Steel Corp. Primary problems to date have been in finding room on the machines for the luminaires and the ballasts. As of this writing evaluation at Mount Braddock had not actually begun.

The work described is developing usable illumination schemes and hardware which will provide reliable, safe, and effective illumination systems for underground mine lighting. Additional work is underway to correct problems encountered in the equipment in the field and to deliver refined, smaller, more reliable luminaires. The other fixtures under investigation (fluorescent, mercury vapor, and incandescent) appear to offer suitable alternatives for low and high coal. Evaluations in operating mines will continue as new hardware becomes available.

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