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ELECTRICAL INSTALLATIONS IN OIL SHALE MINES

Contract J0113061
Foster-Miller, Inc.
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UNITED STATES DEPARTMENT OF THE INTERIOR

FOREWORD

This report was prepared by Foster-Miller, Inc., Waltham, MA, under USBM Contract Number J0113061. The contract was initiated under the Metal/Nonmetal Mine Health and Safety Research Program. It was administered under the technical direction of Pittsburgh Research Center with Mr. Michael Yenchek acting as Technical Project Officer. Mr. Wilson L. Silvis was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period September 1981 to August 1983. This report was submitted by the authors on August 13, 1983.

EXECUTIVE SUMMARY

The energy crisis of the last decade has produced renewed interest in oil shale. As of this writing several experimental mines have been developed, one underground mining project is nearing commercial operation, and other commercial ventures are under development or in the planning stages.

Regulation of oil shale mining is given by statute to the Mine Safety and Health Administration (MSHA). The applicable regulation are found in code of Federal Regulations, Title 30, Part 57- Safety and Health Standards for Metal and Nonmetal Underground Mines.

Oil shale mines, however, posses several characteristics not normally associated with underground metal/nonmetal mines. Oil shale is combustible and oil shale dust can be explosive under certain conditions. The presence of methane could present a potential hazard in many underground oil shale mines. Furthermore, the production rates necessary for economic feasibility are much higher than for other metal and nonmetal mines. The scale of operations required to achieve these high rates may create hazards unique to this industry.

In recognition of increased level of oil shale mining activity, the potential inadequacy of existing regulations and the unique hazards likely to be found in underground oil shale mines, the U.S. Bureau of Mines (USBM) has sponsored several research efforts in this area. This report presents the results of one such effort performed by Foster-Miller, Inc. under USBM Contract No. J0113061, "Electrical Installations in Oil Shale Mines."

The primary concern of this study is the adequacy of existing regulations addressing electrical systems and installations in oil shale mines. A number of recommendations are made regarding high-voltage distribution systems, trailing cables, and electrically-powered face equipment. These recommendations are based on current projections of the systems likely to be used in the future, and the problems likely to be encountered in oil shale mines. Recommendations are summarized in Section 1 and discussed in detail in Section 4 and 5 of this report.

Additional work was also performed on particular problem areas related to electrical systems in oil shale mines. The results of this work are also summarized in Section 1 and are presented in detail in Section 7 through 10.

For most of the duration of this program the preferred systems for mining oil shale and, indeed, the future of the industry seemed somewhat uncertain. During the final stages of the program the following significant trends became evident. First, it appears certain that the current interest in oil shale will, unlike past efforts, result in the establishment of at least one commercial oil shale mine. Several more are likely to follow. Secondly, although a number of possible mine types and mining methods have been considered for oil shale, the room and pillar method utilizing truck haulage is likely to dominate the industry for the forseeable future. Furthermore several MSHA personnel and some other knowledgeable industry sources have expressed the opinion that all underground oil shale mines will eventually be classified gassy. As noted in the text of this report, these developments will have significant impact upon electrical systems and installations used in underground oil shale mines.

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**Reference to specific brands or trade names in this report is made to facilitate understanding and does not imply endorsement by the Bureau of Mines.*

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1. INTRODUCTION

1.1 Objective

The primary objective of this work is to prepare recommendations for guidelines and regulatory changes applicable to electrical installations in underground oil shale mines. These recommendations are based on present knowledge of the mining systems and electrical installations planned by the industry, and on present understanding of the problems and hazards associated with oil shale mining. In developing these recommendations, numerous contacts were made with government agencies, mining companies, research organizations, labor unions, and other interested groups. Prior research into particular problem areas was reviewed. Sections 2 through 6 present the results of this work.

Sections 7 through 10 present the results of work performed under a modification to the original contract. The objective of this work is to investigate specific problem areas related to electrical installations in oil shale mines, including:

a. Ground fault current levels

b. Permissible electric wheel motors

c. Permissible batteries and electric starting systems

d. Intrinsically safe instrumentation and applicability of existing test standards.

Following is a brief summary of each of these sections.

1.2 Background (see Section 2 of text)

The Green River Formation in Colorado, Wyoming and Utah holds vast amounts of petroleum locked in the material known as oil shale. Interest in oil shale began about 1908. Since that time there have been many cycles of boom followed by periods of little or no activity.

Attempts to tap these resources have occurred periodically from about 1915 to 1930, and then again after 1944. Since 1944, there have been frequent changes in property ownership and level of activity.

Many changes are still occurring. In the 1970's and early 80's, spurred by the need for independence from imported oil, activities boomed. Numerous oil shale mining ventures have been proposed and several experimental mines have been developed and operated. Since mid-1982, however, many companies have scaled back or discontinued operations.

Recent economic developments indicate a slowdown in this latest oil shale mining activity. More specifically, several companies have announced postponements or "re-evaluations" of their development activities. One operator, Union Oil, is still moving ahead with plans to mine and retort shale commercially by mid-1983. The Union operation is expected to yield 10,000 barrels per day of high-quality syncrude. Approximately 13,500 tons of shale ore will be mined daily to achieve this goal.

Several questions regarding fire and explosion hazards in oil shale mines remain open. The recent slowdown in activity will provide additional time to resolve these questions before widespread mining operations develop.

1.3 Discussion of Possible Mining Methods for Oil Shale (see Section 3 of text)

A review of possible mine types and mining methods reveals six possible underground mine configurations. These are:

a. In situ retort/non-gassy

b. In situ retort/gassy

c. Room and pillar LHD-belt/non-gassy

d. Room and pillar LHD-belt/gassy

e. Room and pillar truck/non-gassy

f. Room and pillar truck/gassy.

All of these possibilities are under consideration by the industry. However, developments to date reveal:

a. Both operators experimenting with in situ retorts report less than satisfactory results. Further use of this method is in doubt.

b. The Union Oil operation will use room and pillar methods with truck haulage and will begin operations as a non-gassy mine.

c. Other commercial operations developed in the immediately foreseeable future are most likely to be room and pillar mines using truck haulage.

Several problems related to the room and pillar approach have not been resolved. Ventilation problems are especially severe, particularly in the context of a gassy mine classification.

1.4 Applicable Regulations (see Section 4 of text)

The various regulations affecting electrical installations in oil shale mines are discussed. Comments received from oil shale operators regarding regulations (most notably, Part 57) point out a lack of specificity in electrical requirements. Operators feel that existintg regulations offer little by way of guidance and are open to varying interpretations. Accordingly, the following recommendations are made:

a. Adopt, as mandatory regulations or non-mandatory guidelines, standards, similar to the Insultated Cable Engineers Association (ICEA) standards regarding ampacity of cables, to provide more guidance to operators and to lessen the probability of conflicting regulatory interpretation

b. Provide guidance regarding acceptable grounding techniques for underground structures and equipment.

1.5 Description of Electrical Installations With Recommendations For Regulatory Changes (see Section 5 of text)

The electrical installations currently being planned by oil shale operators can be broken into four categories:

a. High voltage power distribution systems

b. Trailing cables

c. Face equipment

d. Ancillary support systems.

Part 57 contains few specific requirements applicable to these systems.

All operators are planning to use a 13.8 kV distribution system. Also planned is the use of shielded high voltage cable, resistance grounded systems, ground fault protection and ground monitoring systems.

The following recommendations are made regarding high voltage power distribution systems in oil shale mines:

a. Require the use of resistance grounded power systems

b. Require the use of shielded cables on all high voltage (>650V) distribution circuits

c. Require the use of overcurrent, short-circuit, ground fault, and undervoltage protection in all three-phase power circuits

d. Require periodic testing and inspection of high voltage circuit breakers and related switchgear

e. Require additional safeguards concerning use of oil-filled electrical equipment in underground oil shale mines

f. Adopt specific guidelines regarding grounding practices for power systems and metal structures underground

g. Require that only properly trained personnel be employed in installation and maintenance of high voltage power distribution systems

h. Require the use of permissible cables in all areas of oil shale mines where such cables would be required if the mine were classed gassy, regardless of the initial or existing classification of the mine.

Trailing cables in oil shale mines are expected to be longer than those currently used in most mining situations. Existing regulations regarding trailing cables are not stringent enough for non-gassy oil shale mine hazards. However, in gassy oil shale mines, the additional requirements of Part 18 result in regulations that are too stringent.

The following recommendations are made regarding the use of trailing cables in all oil shale mines (gassy and non-gassy):

a. Require the provision of short-circuit protection for individual trailing cables

b. Require the use of shielded cables for all high voltage (>650V) trailing cable applications

c. Require all trailing cables to have flame-resistant properties

d. In gassy oil shale mines, the restrictions regarding maximum length of trailing cables found in Section 18.35(a) (5) should not apply.

Various types of electrically-powered face equipment may eventually be needed in oil shale mines. However, plans for the immediate future call for the use of only these types:

a. Face crusher or belt feeder-breaker (electric-powered)

b. Jumbo face drills for development (combination diesel and electric)

c. Roof bolter (combination diesel and electric)

d. Vertical bench drill (combination diesel and electric).

Smaller motors (<250 hp) will be 480V, while larger ones (>250 hp) will be 4160V. Permissible and non-permissible versions of this equipment will be needed, depending upon mine classification. Such equipment can be approved under existing requirements of Part 18, but is not generally available in the sizes required. Non-permissible, high voltage electric face equipment is not subject to the requirements of Part 18. However, if the recommendations for power systems and trailing cables given above are adopted, and if adequate clearances and insulation for the operating voltage(s) are provided, operation of this equipment should not introduce unique hazards in non-gassy oil shale mines. Permissible high voltage face equipment will be required, however, in gassy oil shale mines. Based on experience gained to date, some MSHA personnel and many operators believe it to be very likely that all oil shale mines will eventually be classed gassy.

Ancillary systems include fans, lighting equipment, environmental monitoring systems, and communications equipment. In gassy mine applications, problems arise with respect to the availability of permissible forms of these systems.

1.6 Analysis of Hazards (see Section 6 of text)

Unique hazards associated with oil shale mining include:

a. Use of very large equipment to attain high rates of production

b. Combustibility of the ore being mined

c. Possible explosion hazards due to flammable gases and oil shale dust.

The recommendations made in the proceeding sections are intended to address these hazards.

1.7 The Optimal Level of Ground Fault Current For Resistance Grounded Oil Shale Mine Power Systems (see Section 7 of text)

This section presents the results of an evaluation of the applicability of present coal and noncoal standards for ground fault protection to the underground distribution systems being considered for oil shale mines. A brief description of these systems and existing standards is followed by an analysis to determine the optimal level of ground fault current which should be permitted to flow in resistance grounded systems. The analysis considers the effects of ground fault current on personal safety, prevention of fires and equipment damage, and prevention of dangerous system overvoltages.

The following conclusions regarding optimal levels of ground fault currents are drawn:

a. In 13.8 kV primary distribution systems, the level of ground fault current should be kept as low as possible to provide maximum protection from personal injury, fire, and equipment damage. However, a level of 15A is recommended to provide adequate protection against system overvoltages. Levels of 10A or less will provide a considerable degree of additional protection against shock and may be desirable in particular systems.

b. In 4.16 kV secondary distribution systems, the lowest possible level of fault current will also provide maximum protection from personal injury, fire, and equipment damage. In these systems, fault currents in excess of 5A should provide adequate protection against system overvoltages.

c. In 480V systems, the lowest possible level of fault current should be allowed to flow for maximum protection from personal injury, fire, and equipment damage. Fault currents in excess of 50 mA should provide adequate protection from system overvoltages.

1.8 Permissible Electric Wheel Motors (see Section 8 of text)

This section assesses the potential demand for permissible electric wheel motors in oil shale mines and discusses the problems which must be overcome to develop this type of motor.

The key problems associated with development of an explosion-proof wheel motor appear to be:

a. The large heat dissipation required of wheel motors, especially during dynamic braking operations

b. The large size of the motors and the small size of the mounting spaces

c. Non-availability of permissible diesel/generator sets large enough to power wheel motors.

Mechanical drives are generally used for 85-ton (and smaller) trucks. Development of mechanical drives for larger (100 tons and up) trucks is underway. Use of electric drive starts at 85 tons and predominates in the larger (100+ tons) trucks. The largest truck currently planned for use in oil shale mines is 85 tons. The manufacturers contacted feel that the potential market for an explosion-proof electric drive truck is too small to warrant the extensive development and redesign necessary to address the problems cited above.

At this point, there appears to be essentially no demand in the industry for a permissible electric wheel motor. It is not likely that MSHA will be asked to approve such motors in the near future.

1.9 Permissible Batteries and Electric Starting Systems (see Section 9 of text)

This section presents the results of investigations into two related areas of concern regarding future electrical systems in oil shale mines. These areas are:

a. Permissible batteries

b. Permissible electric starting systems.

Applicable MSHA regulations and potential problems which may be encountered in oil shale mine applications of these systems are discussed. The following conclusions are drawn:

a. There is a demand for the use of permissible batteries on oil shale mining equipment.

b. Permissible forms of the types of batteries needed could be constructed.

c. With proper attention paid to location considerations, permissible batteries could be approved for use on diesel-powered equipment without introducing additional hazards into oil shale mines.

d. Air starting systems appear to offer advantages for starting larger engines (>600 hp) and for use on equipment utilizing compressed air for other purposes, as long as space is available.

e. Electric starting systems offer advantages when used on smaller equipment types where space limitations exist.

f. There is a demand from manufacturers and operators for permissible electric starting systems.

g. Oil shale operators would like to use permissible electric starting systems, if available, in gassy oil shale mines.

h. It should be possible to design and fabricate a permissible electric starting system which is acceptable to MSHA.

i. Additional research into battery location and starter circuit electrical protection is recommended.

1.10 Intrinsically Safe Instrumentation and Applicability of Existing Test Standards
(see Section 10 of text)

This section presents an analysis of the applicability to oil shale mine conditions of five existing test standards used to evaluate intrinsically safe instrumentation and control devices. The five standards considered are:

a. Section 18.68 of Title 30

b. National Fire Protection Association 493

c. Underwriters Laboratories 913

d. American National Standards Institute/Instrument Society of America RP 12.6

e. International Electrotechnical Commission Publication 79-3.

It is concluded that MSHA could substitute the provisions of UL-913 or NFPA-493 for the provisions of Section 18.68 in evaluating intrinsically safe equipment for oil shale mines without reducing the degree of safety provided. In fact, the broader scope of these standards make them more suited to oil shale conditions than Section 18.68. However, all other applicable provisions of Part 18 (such as the adequacy requirement of Section 18.69 and provisions addressed to mineworthiness of all equipment) should be applied to equipment so approved.

An express goal of this study was to perform an evaluation of design and packaging modifications necessary to adopt, for use on oil shale mines, intrinsically safe instruments and devices already accepted as being suitable for NEC Class I, Division 1, hazardous locations. Performance of this task was severely hampered by a lack of knowledge regarding actual oil shale mine operating conditions, and by the lack of development by oil shale operators of designs and specifications for monitoring systems, instrumentation, and other applications requiring such equipment. However, based on the knowledge which does exist, and on the analysis of standards such as UL-913 and NFPA-493, certain conclusions can be drawn:

a. Equipment approved for use in Class I, Division 1 hazardous locations should be tested in Group C and Group D atmospheres before being accepted for use in oil shale mines.

b. Equipment should be constructed so as to prevent the build-up of oil shale dust on heated surfaces.

c. An adequacy test should be required.

d. Intrinsically safe devices intended for use on or with other types of equipment (for example, instrumentation on trucks and loaders) should be evaluated in light of the intended use.

One regulatory development has recently occurred which may ease the concerns which many operators expressed regarding design and specification of monitoring systems acceptable to MSHA for their oil shale operations. On June 21, 1982, MSHA instituted a new procedure designed to simplify and expedite the processing of applications for evaluation of Mine-Wide Monitoring Systems (MWMS), and for classification of sensors and barriers. Because of the potential impact of this development on oil shale mine monitoring systems, a brief discussion of the simplified procedure is included in this report.

2. BACKGROUND

The oil shale industry is introducing a new petroleum recovery technology to the United States mining industry. The economics of the oil shale industry dictate high productivity and high recovery. This, in turn, leads to extremely large electric and diesel equipment operating in extremely large openings. In the case of underground retorting of the shale, controlled fires are being used, releasing from the shale potentially explosive gas and flammable petroleum products which are piped to the surface. Neither the mining industry, the mining equipment manufacturers, nor the regulators of the oil shale industry are fully prepared for this new technology.

Guidelines and recommendations for the installation and use of large equipment and new mining techniques are needed for the oil shale industry.

Oil shale mines, particularly those classified gassy under 57.21-1, are operating under either variances or extensions of notices of violations and orders granted by MSHA. Under the variance procedure the mine requesting the variance must show no reduction in the level of safety as a result of the variance.

The problem with this approach is that there are no guidelines available for MSHA to use in evaluating the variance requests or in preparing new or revised regulations, or for the operators to use in planning for expansion of existing mines or in development of new ones.

The following factors impact the safe installation of electrical equipment in oil shale mines:

a. The mining system

b. The ventilation plan

c. The dust control plan

d. The explosivity of the dust

e. Gases released by the strata

f. The type of mining equipment used

g. Maintenance of equipment

h. The location of auxiliary equipment and systems

i. Gases produced by equipment and underground retorting

j. The use of monitoring systems

k. Personnel training.

All of these factors are interrelated and will be considered in preparing the recommendations.

2.1 Objective

An objective of this contract is to prepare guidelines and recommendations for installation of electrically-powered systems and equipment in oil shale mines, considering the probability of operation in explosive atmospheres and/or combustible materials.

2.2 Scope of Work

The need for guidelines and recommendations arises because of the unique mining systems and hazards associated with oil shale mining. Oil shale mines will, in many ways, resemble other metal and nonmetal mines. A marked distinction, however, is that the material handled can burn, or may be explosive when in dust form. It is probable that in some mining situations the fire hazards will be even greater than those present in coal mines. During this program, an effort was made to perform a comprehensive study of the electrical hazards in oil shale mines, in light of existing knowledge of fire and explosion hazards.

The study was hampered because there are, as yet, no commercial mines in operation. Sometime in 1983 Union Oil should be mining commercially. Even though Union Oil is this close to mining, *no complete mining plans were available to study*. All oil shale mining ventures are still working with preliminary plans in the areas of electrical distribution and face equipment.

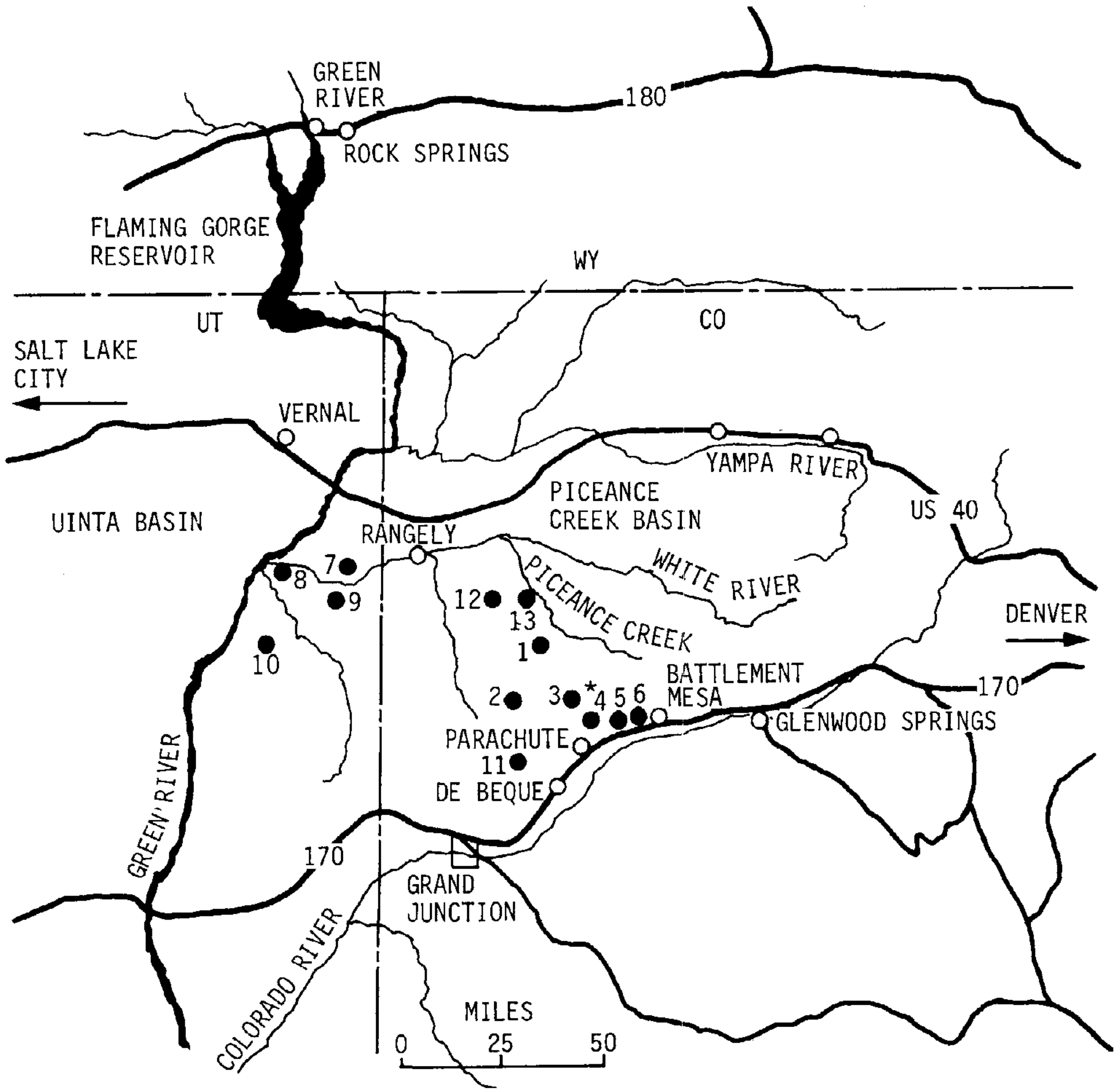
Work on the original part of this contract was done in conjunction and cooperation with the government and private persons engaged in development of the oil shale mining industry. The organizations contacted are listed in Appendix A. As a result of the discussions with these contacts, the types of distribution systems and types and sizes of equipment under consideration were documented. As mentioned earlier, these plans are preliminary. Even so, a good picture of the possible electrical installations was obtained. These electrical installations were then analyzed to determine the problems and hazards of oil shale mining, based on the level of existing knowledge in this field.

All active oil shale ventures showed a willingness to cooperate with Foster-Miller in this program. Meetings were arranged with the principle ventures and government agencies within budgeting and contract limitations. Foster-Miller visited several mine properties. However, no first-hand observations of electrical installations were made. This was expected since no mine has progressed far enough to have permanent installations in place. The mines that have operated as experimental or research facilities are Logan Wash of Occidental and C-a tract of Rio Blanco. The Cathedral Bluffs Mine of Occidental (C-b Tract) was still in the experimental stage when operations were recently suspended. Figure 1 shows the approximate location of the major oil shale ventures.

2.3 Historical Overview

About 90 percent of the identified oil shale resources of the United States are in a formation located in the states of Colorado, Wyoming, and Utah known as the Green River Formation. This rock formation, formed 50 million years ago, holds more petroleum than all the known reserves of the Middle East. This energy-bearing rock is dolomitic marlstone and the black, oily substance trapped in the layers is kerogen. When processed it yields low-sulfur, high quality petroleum products.

Following the turn of this century, when oil reserves were thought to be drying up, efforts to utilize oil shale were made. New discoveries of conventional petroleum reserves caused this early interest to fade.



1. C-b (OCCIDENTAL CATHEDRAL BLUFF/TENNECO)
2. CLEAR CREEK SHALE OIL PROJECT (CHEVRON)
3. COLONY SHALE OIL PROJECT (EXXON)
*4. UNION OIL
5. MOBIL
6. ANVIL POINTS MINE
7. PARAHO UTE PROJECT
8. SAND WASH (TOSCO)
9. U-a/U-b (WHITE RIVER) (SOHIO, SUN, PHILLPS)
10. GEOKINETICS
11. LOGAN WASH (OCCIDENTAL)
12. C-a (RIO BLANCO)
13. MULTI-MINERALS

*CURRENTLY OPERATING THE ONLY ACTIVE UNDERGROUND OIL SHALE MINE

Figure 1. - Site of oil shale activities

During World War II, the government began to actively investigate oil shale recovery on a tract of land north and west of Anvil Points. This government activity has continued through various stages of funding and cooperative projects. The 1973-74 oil embargo, which increased crude oil prices, brought renewed interest in oil shale. The government leased four tracts of land, two in Colorado and two in Utah. These tracts, and the surrounding privately owned areas, are the centers of current efforts to recover oil from these shale deposits.

The Colorado Mining Association has emerged as a spokesman for the various oil shale ventures. They have generated a prioritized list of research areas that need to be addressed.

The following presents a brief synopsis of the current status of the oil shale industry.

Union Oil of California is currently operating the only active underground oil shale mine. They are scheduled to be producing 10,000 tons per day by late 1983. Their mining method is room and pillar with trackless haulage to a surface retort.

Exxon operates the Colony project but has suspended mining activities pending reevaluation of the project. Existing development and plans call for room and pillar mining using trackless haulage.

Occidental has been conducting tests of their in situ mining and retorting process at Logan Wash. The project currently has only two retorts which are nearing completion. Their C-b project, in partnership with Tenneco, is currently waiting financial assistance from the Synfuel Corporation. Present plans for this operation call for smaller entries mined with conventional underground mining equipment.

The Chevron project is in the early planning stages. Initially the mine is projected to be underground with surface mining at a later date.

The Mobil project is on a large tract next to the Naval Strategic Reserve. In the mid 60's an adit was driven to test equipment and mining techniques. During this early development, mining was done using a two-step benching technique to mine 78 ft high entries. The project is currently in a planning stage.

The Anvil Points mine was started in 1945 by the United States Bureau of Mines (USBM) and has since been utilized in a number of studies and research. The room and pillar mine used the two-level mining method to excavate 60 ft high rooms. This mine site is accessible for testing of equipment, but is presently not in active use.

The Tosco Sandwash Project, located in Utah, is presently not active.

The White River Project (U-a and U-b Tract) is presently developing an incline and a shaft to access their underground mine. The mine plans call for room and pillar mining and benching. Present plans indicate production from this operation in 2-3 years.

Geokinetics is operating a true in situ site, but all drilling and blasting is from the surface and no underground mining is planned for the present operation.

The Rio Blanco Project (C-a Tract) has operated several in situ retorts but there is presently no activity at this site.

Paraho operates a retort, used for research and testing, near the Anvil Points mine. Their Ute Project is planned to be a room and pillar mine but further development depends on obtaining SynFuel Corporation assistance.

Multi Minerals had a lease on the Horse Draw Shaft which was drilled to approximately 2400 ft depth by the USBM. There is currently no activity at this site.

In May, 1982, Exxon announced a "withdrawal" from the Colony project. This decision came very suddenly and unexpectedly, and highlighted the current difficulties in the oil shale industry. The "oil glut" and lower oil prices, combined with large cost overruns and retort development problems have led to the present slowdown in activities. Although no company has completely walked away from oil shale, most have visibly slowed development efforts. Economic conditions must improve and reasonable mining plans must be developed before strong interest will be seen again.

One operator, Union Oil, is still moving ahead with plans to mine and retort shale commercially by mid-1983. Union's Parachute Creek Shale Oil Program will produce 10,000 bbl/day of high-quality syncrude from a property containing 1.6 billion barrels of recoverable shale oil. Approximately 13,500 tons of shale rock will be mined daily to support this production.

This slowdown of activities will delay the development of electrical installations in oil shale mines. This could be beneficial for operators and government agencies. Additional time is now available for selection and development of equipment and mining plans, and for developing guidelines and regulations suited to the oil shale mine environment. Several previously identified research areas should be addressed during the "lull," so that the results will be available to future mine planners and regulators.

3. DISCUSSION OF POSSIBLE MINING METHODS FOR OIL SHALE

Many hours of discussions with industry operators, representing nearly twenty ventures into oil shale mining, revealed numerous possible mining methods for oil shale. All are, however, still in the preliminary planning stages and many unanswered questions remain.

Not one underground mine is producing commercial oil from oil shale.

The variety of mining systems range from open pit to in situ retorting. A general overview of the mining systems can be seen in the January 1981, "Mining Engineering." The one known commercial operation is the modified in situ operation of Geokinetics, Inc. in the shallow basin in Utah. They are drilling from the surface to the oil shale, fracturing, and igniting it. Controlled heating is then used to force the oil from the rock, which is then pumped to the surface. The process has been operating for many years now, but does not impact the objective of this contract.

Another interesting discovery was an open pit oil shale mine in Indiana. The Southern Indiana Oil Shale Company has acres of Devonian shales that it is planning to mine by open pit methods.

Figure 2 depicts the relationship between major oil shale mining methods and mine types. This chart shows the major categories of mining which impact the type of electrical installations used underground. The mine method, mine type, and mine classification are used to categorize the methods. The possible headings are:

a. Mine method

   1. In situ retort

   2. Room and pillar LHD/belt

   3. Room and pillar truck

   4. Open pit

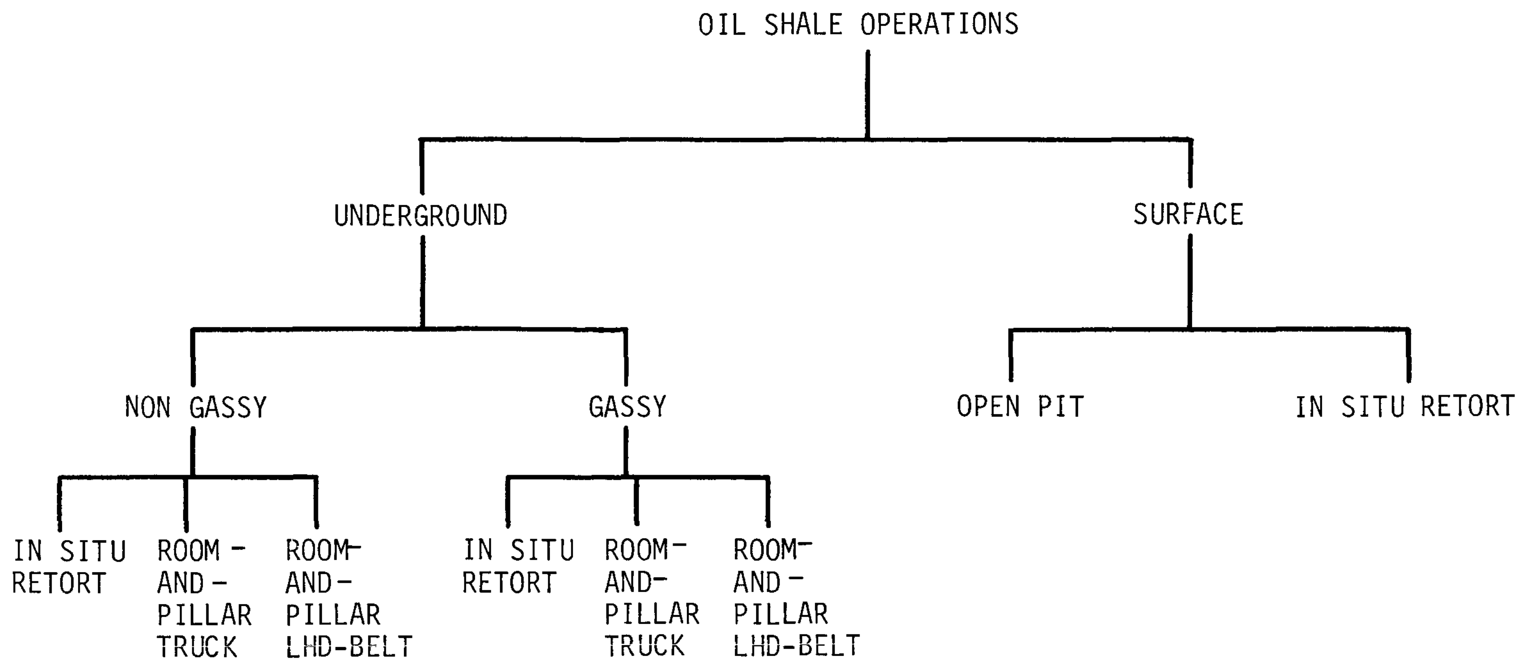


FIGURE 2. Major oil shale mining methods.

b. Mine type

1. Underground

2. Surface

c. Mine classification

1. Non-gassy

2. Gassy.

From this array, 16 subcategories are formed. Of these 16, only 8 are physically possible. The 8 possible mine types and methods are:

a. Surface/open pit/non-gassy

b. Surface/in situ retort/non-gassy

c. Underground/in situ retort/non-gassy

d. Underground/in situ retort/gassy

e. Underground/room and pillar LHD-belt/non-gassy

f. Underground/room and pillar LHD-belt/gassy

g. Underground/room and pillar truck/non-gassy

h. Underground/room and pillar truck/gassy.

Of these 8, the 6 underground methods are relevant to this program. The following sections will describe, to the extent possible, these 6 mining systems. Details of the electrical systems planned for these mining systems will be discussed in Section 5.

3.1 Underground/In Situ Retort/Non-Gassy

This method of oil shale mining was a very popular preliminary experimental process used by two oil shale ventures. The large environmental problems associated with disposing of spent shale (shale residue that remains after oil shale has been removed) on the surface are significantly reduced. However, the technology needed for commercial-size operations is complicated and difficult to control.

The research work done by Occidental at Logan Wash Mine and initially at Cathedral Bluffs was directed at finding a commercial plan. At the present time Occidental is re-evaluating the total mining scheme to decide when and how to proceed.

The Rio Blanco Mine also experimented with underground retorts at the C-a tract. Even though their work appears to have gone very well, they are presently planning an open pit operation for the oil shale property they are leasing.

The underground in situ retorting method is illustrated in Figure 3. The in-place oil shale is retorted underground by:

a. Driving access shafts, drifts, and tunnels into the oil shale zone to provide for ventilation, injection of air, haulage, movement of equipment and collection of oil and gas products

b. Removal of about 20 percent of the oil shale by mining to provide for voidage in the oil shale zone

c. Rubblization (fragmentation) of the in-place shale by explosives

d. Retorting the rubblized shale - heating the shale to remove the oil contained in the rock.

Entries or pipes are used to supply air for burning and to allow for off-gas and oil recovery from the other end of the retort. These entries are isolated from the mine development entries by large bulkheads. Some piping can be brought through mine entries depending on the system used. In the preliminary commercial mine plans, the isolation of retort process and mine development was complete. The only interaction or direct connection was the use of mine air for retort intake. The rate of burning and retort process was controlled by the large off-gas exhausters on the bottom end of the retort system. These exhausters were planned to be located on the surface in the commercial mine, connected to the retorts by a system of shafts, boreholes, and entries. The development mining for this system is quite extensive. A large amount of oil shale rock must be hauled to the surface. Some operations were planning to run a surface retort to recover the oil from this ore.

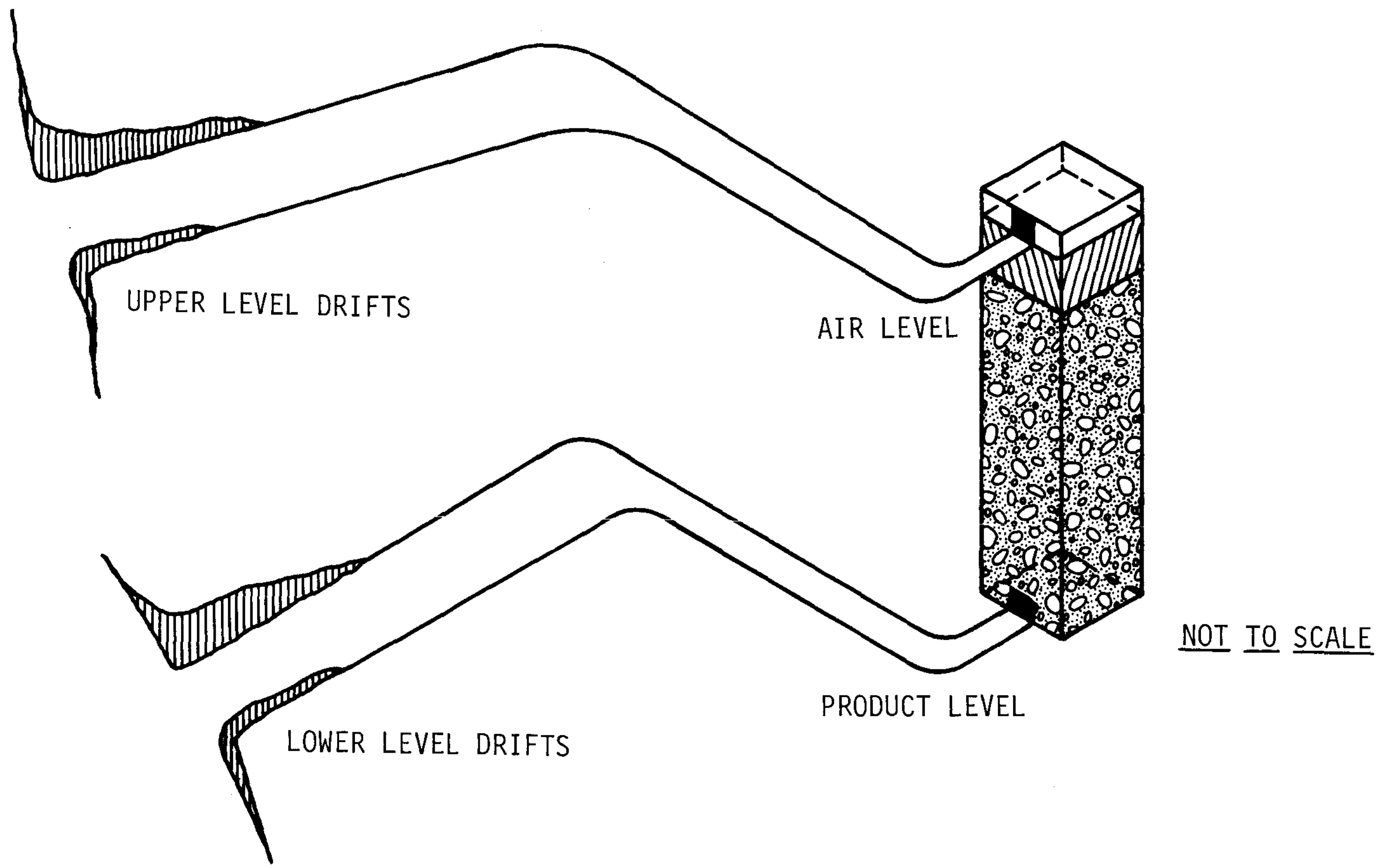


FIGURE 3. - Schematic of an underground retort.

This mining system is similar to other underground systems, except for the retort. The equipment sizes and types are, for the most part, presently available. The retort does require some extra precautions. Large bulkheads will isolate the retort and off-products from the mine. Monitoring systems will be checking the retort process and quality of mine air continuously. These are the major differences in underground operations.

3.2 Underground/In Situ Retort/Gassy

After the Rio Blanco and Cathedral Bluffs Experimental Mines were developed and experimentation and mine development was well underway, they were classified gassy by the federal government (MSHA). These mines then began the long process of complying with the additional standards in Section 57.21 of Part 57, 30CFR. Rio Blanco was able to modify its system and achieve compliance with most of the regulations. The Cathedral Bluffs Mine was still in the process of achieving compliance when it was "idled."

When an existing mine is classified gassy, many changes are required. The major changes concern permissible equipment and the ventilation system. All equipment used beyond the last open crosscut, or in places where flammable gases are present or which may enter the airstream, must be permissible. Loaders, drills, trucks, scalers, powder trucks, fans, and other equipment types are affected. Nonpermissible equipment in use when the mine is classified gassy must be modified or replaced. Power cables, conveyor belting, and hoses not accepted by MSHA as flame resistant must be replaced. For a large mine, the costs of modifications necessary to comply with the permissibility requirement may be prohibitive. In such a case, the mine must seek variances from MSHA to allow for continued operation, or else cease all mining activity.

Gassy mines must also conform with the ventilation requirements of 30CFR 57.20-69. Since mine plans for a gassy oil shale mine are not yet available, particular mining system designs are necessarily speculative. The ventilation system becomes the key to such a design. As was mentioned above, the main fans must be on the surface. Permissible booster and auxiliary fans would direct splits of air to panels and individual working faces. The intake and exhaust air courses must be separated. The load centers must be set outby the last open crosscut and long trailing cables would be used to go to the faces. Multiple entries are likely to be necessary. Rio Blanco drove a second entry in its efforts to achieve compliance after being classified gassy.

3.3 Underground/Room and Pillar-LHD Belt/Nongassy

This scheme of mining was mentioned as a preliminary design consideration by at least two of the operators contacted. Development entries are driven using conventional drilling and blasting techniques. The broken ore is then loaded, using load haul dump (LHD) diesel loaders, which tram to a belt loading pocket or feeder-breaker. The belts then transport the oil shale outside or to the secondary crushing area. This method is very similar to presently used mining methods, except in the size of equipment used to achieve high production rates. Bench work is then done by drilling from the development entries down, blasting, and then loading by LHD onto another belt system. This will give a total mining height of approximately 100 ft.

If the operation remains nongassy, no permissible equipment would be required. Availability of the large pieces of equipment needed to achieve high production rates would not be a problem.

None of the operators mentioning this method had any specific plans. The most detail seen was preliminary plans for 250 to 500 hp crusher-feeders near the development faces. These would feed onto the belt system. However, no sizes of belts, drive motors, or face equipment were indicated. The operators guessed that diesel LHDs would move the broken ore from the face. The drill jumbo would use 300 horsepower electric motors for drilling power and be diesel powered for mobility.

The ventilation system in a non-gassy mine need only provide acceptable air quality to the mine work areas. A number of techniques that are unacceptable in the gassy mine context can be used in a nongassy mine. These include installation of main fans underground, use of nonpermissible fans, minimization (rather than elimination) of some recirculation problems, and use of nonpermissible booster fans. Thus, a non-gassy classification greatly simplifies the ventilation problems associated with oil shale mining.

A nongassy mining operation's concern with ventilation is limited to providing acceptable air quality to the mine areas. As long as the regulated limits of contaminants are not exceeded, the mine can use almost any design of ventilation system.

3.4 Underground/Room and Pillar-LHD Belt/Gassy

When the above mining system is classified gassy, many changes are required. The major changes concern permissible equipment and the ventilation system. The gassy mine requirements discussed in subsection 3.2 are applicable here. Again, reclassification of an existing nongassy mine can require prohibitively costly changes to fully comply with 30CFR 57.21. A greater degree of compliance can be achieved at an acceptable cost level if possible gassy mine classification is anticipated in the early stages of mine development.

3.5 Underground/Room and Pillar Truck/Nongassy

This system is very similar to the previously discussed room and pillar system. Trucks which haul ore to the crusher station replace the belt system. LHDs are replaced by front end loaders at the face. Figure 4 shows this system as it might be used in an oil shale mine. The Union Oil Mine scheduled to open in 1983 will use this mining method.

It is expected that development and benching will be practiced as discussed in subsection 3.3. Details of whether the haulage roads will be separate from intakes or returns, or be a part of either type entry, was not determined. Our discussions indicated that all options were being considered. The operators did not have a good estimate of the dust loading expected from haul roads. If the dust levels will be high, this dust laden air may not be allowed to flow to the production panels.

When this mining method is used in nongassy mines, the equipment required will be very similar to presently used surface mining equipment. While this equipment is large, by underground mining standards, it is presently available. Ancillary equipment, which may have to be custom-built, will be much easier to buy since the mine is nongassy. The details as to which specific types of equipment will be needed are unknown.

The electrical system will be a large capacity system. A "typical" system being considered by several operators is discussed in Section 5. Fan horsepowers are expected to be large, up to 1,800 hp for booster fans and 150 hp for auxiliary fans. Some drilling and possibly explosives charging will be done with electrical equipment.

3.6 Underground/Room and Pillar Trucks/Gassy

This mining system will present many problems for the industry. The equipment and ventilation requirements discussed

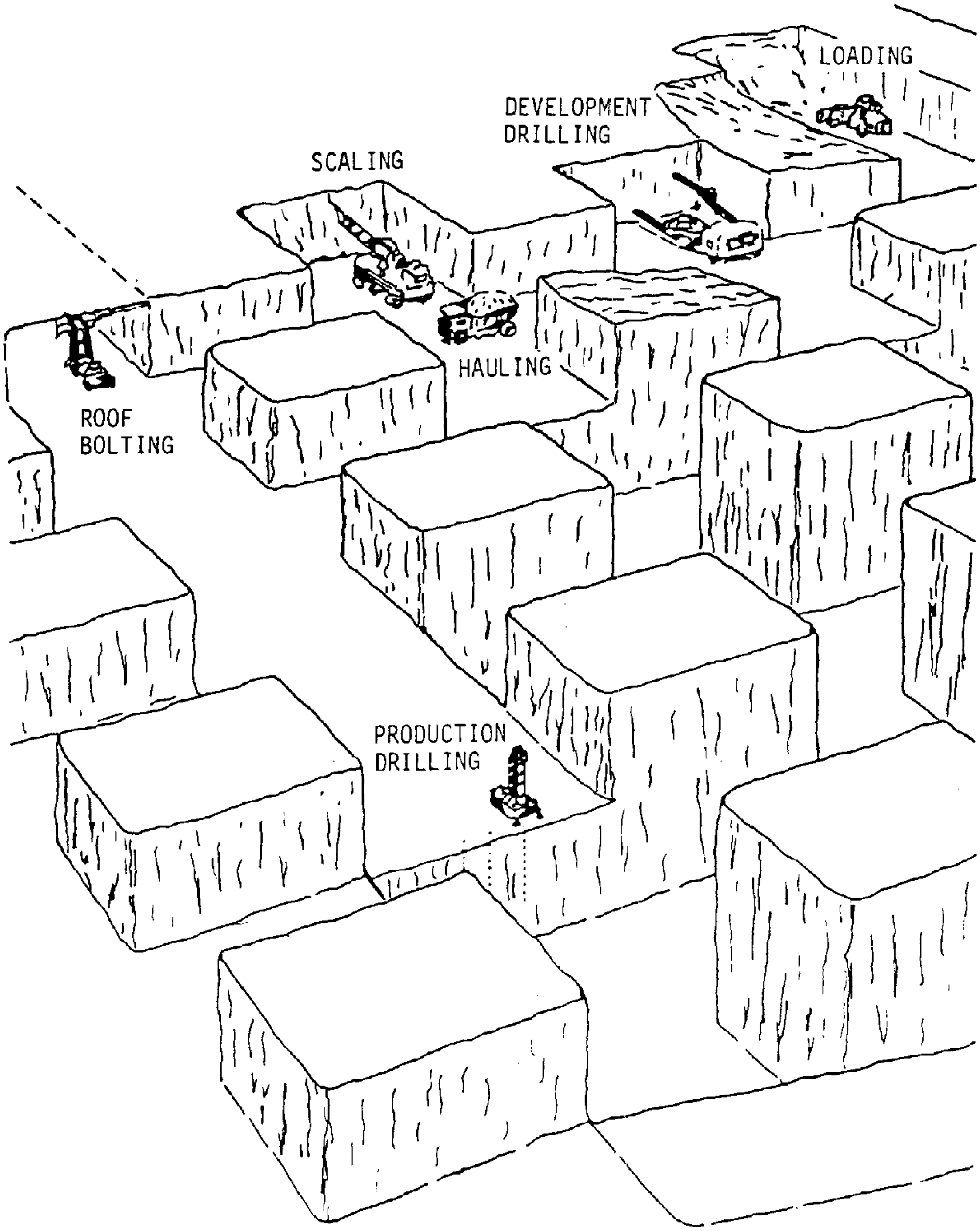


FIGURE 4. - Oil shale room and pillar mining method.

above for gassy mines are applicable here. However, the problems associated with compliance efforts are exacerbated by the large equipment sizes and mine dimensions needed to maintain high production rates. Permissible versions of trucks, loaders, and fans in the size ranges contemplated are not presently available. The possibilities for development of such equipment are uncertain at this time for a variety of technical and economic reasons. Thus, total compliance with the requirements of Part 57 may never be possible for a gassy mine of this type. One operation was planning to operate as a gassy mine from the inception and had analyzed the associated costs. Problems were apparent immediately, because approved equipment was not available in the sizes needed. Equipment manufacturers were hard at work trying to make bids on equipment that was not "off the shelf." The specifications for the electrical equipment could not be obtained. Even the underground fans, which are large, could not be obtained off the shelf, and it was unknown if they could be built.

3.7 General Overview

All six possible systems discussed above are being evaluated by the industry. One operator is designing a gassy mine using in situ retorts. Another operator is designing a gassy room and pillar mine using trucks. Yet another indicated that nonpermissible equipment would be used to start a nongassy room and pillar mine using trucks. Subsequent reclassification as a gassy mine will trigger an equipment modification and replacement program. None of the other operators were far enough along with their plans to know which method would be used. Several were still evaluating alternative ideas.

In general, in situ retorts have a lower oil yield than surface retorts. However, surface retorts require larger quantities of water than in situ retorts. Surface retorting requires a large disposal area, whereas in situ retorting leaves the spent shale in the retort. In situ retorting does, however, require some surface retorting. The development ore must be removed from the mine and processed on the surface.

Electrical systems planned for these mining systems are discussed elsewhere. In situ retorting will increase the complexity of the electrical system. More monitoring and control is required, as well as a more complex developmental mining system. However, the required equipment will not be as large and most types are readily available in permissible and nonpermissible forms.

3.8 Room and Pillar Ventilation

We re-emphasize that no final mining plans or ventilation plans are presently available. Existing plans are either preliminary or proprietary in nature. Operators whose plans are developed far enough to include a ventilation system are planning to place exhausting main fans on the surface. The use of large quantities of air is expected. Some engineers and consultants indicate that design parameters included figures like 500,000 cfm per panel and 100 ft/min in the panel entries. However, it is not known how many panels are to be mined or what the total airflow will be.

Many ideas were mentioned regarding control of airflows. Generally intake and return air courses are planned, separated by stoppings from the drift openings leading to the faces. The large structures required to separate intakes and returns will be difficult to build. Expensive structural solutions have been suggested, as well as limiting the size and number of openings made in the line of pillars separating these air courses. In addition, such a ventilation system requires that overcasts be provided. This too raises construction problems due to the size of the overcasts and amount of airflow. The separation problem will occur in the panels also. Some predict that separation will require stoppings 60 ft wide by 100 ft high. Construction of such stoppings in a mine with high production and advance rates may not be practical or cost-effective. The alternative is to leave some material in place so that the opening is much smaller.

The large face areas to be ventilated present problems for system designers. Dust must be controlled because of the respirable exposure hazard to workers and because of its explosive potential. Just how explosive this dust will be is not known. While it is generally true that dust from richer grades of oil shale is more easily ignited under the right conditions, precise limits have yet to be determined. Another problem in the faces is flammable gas. Methane occurs naturally in oil shale, but varies in quantity from mine to mine. At present, three oil shale mines (Multi-Minerals, Rio Blanco, and Cathedral Bluffs) have been classified gassy by MSHA. Of these three mines, Multi-Minerals has closed down, Rio Blanco will be closed as soon as the last retort has cooled, and Cathedral Bluffs has been idled. It is unknown at this time whether Cathedral Bluffs will reopen using underground retorts. It seems clear that all underground oil shale mines are potentially gassy mines. The operators are well aware of this and are working to prevent and prepare for this possibility. The importance of effective face ventilation is obvious. In a theoretical panel assume the following parameters:

Development: 7 entries plus return
30 ft × 60 ft

Benching: 60 × 60
assume design to 100 ft/min minimum

$$[7 \times (30 \times 60) \times 100] = 1{,}260{,}000 \text{ cfm per panel}$$

Each entry would require 1,800 × 100 = 180,000 cfm. If the designer is allowing 500,000 cfm per panel, the mean entry air velocity reduces to 40 ft/min. However, if the panel air is used properly in the faces where most of the dust and gas is produced, this air quantity may be sufficient.

In addition to flammable gas, exhaust gases from diesel engines, will be present (CO, CO_2, NO, NO_2, SO_2 and particulates). Large (50 to 85 ton) trucks, 15 cubic yard loaders, and a number of other pieces of equipment will be exhausting large amounts of toxic gases which must be diluted by the ventilating air.

The prime objective of quality control in ventilation is to contend with the two airborne contaminants (gases and dust particulate matter) by diluting and removing them. This combination of hazards can be handled by the same airflow. If 500,000 cfm is provided to each panel and the face ventilation system is properly designed, this air may be adequate to dilute and render harmless the dust and gas present. There remains the question of whether a practical system can be provided to do this. The effects of leakage, recirculation, and damage from face blasting are yet to be determined.

4. APPLICABLE REGULATIONS

Electrical installations in oil shale mines are affected by many regulations. These regulations are intended to ensure the safe operation and maintenance of electrically-powered systems used in mines. Other standards, such as the National Electric Code and other parts of Title 30 are incorporated by reference into Part 57. These standards and regulations, as applied to oil shale mining, are discussed below.

4.1 Relationship Between Regulations

Oil shale electrical installations are regulated primarily by Part 57 of 30CFR. This part incorporates Part 18 of 30CFR through the standard for gassy mines, §57.21-78. In those areas where permissible equipment is required under §57.21-78, that equipment is approved under the provisions of Part 18, "Electric Motor-Driven Mine Equipment and Accessories". However, not all the types of electrical equipment needed by oil shale mines have been approved under Part 18, nor can all monitoring systems needed be approved under existing regulations.

A more detailed discussion of Part 18 follows later. Other types of permissible equipment are covered by other Parts of 30CFR. These are:

a. Part 19 - Electric cap lamps

b. Part 20 - Electric mine lamps other than standard cap lamps

c. Part 21 - Flame safety lamps

d. Part 22 - Portable methane detectors

e. Part 23 - Telephones and signaling devices

f. Part 25 - Multiple shot blasting units

g. Part 26 - Lighting equipment for illuminating underground workings

h. Part 27 - Methane monitoring systems

i. Part 36 - Mobile diesel powered transportation equipment for gassy noncoal mines and tunnels.

Additional parts are needed to allow for MSHA approval of other equipment types. For example, the environmental monitoring systems comtemplated by some operators cannot be approved under these schedules. MSHA is in the process of developing approval criteria for these systems. In the interim, oil shale operators have used Underwriters Laboratory (UL) systems.

Another area that may raise questions in oil shale mines is lighting. Although no lighting systems have been designed or installed, permissible lighting systems large enough for use in a gassy oil shale mine may not be feasible to design and build under current regulations. The approval schedule for permissible lights contains a temperature limitation imposed by the lamp materials. This limits the types of lighting fixtures available in approved form.

Other standards referenced directly in Part 57 include the National Electric Code and the National Electrical Safety Code. These standards contain general requirements for the use of electrical equipment in hazardous and nonhazardous locations. A classification scheme is set forth in the NEC for hazardous areas and equipment is approved by Underwriter's Laboratories, and others, for use in each classified area. Possible use in oil shale mines of equipment approved under these regulations is discussed in other sections of this report.

Even though oil shale mining is regulated under Part 57 as a metal-nonmetal type mine, some oil shale operators indicated that they were using Part 75, "Mandatory Safety Standards - Underground Coal Mines", for guidance in designing electrical systems. Several others commented on the lack of specificity in certain areas of the Part 57 electrical requirements. It was felt that the regulations offer little by way of guidance and specifications as to what is a proper system design, and that some sections are open to varying, often conflicting, interpretations. Specific examples of such regulations are:

a. §57.12-1 - Circuits shall be protected against excessive overloads by fuses or circuit breakers of the correct type and capacity.

b. §57.12-4 - Electrical conductors shall be of a sufficient size and current-carrying capacity to ensure that a rise in temperature resulting from normal operations will not damage the insulating materials...

c. §57.12-25 - All metal enclosing or encasing electrical circuits shall be grounded or provided with equipment protection...

Therefore, the following recommendations are made:

a. *Adopt, as mandatory regulations or non-mandatory guidelines, standards, similar to the Insulated Cable Engineers Association (ICEA) standards regarding ampacity of cables, to provide more guidance to operators and to lessen the probability of conflicting regulatory interpretation* - Similar guidelines should be provided to replace "excessive overloads," "correct type," and other vague phrases with more specific standards that will allow the operator and inspector to more readily identify acceptable designs.

b. *Provide Guidance Regarding Acceptable Grounding Techniques for Underground Structures and Equipment* - Such guidance could be provided by a section similar to Subpart H of Part 75, which enumerates approved methods of grounding various types of facilities and equipment.

4.2 Problems with Understanding and Interpretation of Certain Regulations in Part 57

In light of the problems with ventilation control discussed in Section 3, the interpretation of 30CFR 57.21-78 becomes very important.

> *§57.21-78 Mandatory - Only permissible equipment maintained in permissible condition shall be used beyond the last open crosscut or in places where dangerous quantities of flammable gases are present or may enter the air current.*

The physical place where the last open crosscut occurs may or may not be clearly definable. Yet in a mine classified as gassy, permissible equipment will be required from this point inby to the faces and through the return air courses. This standard also has a second part to it. It requires permissibility, "... in places where dangerous quantities of flammable gases are present or may enter the air current." This phrase requires interpretation. One possible interpretation is that the whole last open crosscut, every area in the airstream past the first production face, and all entries and crosscuts in the face area where the air is recirculating because of the type of face ventilation system, will require permissible equipment. This means that where jet fans or auxiliary fans are used without lengths of tubing, the recirculation caused by this type of installation can require permissible equipment. This recirculation can be quite extensive and, while the exact distance is unknown, could conceivably reach several crosscuts outby the last open crosscut and faces.

The impact on the electrical system is apparent. The location of power centers and electrical distribution equipment can be very important, since present regulations restrict trailing cable lengths. Other equipment, such as crushers, belt feeders, belts, and certain mobile equipment, would be required to be permissible also.

Just how 30CFR 57.21-78 will be interpreted depends very much on the design of the face ventilation system. Since these designs are not known at this time, an exact answer to these questions is not available. Face ventilation has been designated as a high priority research area by the oil shale operators.

These uncertainties have contributed to the delays presently being experienced by the industry. Neither mine planners nor federal regulatory officials can make clear decisions because of these uncertainties.

Because of the recent passage of changes to Part 36 one additional problem has been resolved. This recent standard change allows electrical equipment approved under Part 18 to be used on diesel-powered equipment approved under Part 36. Several operators are now considering use of equipment with diesel mobility and electric/hydraulic power systems for drilling and bolting.

4.3 Petitions for Modifications

The Federal Mine Safety and Health Act of 1977 allows for petitions by the operator to the Secretary for modification of the application of mandatory safety standards. This provision is found in Title I of the Act, Section 101(c).

It was foreseen by Congress that not every standard was applicable to every mining situation. Therefore, when an operator decides that a particular standard does not apply to his mine situation, the operator can petition for a modification. The alternate method suggested by the operator must at all times guarantee no less than the same measure of protection afforded the miners by the standard. Stated another way, the application of the alternate method must not result in a diminution of safety to the miners working in that mine.

This section of the act also allows an operator to petition for modification of a standard when the technology to be used at the mine is not addressed by existing standards. If it is felt that a new type of technology, mining system, or piece of equipment is just as safe as present practice, its use would be allowed. Such use is rigidly controlled by written safeguards and operating procedures.

5. DESCRIPTION OF ELECTRICAL INSTALLATIONS WITH RECOMMENDATIONS FOR REGULATORY CHANGES

As noted above, no oil shale mines are operating on a commercial basis at this time. Plans for most operations are still in the preliminary stage and are subject to change before operations begin. The following descriptions and discussions are based on these preliminary plans.

For purposes of this discussion, electrical installations in oil shale mines are broken into the following categories:

a. <u>High Voltage Power Distribution Systems</u> - This system begins with the borehole cable entering the mine, and extends to the power center on the section or in other locations where power is needed.

b. <u>Trailing Cables</u> - The cables extending from the power center to the power consuming devices.

c. <u>Face Equipment</u> - Equipment directly involved in the production process.

d. <u>Ancillary Support Systems</u> - Ventilation equipment (booster and auxiliary fans), lighting, environmental monitoring and communication systems.

The electrical installations planned by existing and potential operators are described. Existing regulations are discussed and recommendations for change are made, where appropriate, to address the unique hazards existing in oil shale mining.

5.1 High Voltage Power Distribution Systems

Part 57 contains few specific requirements for high voltage power distribution systems. The general electrical requirements of Section 57.12 applicable to these systems are:

a. §57.12-1 - Circuits shall be protected against excessive overloads by fuses or circuit breakers of the correct type and capacity.

b. §57.12-2 - (switches and controls shall be provided).

c. §57.12-4 - Electrical conductors shall be of sufficient size and current carrying capacity to ensure that a rise in temperature resulting from normal operations will not damage the insulating materials. Electrical conductors exposed to mechanical damage shall be protected.

d. §57.12-11 - High-potential electrical conductors shall be covered, insulated or placed to prevent contact with low potential conductors.

Other sections add more requirements for *all* electrical circuits, including:

a. Protection of cables from mobile equipment

b. Provision of visible disconnects on distribution boxes

c. A requirement that power-cable connections not be made or broken under load

d. Provision of adequate insulation

e. General requirements related to splice quality

f. Provisions for "suitable" clearances, circuit labeling, insulating mats at switches, correction of potentially dangerous conditions, etc.

These provisions are relatively broad and somewhat vague. To say that a high voltage distribution system is designed to meet the requirements of Part 57 conveys little specific information about that system. Not surprisingly, systems being planned by oil shale operators meet, and exceed, the Part 57 requirements.

A plan that represents the approach typically contemplated by potential operators is pictured in Figure 5. All operators interviewed plan to use a 13.8 kV distribution system.

The decision to use 13.8 kV is based on the size of the electrical loads planned, and the desire to minimize the number of boreholes and the size (and cost) of cables. Little consideration has been given to the additional maintenance (particularly

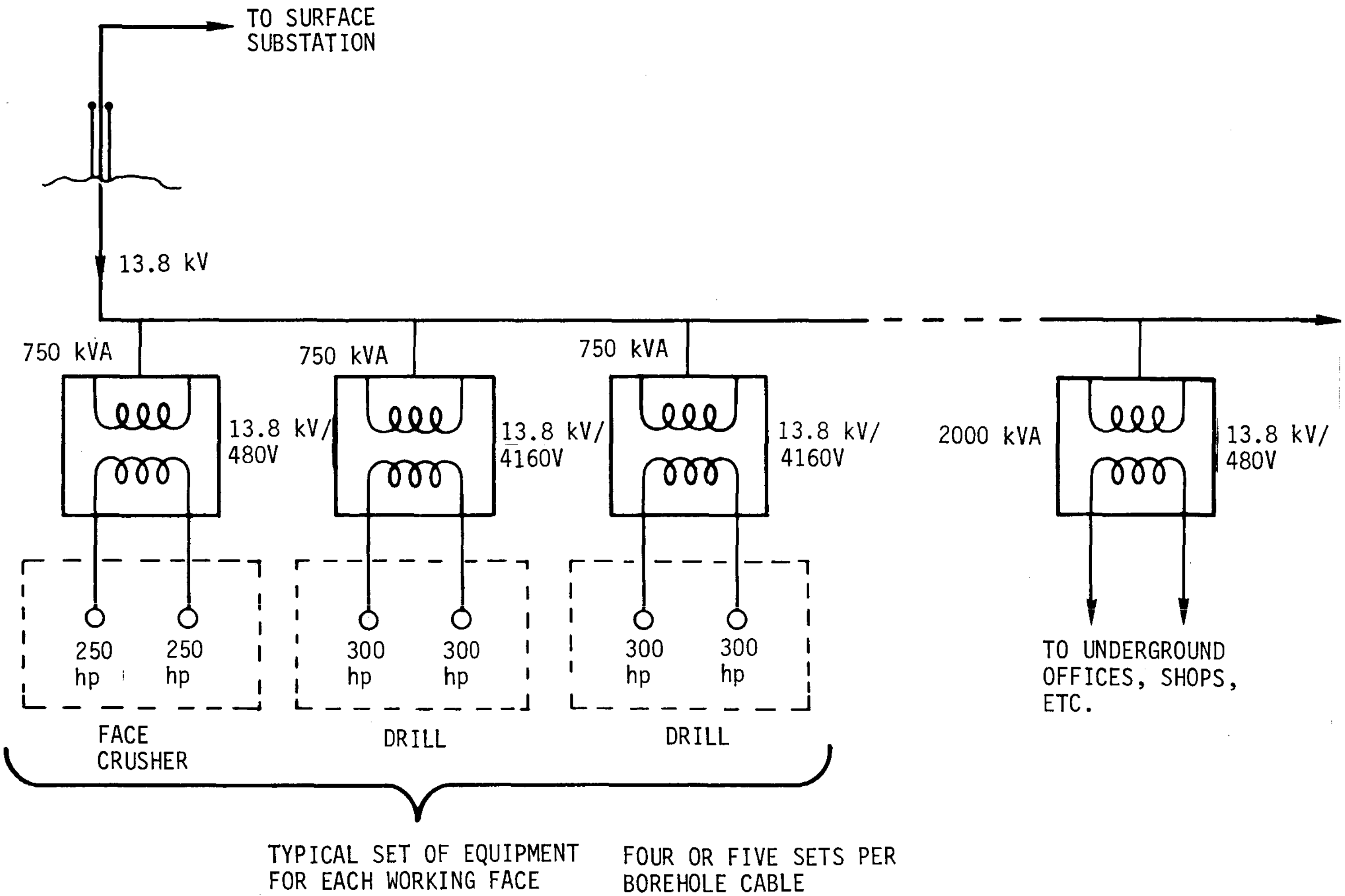


FIGURE 5. - High voltage distribution system for underground oil shale mine.

in the underground environment) and increased quality of installation required for successful operation at this voltage. Experience in coal mining has shown that considerably more effort is required to maintain and operate a 13.8 kV system, under "typical" mining conditions*, than is needed for a 7200V system. This situation, when coupled with the lack of mandatory safety standards for high voltage power distribution systems in Part 57, makes adoption of the recommendations given below a matter of great importance.

Current plans call for transformers to be located as close as possible to the connected loads. Due to the size of equipment contemplated, and the relatively long distances between equipment on the same section, several smaller transformers, rather than one central unit, are envisioned. Secondary voltages will vary, depending on the size of the largest motors in the circuit. As with the primary voltage, operators are uniform in their intentions to operate at 480V when motors are smaller than 200-250 hp, and at 4160V when motors are larger.

Other aspects of high voltage distribution systems common to most planned oil shale operations include:

a. Use of shielded high voltage cables

b. Use of a grounded electrical system (in most cases, a resistance grounded system is planned)

c. Use of ground fault protection and ground monitoring systems.

None of these characteristics are *required* by Part 57. However, Section 18.47 of Part 18 does require these types of protection for permissible equipment operating at voltages in excess of 660V.

A potential problem arises in mines that begin operation as non-gassy mines, and are subsequently classed gassy. Switches, transformers and other hardware, when not located in intake

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*Dust and moisture contamination can lead to premature failure of high voltage components. Oil shale is thought to be conductive at higher voltages.

airways, are relatively easy to relocate in the event of gassy classification. However, cables located in return air courses and shafts, or in other "places where dangerous quantities of flammable gases are present or may enter the air current," are not easy to relocate. Replacing such cables with permissible (flame-resistant) cables is also difficult, and would often prove economically impractical. Thus, it is recommended that operators install permissible cables in all areas where such cables would be required in a gassy mine, *regardless* of the initial mine classification. High-voltage couplers, not presently available in permissible form, should be confined to intake air courses. The combustibility of oil shale offers ample justification for the use of these flame-resistant cables, even in the absence of a gassy classification.

Recommendations

The following recommendations are made regarding high voltage power distribution systems in oil shale mines:

a. Require the Use of Resistance Grounded Power Systems - Although most operators are planning to use such systems, it is not required by Part 57. The combustibility of oil shale offers ample justification for this requirement in all oil shale mines.

b. Require the Use of Shielded Cables on All High Voltage (>650 Volts) Distribution Circuits - The personal protection offered by these cables is well documented. Their use also minimizes the occurrence of phase-to-phase faults, and thus reduces a potential fire hazard.

c. Require the Use of Overcurrent, Short-Circuit, Ground Fault, and Undervoltage Protection in All Three-Phase Power Circuits - Only overcurrent protection is required by existing Part 57 regulations. Short-circuit protection should be provided for cables. Ground fault protection will reduce flash hazards to personnel and fire hazards resulting from ground faults in cables and equipment. Undervoltage protection will prevent the development of overheating in motors and provides a means by which other protective devices can be used to de-energize power circuits.

d. Require Periodic Testing and Inspection of High Voltage Circuit Breakers and Related Switchgear - To ensure adequate maintenance and proper operation of circuit protective devices, periodic inspections are essential. While most operators are likely to institute such programs voluntarily, lack of specific guidelines regarding inspection frequency and procedures will lead to disputes.

e. Require Additional Safeguards Concerning Use of Oil-Filled Electrical Equipment in Underground Oil Shale Mines - Specifically, require that such equipment be permanently housed in fire resistant rooms and ventilated with separate splits of intake air.

f. Adopt Specific Guidelines Regarding Grounding Practices for Power Systems and Metal Structures Underground - Discussions with mine operators reveal much confusion on the part of miners and inspectors regarding proper grounding practices. For example, some inspectors have required installation of ground rods in the mine to ground metal doors and stoppings through which cables pass. Alternatives, such as connecting these structures to the neutral conductor of the power system should be allowed. Section 57.12-25 was specifically cited as the source of some of this confusion. Most operators feel that specific guidelines, or even requirements, are preferable to the "Ad Hoc" approach now taken. Some inspectors refer to the National Electric Code to determine what is "proper." Perhaps a better guide might be appropriate sections of Part 75.

g. Require that Only Properly Trained Personnel be Used in Installation and Maintenance of High Voltage Power Distribution Systems - This is particularly important since use of higher voltages (13.8 kV) is contemplated by virtually all oil shale operators. Comments from industry personnel indicate that this problem may be severe in particular operations.

h. Require the Use of Permissible Cables in All Areas of Oil Shale Mines Where Such Cables Would be Required if the Mines Were Classified Gassy, Regardless of the Initial or Existing Classification of the Mine - Experience has shown that, once installed, it is unlikely that main distribution cables would be replaced in the event of mine reclassification. The combustibility of the ore, which is a problem in gassy and non-gassy mines, offers ample justification for this requirement.

5.2 Trailing Cables

The trailing cable, or portable cable, has been defined as "that portion of the power-supply system between the last short-circuit protective device, acceptable to MSHA, in the system and the machine or accessory to which it transmits electrical energy."* In room and pillar mining situations, such as those planned for oil shale mines, a trailing cable begins at the sectional power center and ends at the face machine or auxiliary equipment consuming the power.

For non-gassy metal and non-metal mines, including oil shale, the following regulations apply specifically to trailing cables:

a. §57.12-3 - Individual overload protection *or* short-circuit protection shall be provided for the trailing cables of mobile equipment (emphasis added).

b. §57.12-27 - Frame grounding or equivalent protection shall be provided for mobile equipment powered through trailing cables.

c. §57.12-38 - Trailing cables shall be attached to machines in a suitable manner to protect the cable from damage and to prevent strain on the electrical connections.

d. §57.12-39 - Surplus trailing cables to shovels, cranes and similar equipment shall be:

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*See Section 18.2 - Definitions, Part 18.

1. Stored in cable boats

2. Stored in reels mounted on the equipment or

3. Otherwise protected from mechanical damage.

e. §57.12-88 - No splice, except a vulcanized splice or its equivalent, shall be made in a trailing cable within 25 ft of the machine unless the machine is equipped with a cable reel or other power feed cable payout-retrieval system. However, a temporary splice may be made to move the equipment for repair.

Other general electrical requirements calling for adequate insulation, sufficient conductor size, protection from mobile equipment, etc., also apply to trailing cables.

In gassy mines, detailed requirements for trailing cables are added by Part 18. Section 18.35* specifies:

a. The current-carrying capacity of cable conductors

b. Minimum conductor sizes

c. Flame-resistant properties

d. Short-circuit protection

e. Maximum length

f. Outside dimensions

g. Number of allowable temporary splices.

In addition to these requirements, Section 18.47 (2), (4) and (5) calls for shielded power conductors and a ground check conductor to allow for continuous ground monitoring in trailing cables used on equipment operating at voltages in excess of 660V.

This dual approach to regulation is not well suited to trailing cable use in oil shale mines. On the one hand,

*The full text of Section 18.35 is presented on pages 58 to 62 at the end of this section.

the requirements for trailing cables in non-gassy mines are not stringent enough to address the fire hazards and the personal hazards created by the planned use of high voltage (4160V) trailing cables. On the other hand, the requirements for gassy mines, especially those limiting the maximum length of trailing cables, are unnecessarily stringent in the oil shale context. Specific deficiencies in these regulations are discussed below, along with recommendations for appropriate changes.

Recommendations

The following recommendations are made regarding the use of trailing cables in all oil shale mines (gassy and non-gassy):

a. Require the Provision of Short-Circuit Protection for Individual Trailing Cables - Part 57 presently allows provision of overload protection *only* to suffice. In circuits with high available short-circuit fault currents, damage to cables, resulting in hazards to personnel and property, may result from cable faults. (Already required by Part 18.)

b. Require the Use of Shielded Cables for All High Voltage (>650V) Trailing Cable Applications - The additional safety afforded by this type of cable construction is well documented. (Already required by Part 18.)

c. Require All Trailing Cables to Have Flame-Resistant Properties - These cables are commonly available. Most cables made specifically for mining applications are flame-resistant. This is a relatively easy way to remove a fire hazard from oil shale mines. (Already required by Part 18.)

d. In Gassy Oil Shale Mines, the Restrictions Regarding Maximum Length of Trailing Cables Found in Section 18.35(a) (5) Should Not Apply - These restrictions (see page 58) limit trailing cables to a maximum of 1,000 ft. They are designed to prevent excessive (>25V) voltage drop in trailing cables, primarily in coal mining situations. The limits set in Table 9, Appendix I, Part 18 effectively limit voltage drop in low voltage circuits to approximately 3 to 5 percent. In a 4160 volt circuit, using the same ampacity figures found in Table 9, limiting voltage drop to 2 percent would allow for use of cables approximately 3,000 ft long. The physical layout of mining systems planned for oil shale are likely to demand such longer cables. The requirements that should apply to these cables are:

1. They should be adequately sized to prevent excessive voltage drop.

2. Excess cable should be protected as required by Sections 57.12-5 and 57.12-39.

The requirements for trailing cables from Part 18 are presented on the following pages.

Part 18 - Requirements for Trailing Cables

§18.35 Portable (trailing) cables and cords.

(a) Portable cables and cords used to conduct electrical energy to face equipment shall conform to the following:

(1) Have each conductor of a current-carrying capacity consistent with the Insulated Power Cable Engineers Association (IPCEA) standards. (See Tables 1 and 2 in Appendix I.)

(2) Have current-carrying conductors not smaller than No. 14 (AWG). Cords with sizes 14 to 10 (AWG) conductors shall be constructed with heavy jackets, the diameters of which are given in Table 6 in Appendix I.

(3) Have flame-resistant properties. (See § 18.64.)

(4) Have short-circuit protection at the outby (circuit-connecting) end of ungrounded conductors. (See Table 8 in Appendix I.) The fuse rating or trip setting shall be included in the assembler's specifications.

(5) Ordinarily the length of a portable (trailing) cable shall not exceed 500 feet. Where the method of mining requires the length of a portable (trailing) cable to be more than 500 feet, such length of cable shall be permitted only under the following prescribed conditions:

(i) The lengths of portable (trailing) cables shall not exceed those specified in Table 9, Appendix I, titled "Specifications for Portable Cables Longer Than 500 Feet."

(ii) Short-curcuit protection shall be provided by a protective device with an instantaneous trip setting as near as practicable to the maximum starting-current-inrush value, but the setting shall not exceed the trip value specified in MSHA approval for the equipment for which the portable (trailing) cable furnishes electric power.

(6) Have nominal outside dimensions consistent with IPCEA standards. (See Tables 4, 5, 6, and 7 in Appendix I.)

(7) Have conductors of No. 4 (AWG) minimum for direct-current mobile haulage units or No. 6 (AWG) minimum for alternating-current mobile haulage units.

(8) Have not more than five well-made temporary splices in a single length of portable cable.

(b) Sectionalized portable cables will be acceptable provided the connectors used inby the last open crosscut in a gassy mine meet the requirements of §18.41.

(c) A portable cable having conductors smaller than No. 6 (AWG), when used with a trolley tap and a rail clamp, shall have well insulated single conductors not smaller than No. 6 (AWG) spliced to the outby end of each conductor. All splices shall be made in a workmanlike manner to insure good electrical conductivity, insulation, and mechanical strength.

(d) Suitable provisions shall be made to facilitate disconnection of portable cable quickly and conveniently for replacement.

APPENDIX I

List of tables

Table No.	Title
1	Portable power cable ampacities—600 volts.
2	Portable cord ampacities—600 volts.
3	Portable power cable ampacities—601 to 5,000 volts.

APPENDIX I—Continued

List of tables

Table No.	Title
4	Normal diameter of round cables with tolerances in inches—600 volts.
5	Nominal dimension of flat cables with tolerances in inches—600 volts.
6	Nominal diameter of heavy jacketed cords with tolerances in inches—600 volts.
7	Nominal diameter of three-conductor portable power cables with tolerances in inches—601 to 5,000 volts.
8	Fuse ratings or instantaneous settings of circuit breakers for short-circuit protection of portable cables.
9	Specifications for portable cables longer than 500 feet.

TABLE 1—PORTABLE POWER CABLE AMPACITIES—600 VOLTS (AMPERES PER CONDUCTOR BASED ON 60° C. COPPER TEMPERATURE—40° C. AMBIENT)

Conductor size—AWG or MCM	Single conductor	2-conductor, round or flat	3-conductor, round or flat	4-conductor	5-conductor	6-conductor
8	45	40	35	30	25	20
6	60	50	50	40	35	30
4	85	70	65	55	45	35
3	95	80	75	65	55	45
2	110	95	90	75	65	55
1	130	110	100	85	75	65
1/0	150	130	120	100	90	80
2/0	175	150	135	115	105	95
3/0	205	175	155	130	120	110
4/0	235	200	180	150	140	130
250	275	220	200	160		
300	305	240	220	175		
350	345	240	235	190		
400	375	280	250	200		
450	400	300	270	215		
500	425	320	290	230		

TABLE 2—PORTABLE CORD AMPACITIES—600 VOLTS (AMPERES PER CONDUCTOR BASED ON 60° C. COPPER TEMPERATURE—40° C. AMBIENT)

Conductor size—AWG	1-3 conductor	4-6 conductor	7-9 conductor
14	15	12	8
12	20	16	11
10	25	20	14

TABLE 3—PORTABLE POWER CABLE AMPACITIES—601 TO 5,000 VOLTS (AMPERES PER CONDUCTOR BASED ON 75° C. COPPER TEMPERATURE—40° C. AMBIENT)

Conductor size—AWG or MCM	3-conductor types G-GC and SHC–GC 2,000 volts	3-conductor type SHD-GC 2,001-5,000 volts
6	65	65
4	85	85
3	100	100
2	115	115
1	130	130
1/0	145	145
2/0	170	170
3/0	195	195
4/0	220	220
250	245	245
300	275	275
350	305	305

TABLE 4—NOMINAL DIAMETERS OF ROUND CABLES WITH TOLERANCES IN INCHES—600 VOLTS

Conductor size—AWG or MCM	Single conductor	2-conductor			3-conductor			4-conductor—Types W & G	5-conductor—Types W & G	6-conductor	
		Types W & G twisted	Type PG, 2 power	Type PCG, 3 power, ground	Types W & G	Type PG, 3 power, ground	Type PCG, 3 power, 2 control, ground			Type w	Tolerance
8	0.44	0.81	0.84	0.94	0.91	0.93	1.03	0.99	1.07	1.18	±0.03
6	.51	.93	.93	.98	1.01	1.03	1.18	1.10	1.21	1.31	±.03
4	.57	1.08	1.08	1.10	1.17	1.20	1.29	1.27	1.40	1.52	±.03
3	.63	1.17	1.17	1.20	1.24	1.27	1.31	1.34	1.48	1.61	±.03
2	.66	1.27	1.27	1.29	1.34	1.34	1.39	1.48	1.61	1.75	±.03
1	.74	1.44	1.44	1.44	1.51	1.52	1.52	1.68	1.88	2.05	±.03
1/0	.77	1.52	1.52	1.52	1.65	1.68	1.68	1.79	1.96	2.13	±.04
2/0	.82	1.65	1.65	1.65	1.75	1.79	1.79	1.93	2.13	2.32	±.04
3/0	.87	1.77	1.77	1.77	1.89	1.93	1.93	2.07	2.26	2.49	±.05
4/0	.93	1.92	1.92	1.92	2.04	2.13	2.13	2.26	2.46	2.71	±.05
250	1.03	2.16	2.16	2.16	2.39	2.39	2.39	2.66			±.06
300	1.09	2.32			2.56			2.84			±.06
350	1.15	2.43			2.68			2.98			±.06
400	1.20	2.57			2.82			3.14			±.06
450	1.26	2.67			2.94			3.26			±.06
500	1.31	2.76			3.03			3.40			±.06

TABLE 5—NOMINAL DIMENSIONS OF FLAT CABLES WITH TOLERANCES IN INCHES—600 VOLTS

Conductor size—AWG	2-conductor								3-conductor—Type G			
	Type W				Type G				Major		Minor	
	Major		Minor		Major		Minor					
	O.D.	Tolerance	O.D.	Tolerance	O.D.	Tolerance	O.D.	Tolerance	O.D.	Tolerance	O.D.	Tolerance
8	0.84	±0.04	0.51	±0.03								
6	.93	±.04	.56	±.03	1.02	±.04	0.56	±.03	1.65	±0.06	0.67	±0.05
4	1.05	±.04	.61	±.03	1.15	±.04	.61	±.03	1.85	±.06	.75	±.05
3	1.14	±.04	.68	±.03	1.26	±.04	.68	±.03	1.99	±.06	.77	±.05
2	1.24	±.04	.73	±.03	1.35	±.04	.73	±.06	2.10	±.06	.81	±.05
1	1.40	±.04	.81	±.03	1.55	±.04	.81	±.03	2.43	±.06	.97	±.05
1/0	1.51	±.04	.93	±.03	1.67	±.04	.93	±.03				
2/0	1.63	±.04	.99	±.03	1.85	±.04	.99	±.03				
3/0	1.77	±.04	1.03	±.03	2.00	±.04	1.03	±.03				
4/0	1.89	±.04	1.10	±.03	2.10	±.04	1.10	±.03				

TABLE 6—NOMINAL DIAMETERS OF HEAVY JACKETED CORDS WITH TOLERANCES IN INCHES—600 VOLTS

Conductor size—AWG	2-conductor		3-conductor		4-conductor		5-conductor		6-conductor		7-conductor	
	Diameter	Tolerance	Diameter	Tolerance	Diameter	Tolerance	Diameter	Tolerance	Diameter	Tolerance	Diameter	Tolerance
14	0.64	±0.02	0.67	±0.02	0.71	±0.02	0.78	±0.03	0.83	±0.03	0.89	±0.03
12	.68	±.02	.72	±.03	.76	±.03	.83	±.03	.89	±.03	.98	±.03
10	.73	±.03	.80	±.03	.84	±.03	.90	±.03	1.00	±.03	1.07	±.03

TABLE 7—NOMINAL DIAMETERS OF THREE-CONDUCTOR PORTABLE POWER CABLES WITH TOLERANCES IN INCHES—601 to 5,000 VOLTS

Conductor size—AWG or MCM	Type G-GC (nonshielded) 2,000 volts		Type SHC-GC (shielded overall) 2,000 volts		Type SHD-GC (individually shielded power conductors) 2,001-3,000 volts		Type SHD-GC (individually shielded power conductors) 3,001-5,000 volts	
	Diameter	Tolerance	Diameter	Tolerance	Diameter	Tolerance	Diameter	Tolerance
6	1.25	+0.10, −0.06	1.39	+0.11, −0.07	1.62	+0.13, −0.08	1.78	+0.14, −0.09
4	1.40	+.11, −.07	1.55	+.12, −.08	1.77	+.14, −.09	1.90	+.15, −.10
3	1.48	+.12, −.07	1.62	+.13, −.08	1.84	+.15, −.09	1.98	+.16, −.10
2	1.55	+.12, −.08	1.71	+.14, −.09	1.92	+.15, −.10	2.09	+.17, −.11
1	1.74	+.14, −.09	1.89	+.15, −.09	2.04	+.16, −.10	2.18	+.17, −.11
1/0	1.84	+.15, −.09	2.02	+.16, −.10	2.18	+.17, −.11	2.34	+.19, −.12
2/0	1.99	+.16, −.10	2.16	+.17, −.11	2.29	+.18, −.12	2.46	+.20, −.12
3/0	2.12	+.17, −.11	2.30	+.18, −.11	2.45	+.20, −.12	2.62	+.21, −.13
4/0	2.30	+.18, −.12	2.48	+.20, −.12	2.62	+.21, −.13	2.76	+.22, −.14
250	2.46	+.20, −.12	2.70	+.22, −.13				
300	2.63	+.21, −.13	2.84	+.23, −.14				
350	2.75	+.22, −.14	2.97	+.24, −.15				

TABLE 8—FUSE RATINGS OR INSTANTANEOUS SETTING OF CIRCUIT BREAKERS FOR SHORT-CIRCUIT PROTECTION OF PORTABLE CABLES AND CORDS

Conductor size—AWG or MCM	Ohms/ 1,000 ft. at 25° C.	Maximum allowable fuse rating (amperes)	Maximum allowable circuit breaker instantaneous setting (amperes) [1]
14	2.62	20	50
12	1.65	30	75
10	1.04	40	150
8	.654	80	200
6	.410	100	300
4	.259	200	500
3	.205	250	600
2	.162	300	800
1	.129	375	1,000
1/0	.102	500	1,250
2/0	.081		1,500
3/0	.064		2,000
4/0	.051		2,500
250	.043		2,500
300	.036		2,500
350	.031		2,500
400	.027		2,500
450	.024		2,500
500	.022		2,500

[1] Higher circuit-breaker settings may be permitted for special applications when justified.

TABLE 9—SPECIFICATIONS FOR PORTABLE CABLES LONGER THAN 500 FEET [1]

Conductor size—AWG or MCM	Max. allowable length (feet)	Normal ampacity at 60° C. copper temperature (40° C. ambient)	Resistance at 60° C. copper temperature (ohms)
6	550	50	0.512
4	600	70	.353
3	650	80	.302
2	700	95	.258
1	750	110	.220
1/0	800	130	.185
2/0	850	150	.157
3/0	900	175	.130
4/0	1,000	200	.116
250	1,000	220	.098
300	1,000	240	.082
350	1,000	260	.070
400	1,000	280	.061
450	1,000	300	.054
500	1,000	320	.050

[1] Fuses shall not be used for short-circuit protection of these cables. Circuit breakers shall be used with the instantaneous trip settings not to exceed the values given in Table 8.

5.3 Face Equipment

As mining systems for oil shale develop, many new types of face equipment are likely to be needed. Some types will be diesel powered, and some will be electric. Some of the electric equipment will be permissible, and some will not. However, discussions with operators reveal that, in the foreseeable future, the following mix of equipment is most likely to be found in the face areas of underground oil shale mines:

a. 12 to 15 cubic yard front-end loaders (diesel-powered)

b. 12 to 15 cubic yard load-haul-dump (diesel-powered)

c. 50-85 ton trucks (diesel-powered)

d. Face crusher or belt feeder-breaker (electric-powered)

e. Jumbo face drills for development (combination diesel and electric)

f. Roof bolter (combination diesel and electric)

g. Roof scaler (diesel-powered)

h. Vertical bench drill (combination diesel and electric)

i. Explosives truck (diesel-powered).

The only totally electric piece of face equipment now contemplated is the crusher (or feeder breaker). Indications are that this machine would be powered by two 250 hp, 4160V or 480V motors. It would be used in conjunction with a load-haul-dump (LHD) and a belt conveyor haulage system. Permissible and non-permissible versions will be needed, depending on mine classification. However, it should be emphasized that this particular system, while feasible, will not be used in the commercial mines scheduled to open in the near future. Large diesel truck haulage is planned for these operations.

The primary use of electric power on face equipment will be for drilling. Jumbo face drills, vertical bench drills and roof drills are expected to be diesel electric combinations, using diesel power for mobility and electric power for drilling. Operators were unanimous in their intentions to consider two possible operating voltages for this equipment:

- 480V will be used for equipment consuming less than 200 to 250 hp

- 4160V will be used for equipment consuming more than 250 to 300 hp.

Roof drills are expected to fall into the 480V category, with jumbos and vertical drills requiring 4160V. In most instances, the equipment will be trammed into position using diesel power, and then plugged in for drilling with electric power.

Permissible electric face equipment of these types can be approved under Part 18. Section 18.47(d) lists the conditions necessary for approval of high voltage (660V - 4160V) machines. They include:

- Provision of adequate clearances and insulation
- Use of frame grounding, ground monitoring, ground fault protection and resistance grounding
- Remote location of switchgear for equipment operating at voltage of 1001 - 4160V
- Use of shielded cables for high voltage equipment.

MSHA has approved 4160V motors for use in coal mining applications. However, starters and other switchgear are required by Section 18.47(d) (3) to be located remotely, and have thus not been approved in permissible form. This arrangement presents no substantial problems in oil shale mining situations.

Nonpermissible, high voltage electric face equipment is not subject to the requirements of Part 18. However, if the recommendations for power systems and trailing cables given above are adopted, and if adequate clearances and insulation for the operating voltage(s) are provided, operations of this equipment should not introduce unique hazards in oil shale mines.

5.4 Ancillary Support Systems

Various additional types of electrical equipment and systems are being considered for use in underground oil shale mines. These include systems for ventilation, lighting, environmental monitoring and communications. Plans for these ancillary systems are still preliminary. The following discussion presents a brief look at ideas under consideration, and at potential problems that may arise.

5.4.1 Ventilation

Main ventilation fans will usually be located on the surface. However, some operators are considering the use of large booster. fans underground. Due to the large amounts of air required, fans up to 1800 hp are being considered. The desire to make these fans permissible was expressed. At this time, however, MSHA lacks the capability for approving such large motors.

The use of smaller auxiliary fans is planned by some operators. These fans are likely to be located close to the operating face. They will require approximately 75 hp and will likely be powered at 480V from a sectional power center. Permissible units are available and will be required in gassy mines. Some operators have indicated their intentions to use permissible units regardless of initial mine classification.

5.4.2 Lighting

Most operators intend to use task lighting (e.g., headlights) as normally provided on loaders, trucks, and similar equipment. Little area lighting on the face is being considered. Operators questioned the practicality of, and need for, providing area lighting in the large entries planned for oil shale mines. Questions were also raised concerning the availability of permissible lighting systems large and powerful enough for use in oil shale.

The possible use of some area lighting on main haulageways and around permanent electrical installations is being considered. Permissible lighting equipment is not deemed necessary for these applications. However, some UL-approved, explosion-proof lighting fixtures were used underground at Rio Blanco.

5.4.3 Environmental Monitoring

Environmental monitoring systems that are much more complex and sophisticated than those used in mining in the past are planned for some oil shale mines. Mines may have a need to monitor methane, carbon monoxide, sulfur dioxide, airborne dust, underground temperature, surface temperature, relative humidity, air velocity, fan pressure, main power supply status, and perhaps have smoke/fire sensors on belt liner. Where such systems are used in a gassy mine "beyond the last open crosscut" or in places where dangerous quantitites of flammable gases are present or may enter the air current," they must be permissible. This raises the question of availability of the needed instrumentation in permissible form. It is not likely that the relatively small number of oil shale mines that may open in the foreseeable future will create a market large enough to prompt the appropriate manufacturers to seek MSHA approval of their environment. MSHA has, however, allowed equipment approved by UL (and other similar organizations) to be used around the underground retort of the

Rio Blanco mine. They have indicated a willingness to accept this type of equipment, when permissible equipment is not available, provided that it can be shown that such equipment has been tested or can be modified to provide an adequate level of protection. Approval procedures for mine-wide monitoring systems have recently been released by MSHA. These procedures are discussed in other sections of this report.

5.4.4 Communications

Operators are nearly unanimous in their intentions to use a wireless (radio) communication system in oil shale mines. An FM system is planned and, based on use in pilot projects to date, no insurmountable problems are expected. Repeater installations will be necessary at various points throughout a mine. These will be located in fresh-air areas. Permissible handsets (walkie-talkies) are available for use at the face.

6. ANALYSIS OF HAZARDS

All underground mining operations involve activities which are inherently hazardous. Oil shale mines will suffer many of the same hazards present in other types of metal and nonmetal mines. However, additional unique hazards associated with large equipment sizes, combustible ore bodies, and flammable gases will be present in oil shale.

An attempt to detail each and every hazard associated with oil shale mining was not made. The major hazards associated with anticipated mining systems were emphasized. Table 1 shows the general categories and organization of these hazards. Our discussions with oil shale operators indicate planned similarities in high voltage distribution systems and face equipment. The hazard analysis was organized around these two categories. Subcategories of personal hazards, fire, and explosive gas were used to further identify particular dangers. The column on the right side of Table 1 lists the recommendations in general form. These generalized recommendations are further analyzed in other sections of this report where specific recommendations are made.

The question of explosive dust in oil shale mines has been discussed and studied for years. Although much has been learned and several facts have been documented, questions still remain. There is little disagreement with the fact that under the proper conditions, oil shale will burn and can sustain a fire. However, under certain conditions of ore grades and size distribution, burning is not possible. Researchers have tried to define the conditions under which oil shale is combustible and explosive. Work done by John Nagy* in 1967 indicated that an explosion hazard can exist under certain conditions. J.K. Richmond and others** confirmed Nagy's conclusions. This work generally shows that rich grades of oil shale will ignite while leaner grades will not.

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*Memo to F.W. Felegy, District Manager, Health and Safety District E from John Nagy Project Coordinator, Dust & Ventilation. Subject-Explosibility of Oil Shale samples from the Anvil Points Mine, Rifle, CO, December 18, 1967.

**Richmond, J.K., et al., "Explosion Hazards in Gassy and Non-gassy Oil Shale Mines," 14th Oil Shale Symposium, Denver, CO, April 1981.

**Richmond, J.K., et al., "Fire and Explosion properties of Oil Shale, Part II," 13th Oil Shale Symposium, Colorado School of Mines, Golden, CO, April 1980, pp. 193-207.

TABLE 1. - Oil shale hazards

<table>
<tr><th>Hazards</th><th>Specific Actions</th><th>General Recommendations</th></tr>
<tr><td colspan="3">High Voltage Distribution System</td></tr>
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• Physical damage from vehicles</td><td>A,B,C,D,
I,K,L</td><td rowspan="3">A. Required training
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C. Proper cable design and installation
D. Protected installation
E. Research to set temperature limits
F. Inerting dust
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<tr><td>2. Fire
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<tr><td>2. Fire
• Surface temperature
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G,H</td></tr>
<tr><td>3. Explosive Gas
• Strata gas
• Gas from broken ore</td><td>F,G,H,I,
J,K</td></tr>
</table>

The question which remains concerns the composition of oil shale dust generated by an operating mine. Even though the ore body is well known and the average ore grade has been determined, the composition of the dust which will be produced during mining remains unknown. Additional research is needed to clarify which types of dust will burn and explode, and to develop appropriate sampling procedures for mine operators and regulators. As 30CFR 57.20-9 indicates, a determination of the explosive dust hazard present in individual mines will be necessary.

> *57.20-9 Mandatory. Dusts suspected of being explosive shall be tested for explosibility. If tests prove positive, appropriate control measures shall be taken.*

A related question involves the surface temperature limit for electrical enclosures. This limit is currently set at 150°C. There are conflicting opinions regarding the degree of safety afforded by this limit. This area should be re-examined when data from commercial oil shale operations becomes available.

Spontaneous combustion may also present a hazard in oil shale mines. Some operators plan to use piles of shale ore in cross-cuts for ventilation control. All will have ore piles resulting from mining activity at the face. The routing of electrical power lines and the provision of monitoring systems should be planned with hazards in mind.

The existance of hazards from flammable gases seem certain in some oil shale mines. Three developmental mines have been classified gassy to date. The occurrance of methane in oil shale mines has been studied by the Bureau of Mines* These studies indicate that the degree of hazard is likely to be less than that present in bituminous coal mines.

All operators are aware of the possibility of a gassy classification. Most hope to avoid this possibility for as long as possible by providing adequate ventilation. Contingency plans designed to ease conversion to gassy mine operation are being made by some. Complete compliance with existing standards may not be possible; however, due to the limitations imposed by equipment

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*Thimons, Edward D., R.P., Vinson, F.N. Kissell, "Forecasting Methane Hazards in Metal and Nonmetal Mines." U.S. Department of the Interior, Bureau of Mines, Report of Investigation No. 8392, 1979 size and scale of operations planned, a combination of monitoring systems, safe mining procedures and equipment will be needed to ensure safety.

This analysis and the recommendations made in other sections, of this report are based on the existing knowledge of operators, regulators, researchers, and others interested in the development of the oil shale industry. A lack of specific information regarding actual operations hampered this study. Re-examination of many of the problems discussed will be in order when commercial oil shale mines begin operation.

7. THE OPTIMAL LEVEL OF GROUND FAULT CURRENT FOR RESISTANCE GROUNDED OIL SHALE MINE POWER SYSTEMS

This section presents the results of an evaluation of the applicability of present coal and noncoal standards for ground fault protection to the underground distribution systems being considered for oil shale mines. A brief description of these systems and existing standards is followed by an analysis to determine the optimal level of ground fault current which should be permitted to flow in resistance grounded systems. The analysis considers the effects of ground fault current on personal safety, prevention of fires and equipment damage, and prevention of dangerous system overvoltages.

7.1 Electrical Distribution Systems Planned for Oil Shale Mines

Current plans for electrical distribution systems in oil shale mines are discussed in Section 5. A summary of this discussion is presented below. (The reader is referred to Section 5 for more detail.)

All operators plan to use a primary distribution voltage of 13.8 kV. This distribution system will supply power to load-centers located close to the equipment. Secondary voltage will vary depending on the size of large motors in the circuit. Circuits powering motors larger than 200 to 250 hp will operate at voltages of 4.16 kV, while 480V circuits will be used to power smaller motors. A typical distribution system is shown in Figure 4 in subsection 5.1.

In most cases, the primary distribution system will be a resistance grounded system. These systems are modeled on coal mine power systems with resistors sized to allow a ground fault current of 15 to 25 amperes to flow. Use of protective devices is planned to interrupt the circuit in the event of a ground fault. Ground monitoring systems and shielded cables will also be used.

The secondary distribution system will also be a resistance grounded system. Face equipment operated at 4.16 kV will be fed by shielded cables. Use of shielded cables is not planned for mobile equipment operating at 480V. Ground fault protection will be provided to open circuits in the event of a ground fault. Ground monitoring circuits will be used on these secondary circuits.

7.2 Standards for Ground Fault Protection in Coal and Noncoal Mines

The general requirements of Part 57 for noncoal mine electrical distribution systems are discussed in Section 5 of this report. As noted there, ground fault protection is not required by Part 57, except where incorporated through Part 18 (30CFR 18.47) for permissible equipment operated in excess of 660V. For the electrical systems described above, this exception will reach only 4160V permissible equipment.

7.2.1 Coal Mine Standards

Requirements for electrical distribution systems in underground coal mines are found in Part 75 of Title 30, CFR. Electrical requirements are found in the following subparts:

a. Subpart F - Electrical Equipment - General

b. Subpart G - Trailing Cables

c. Subpart H - Grounding

d. Subpart I - Underground High-Voltage Distribution

e. Subpart J - Underground Low- and Medium-Voltage Alternating Current Circuits

f. Subpart K - Trolley Wires and Trolley Feeder Wires.

Three sections of Subpart I contain the specific requirements related to ground fault protection in high voltage (>1000V) distribution circuits:

a. Ground fault protection is required by 30CFR 75.800:

§75.800 High-Voltage Circuits; Circuit Breakers
STATUTORY PROVISIONS

> High-voltage circuits entering the underground area of any coal mine shall be protected by suitable circuit breakers of adequate interrupting capacity which are properly tested and maintained as prescribed by the Secretary. Such breakers shall be equipped with devices to provide protection against under-voltage grounded phase, short circuit, and overcurrent.

b. The type of ground system to be used is specified in 30CFR 75.802(a):

§75.802 Protection of High-Voltage Circuits Extending Underground

(a) Except as provided in paragraph (b) of this section, high-voltage circuits extending underground and supplying portable, mobile, or, stationary high-voltage equipment shall contain either a direct or derived neutral which shall be grounded through a suitable resistor at the source transformers, and a grounding circuit, originating at the grounded side of the grounding resistor, shall extend along with the power conductor for the frames of all high-voltage equipment supplied power from that circuit.

c. The size of the grounding resistance is set by 30CFR 75.801:

§75.801 Grounding Resistors
STATUTORY PROVISIONS

The grounding resistor, where required, shall be of the proper ohmic value to limit the voltage drop in the grounding circuit external to the resistor to not more than 100V under fault conditions. The grounding resistor shall be rated for maximum fault current continuously and insulated from ground for a voltage equal to the phase-to-phase voltage of the system.

During a phase-to-ground fault, most of the voltage drop appearing across the grounding circuit will also appear across the person's body. Consequently, if a 25-ampere grounding resistor is used, the maximum impedance of the grounding circuit cannot exceed 4 ohms.

Subpart J contains similar requirements for low ($\leq$600V) and medium (661 to 1000V) voltage circuits.

a. Ground fault protection is required by 30CFR 75.900

§ 75.900 Low- and Medium-Voltage Circuits Serving Three-Phase Alternating Current Equipment; Circuit Breakers
STATUTORY PROVISIONS

Low- and medium-voltage power circuits serving three-phase alternating current equipment shall be protected by suitable circuit breakers of adequate interrupting capacity which are properly tested and maintained as prescribed by the Secretary. Such breakers shall be equipped with devices to provide protection against undervoltage, grounded phase, short circuit, and overcurrent.

b. The type of grounding system to be used is specified in 30CFR 75.901:

§75.901 Protection of Low- and Medium-Voltage Three-Phase Circuits Used Underground
STATUTORY PROVISIONS

(a) Low- and medium-voltage three-phase alternating-current circuits used underground shall contain either a direct or derived neutral which shall be grounded through a suitable resistor at the power center, and a grounding circuit, originating at the grounded side of the grounding resistor, shall extend along with the power conductors and serve as a grounding conductor for the frames of all the electrical equipment supplied power from that circuit, except that the Secretary or his authorized representative may permit ungrounded low- and medium-voltage circuits to be used underground to feed such stationary electrical equipment if such circuits are either steel armored or installed in grounded rigid steel conduit throughout their entire length. The grounding resistor, where required, shall be of the proper ohmic value to limit the ground fault current to 25 amperes. The grounding resistor shall be rated for maximum fault current continuously and insulated from ground for a voltage equal to the phase-to-phase voltage of the system.

7.2.2 Applicability to Oil Shale Mines

As noted in earlier sections of this report, the lack of requirements for ground fault protection in Part 57 provide an inadequate level of protection for personnel and equipment in oil shale mines. Oil shale operators recognize this and are providing ground fault protection in all circuits. Some are using the requirements of Part 75 as guidelines for power system designs. Although oil shale mines will utilize high energy demand systems, voltages and power capacities currently planned are not excessive by coal mine standards. Thus, it must be concluded that the requirements for ground fault protection of Part 75, if imposed on oil shale mining operations, would not present unreasonable design problems.

7.3 The Optimal Level of Ground Fault Current

There are many ways in which to ground a power system. The complete discussion of this subject is beyond the scope of this program task. The reader is referred to prior work by the Bureau of Mines (12) or to publications by such organizations as the Institute for Electrical & Electronic Engineers (11) for a detailed treatment of different types of ground systems.

The discussion which follows is limited to the type of system commonly used in the mining industry, that is, a Y-connected transformer secondary with resistance grounded neutral. More specifically, the analysis presented below is intended to determine the "optimal" level of ground fault current which should be allowed to flow in oil shale mine power systems. This determination is made by considering the effect of ground fault current magnitude on personal safety, prevention of fires and equipment damage, and prevention of dangerous system overvoltages.

Resistance grounded systems can be classified into one of two types, depending on the amount of ground fault current allowed to flow. Low resistance systems are those which allow ground fault currents of from 25 to several thousand amperes to flow. High resistance systems usually limit ground current to 10 amps or less. Low resistance systems allowing high ground fault current flows are often used where short-circuit and overcurrent devices are relied upon to interrupt circuits in the event of a ground fault. High resistance systems allowing very low levels of current flow are generally used in systems where an <u>indication</u>, rather than a power interruption, is desired when a ground fault occurs. Power systems of interest to this study are presumed to be provided with ground fault devices which will <u>interrupt</u> the circuit at some predetermined ground fault current flow. Generally speaking, it would seem that the lowest current level that can be reliably detected would offer the maximum degree of safety from fire hazards, equipment damage, and personal injury. However, dangerous system overvoltages can occur if an insufficient amount of fault current is allowed to flow.

A power system conforming to the requirements Part 75 can technically be classified as a low resistance system. However, the maximum ground current allowed to flow (25 amps) is at the lower limit for low resistance grounded systems. In practice, most coal mine operators limit ground fault current to 15 amps, with detection devices set to trip at 7 to 8 amps. This system has a long history of successful operation under severe mining conditions in the underground coal mining industry. As noted earlier, many oil shale operators are planning to operate with this same type of system. These facts are taken to indicate that, for purposes of this analysis, the present requirements of Part 75 represent maximum levels of ground fault current which should be allowed to flow in high and low voltage circuits installed in oil shale mines. The remainder of this discussion is devoted to the question of whether or not a <u>lower</u> level of ground fault current flow should be recommended for these power systems. High voltage systems and low voltage systems are considered separately, followed by conclusions and recommendations.

7.3.1 Optimal Level of Ground Fault Current in High Voltage Systems

High voltage power systems planned for oil shale mines will operate at 13.8 kV and 4.16 kV. The analysis below attempts to determine the maximum level of ground fault current which should be allowed to flow in order to offer the maximum degree of safety from personal injury, fire hazards, equipment damage, and dangerous system overvoltages.

7.3.1.1 Personal Safety

Personal injury can result from ground faults on high voltage power systems in two ways:

a. Shock - Personnel come in direct contact with energized conductors, thus providing the path to ground through which current flows.

b. Burns and Flash - Personnel are exposed to the arc resulting when an energized conductor contacts a grounded surface.

Shock

Prior Bureau of Mines studies have established that extremely low quantities of electrical energy can be injurious, or even fatal, to humans (12). Current levels of 1 to 9 mA can produce mild to painful shocks, while currents in excess of 9 mA can result in paralysis, ventricular fibrillation, and cardiac arrest. Elimination of this shock hazard in high voltage systems of the type contemplated in oil shale mines would require a high degree of isolation from ground. However, it is known that systems with no intentional connection to ground (that is, systems with a ground resistor of infinite value) are in reality coupled to ground through the distributed capacitance of transformer phase windings and system conductors. The degree of capacitive coupling (see subsection 7.3.1.3 below) present in a high voltage power system in oil shale mines suggests that it may not be possible to provide personal protection from shock resulting from direct contact with energized conductors.

A shock to personnel is also created when an energized conductor contacts a grounded equipment frame (see Figure 6). Personnel in contact with the equipment frame will be exposed to a voltage rise equal to the product of the neutral wire resistance and the ground fault current. Part 75 regulations for high voltage systems allow a maximum voltage rise of 100V. This level of voltage represents a dangerous shock hazard to personnel.

If a neutral wire resistance of 4 ohms is assumed, the 100V standard allows a ground fault current flow of 25 amps. Viewed solely from the standpoint of personnel protection, these levels are clearly excessive. The optimal solution to this problem is to reduce both ground wire resistance and ground fault current flow to the lowest possible levels. Although problems arising from momentary system imbalances, sensitivity of detection devices, and other practical constraints not explored in this study are likely to arise, it seems reasonable to assume that a maximum ground fault current level of 10 amps or less could be successfully imposed. If achieved, this current level would reduce the voltage rise to which personnel would be exposed to 40V in systems with a 4 ohm neutral wire resistance. In practice, lower neutral wire resistances should be easily achieved, particularly in relatively short 4160V trailing cables. This would, of course, further reduce the voltage rise to which personnel would be exposed.

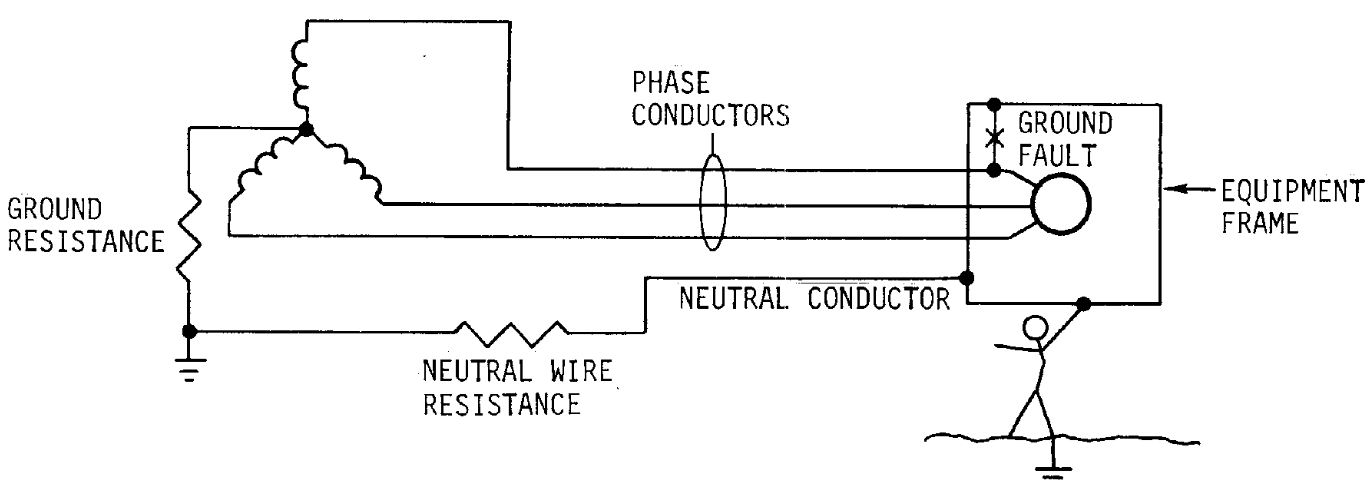


FIGURE 6. - Shock hazard from contact with equipment.

Burns and Flash

As applied, the present 100V standard from Part 75 allows currents of up to 25 amps to flow in the event of a ground fault. While this current level is not likely to present a serious burn or flash hazard under most conditions, it is clear that whatever degree of hazard is present would be reduced if a lower current level is imposed. The more serious burn and flash hazard arises when two or more conductors are grounded simultaneously. This hazard will not be significantly reduced by a reduction in allowed ground fault current level.

7.3.1.2 Prevention of Fires and Equipment Damage

A major advantage of resistance grounded systems is a reduction in the intensity of the arc produced by an arcing ground fault. This advantage is particularly apparent in resistance grounded systems which limit ground fault current flow to less than 25 amps. Experience with these systems has shown that serious equipment damage does not usually result in the event of a single ground fault. Serious fire hazards are likewise avoided unless such a fault occurs in the presence of highly flammable gases or liquids. Previous Bureau of Mines studies have shown that, for systems operated at high voltages, it is not practical to limit fault current to a level which would not ignite an explosive methane air mixture.

As with personal hazards related to burns and flash from arcs, serious equipment damage and fire hazards can result when two or more phases are grounded simultaneously. Reducing the magnitude of allowable ground fault current does little to lessen this hazard. However, prompt operation of the circuit interruptors, by either short circuit or ground fault detection devices, will reduce the extent of equipment damage and the probability of serious fires.

For maximum protection from fires and equipment damage, the level of ground fault current in high voltage oil shale mine power systems should be restricted to the lowest possible level consistent with operating constraints and considerations for other hazards. For the purpose of this analysis, the 25 amp limit contained in Part 75 seems low enough to provide adequate protection. A "better" choice would seem to be the 15 amp level commonly provided in may mine power systems.

7.3.1.3 Prevention of Dangerous System Overvoltages

Some common sources of overvoltages in power systems are:

a. Lightning
b. Switching surges
c. Static
d. Contact with a higher voltage system
e. Line-to-ground faults
f. Resonant conditions
g. Restriking ground faults.

Neutral grounding does little to reduce the magnitude of overvoltages produced by lightning and switching surges. Surge arrestors and shielding of open-wire circuits are normally relied on for protection from these hazards.

Neutral grounding does offer protection from the other sources of system overvoltages by holding the phases to their approximate normal voltage to ground and by preventing displacement of the neutral from ground potential. These effects are discussed in detail in Reference 11.

In order to stabilize the neutral and provide protection from these types of overvoltages, an adequate level of ground fault current must be allowed to flow in the event of a fault. For maximum protection, the value of this current should be equal to, or slightly greater than, the total system current resulting from the capacitive coupling to ground inherent in all elements of the system. Approximate levels of this current, called the system charging current, are estimated below for 13.8 kV and 4.16 kV oil shale power systems.

Each component of a high voltage power system will contribute to the total system capacitance. However, a major contributor in high voltage systems planned for oil shale mines will be shielded power cables. The magnitude of the charging current for 1000 ft of shielded, single-conductor cable is (10):

$$I = \frac{2,772.46\ (kV)\ e}{(10^6)\ \text{Log}\ (D/d)}$$

where

I = Amperes

kV = Kilovolts between conductor and shield

e = Specific Inductive Capacity (SIC), the dielectric constant of the insulation

D = Outside diameter of the insulation

d = Inside diameter of the insulation.

For the 13.8 kV system presented in Figure 5, the following assumptions are made:

a. SIC (dielectric constant) is equal to 4

b. D/d is approximately 1.8.

Using these figures, the charging current for each conductor is approximately 348 mA per 1000 ft of cable. The charging current per conductor for 10,000 ft of cable is approximately 3.5 amps, and for 20,000 ft is approximately 7.0 amps.

For a 4.16 kV system, using the same assumptions for dielectric constant and insulation diameter ratio, a charging current of approximately 104 mA per 1000 ft of cable results. Five thousand feet of cable would require approximately 520 mA charging current.

These approximate values should be viewed as maximum levels of system charging current, since contributions from other components are ignored. The high levels of charging current associated with long lengths of cable in the primary (13.8 kV) distribution system suggest that ground fault currents of several amperes should be allowed to flow in these systems. Successful operation of coal mine distribution systems allowing 15 amps ground fault current to flow indicates that this level provides adequate protection from the dangers of system overvoltages.

For 4160V circuits supplying power to equipment through relatively short trailing cables, a reduced level of ground fault current should be considered. A level of 5 amps would seem to provide a more than adequate margin of safety from the dangers of system overvoltages. Large currents would, of course, increase the degree of protection from this hazard.

7.3.2 Optimal Level of Ground Fault Current in Low Voltage Systems

Low voltage distribution systems planned for oil shale mines consist of circuits supplying power to individual pieces of face equipment. Many of the considerations discussed above for high voltage systems are equally valid for low voltage systems. Thus, the paragraphs below focus primarily on the differences brought about by the lower operating voltage.

7.3.2.1 Personal Safety

The analysis regarding shock hazards in high voltage systems applies as well to 480V systems. The Bureau of Mines studies cited there conclude that direct contact with energized conductors of an ungrounded 480V system supplying power to even a limited amount of cable and equipment can be hazardous. Likewise, the lowest possible level of ground fault current will provide the highest degree of protection from shock, burn, and flash hazards resulting from faults to grounded machine components.

Although the results of contacting an energized conductor in a 480V system may be as hazardous as contact with a higher voltage conductor, the probability of such contact occurring in the 480V case may be much higher. This results from the planned use of unshielded cables in 480V systems. Such cables are commonly used in mining due to the difficulty of maintaining shield continuity when operating with cable reels. Many European countries utilize sensitive ground fault protection units, operating at current levels of a few hundred mA, which allow the use of semiconductor shielded cables in these applications. Limited success with these units has been reported in United States coal mines (13). Serious consideration should be given to the use of these units, in conjunction with semiconductor-shielded 480V cables, in oil shale mine 480V distribution systems.

7.3.2.2 Prevention of Fires and Equipment Damage

The discussion of fire hazards and equipment damage resulting from ground faults in high voltage systems also applies to low voltage systems. The lowest possible fault level will provide the highest degree of protection. Experience with coal mine systems indicates that a level of 15 amps or less is preferable.

7.3.2.3 Prevention of Dangerous System Overvoltages

System overvoltages can occur in 480V systems. A grounded neutral will reduce the hazards associated with such overvoltages. However, unlike high voltage systems, the 480V circuits planned for oil shale mines will not have large values of capacitance and charging current associated with them. Because of the lower voltage, these cables will be kept as short as possible. As noted above, the use of unshielded cables which have less capacitance than shielded cables is planned.

Even if shielded cables are used in low voltage systems, system charging current is still expected to be low. Using the same formula and assumptions above to calculate the charging current for a 480V cable yields a current value of approximately 12 mA per 1000 ft. This current is below the level of leakage current observed in many mine power systems.

Allowances for additional cable and other components will increase the charging current. Thus, it is recommended that ground fault currents of no less than 50 mA be allowed to flow under fault conditions in low voltage systems to provice protection against the hazards of dangerous system overvoltages.

7.4 Conclusions/Recommendations

The recommended optimal levels of ground fault currents are summarized in Table 2. This table suggests the following conclusions:

a. In 13.8 kV primary distribution systems, the level of ground fault current should be kept as low as possible to provide maximum protection from personal injury, fire, and equipment damage. However, a level of 15 amps is recommended to provide adequate protection against system overvoltages. Levels of 10 amps or less will provide a considerable degree of additional protection against shock and may be desirable in particular systems.

b. In 4.16 kV secondary distribution systems, the lowest possible level of fault current will also provide maximum protection from personal injury, fire, and equipment damage. In these systems, fault currents in excess of 5 amps should provide adequate protection against system overvoltages.

c. In 480V systems, the lowest possible level of fault current should be allowed to flow for maximum protection from personal injury, fire, and equipment damage. Fault currents in excess of 50 mA should provide adequate protection from system overvoltages.

TABLE 2. - Optimal levels of ground fault current

	Oil shale mine electrical systems		
	High voltage systems		Low voltage systems
Hazards considered	13.8 kV primary distribution	4160V equipment	480V equipment
Personal safety	Lowest possible level (preferably less than 10 amps)	Lowest possible level (preferably less than 10 amps)	Lowest possible level
Prevention of fires and equipment damage	Lowest possible level (preferably less than 15 amps)	Lowest possible level (preferably less than 15 amps)	Lowest possible level (preferably less than 15 amps)
Prevention of system overvoltage	greater than 15 amps	greater than 5 amps	Greater than 50 mA

8. PERMISSIBLE ELECTRIC WHEEL MOTORS

The purposes of this section are to identify problems which may arise in the development of an explosion-proof electric wheel motor for large diesel-electric haul trucks, and to assess the potential demand for permissible electric wheel motors in the oil shale mining industry. Contacts were made with oil shale mine operators and diesel-electric truck manufacturers in efforts to gather information on these topics. Section 8.1 presents the results of a survey of mine operators to assess current and future plans regarding the use of haul trucks. Section 8.2 discusses the characteristics of currently available equipment. Section 8.3 discusses the problems associated with development of permissible forms of existing wheel motors. Conclusions are presented in Section 8.4.

8.1 Truck Applications in Oil Shale Mines

A survey of several active and planned oil shale mines indicated that there are no trucks larger than 85 tons under consideration. The direction which the different mines have taken (or plan to take) also differs. A survey of five operators produced the following information:

Mine 1

One active mine has purchased 50 ton haul trucks, which are basically of standard design. They use mechanical drive and a 12 cylinder engine for propulsion. The use of side boards increases the carrying capacity, since the density of oil shale is much lower than that of other ores (such as iron, copper, etc.).

The loaders will be in the 15 cubic yard bucket size range. All haulage will be by trucks to a central crusher area near the mine entry.

Mine 2

A mine presently under reevaluation had originally planned truck haulage with large 85 ton mechanical drive trucks. Their plans point now more towards the 50 ton truck. The articulated tractor and bed type design is under consideration. Loaders would be in the 12 to 15 cubic yard bucket size range for startup and the engines considered are in the 500 hp range. The mine has reduced the mining height from 30 to 25 ft, which allows operation with standard equipment. Only mechanical drive trucks have been considered.

Mine 3

This mine is presently in an early planning stage. The company is considering articulated 50 to 60 ton mechanical drive trucks and 12 to 15 cubic yard loaders. All equipment will be standard since they do not expect gassy operation. The mine will be room and pillar with all truck haulage. Design of the mine should start in June.

Mine 4

As a shaft operation, this mine plans to use smaller equipment of less than 150 hp, all approved per Part 36. Part of the mine will be room and pillar, for a faster initial payback with in-situ retorting planned for the long term. The mine headings are planned at 40 ft by 50 ft, benching down after the initial cut.

Mine 5

This mine is presently driving their incline and ventilation shafts. Their latest plans include use of 85 ton mechanical drive trucks and 13.5 cubic yard loaders if truck haulage is used. Conveyor haulage has also been considered.

From this brief survey of mining companies, it becomes quite clear that no operators are presently considering use of electric wheel motors.

8.2 Available Equipment

The range of haulage truck capacities presently planned for oil shale is 50 to 85 tons. There are two types of truck body styles under consideration, the rear dump and the articulated trailer. Figure 7 shows an 85 ton Caterpillar 777* rear dump truck. A larger articulated truck is pictured in Figure 8.

* Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

FIGURE 7. - Caterpillar 777* rear dump truck with 85 ton capacity.

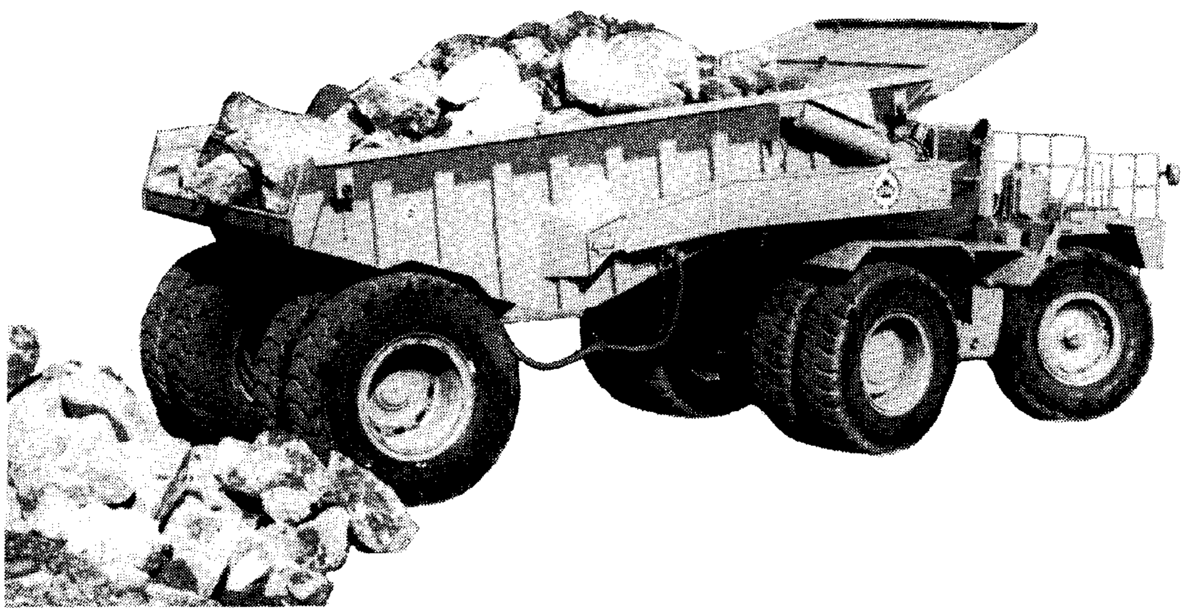


FIGURE 8. - Atlas* articulated truck body with standard Caterpillar* tractor unit.

* Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

The Caterpillar* units all have mechanical transmissions typically 7 forward speeds and 1 reverse. Controlled by a single lever, the transmission will automatically shift up or down between the first and top gear selected by the operator. Clutch plates and gears are continuously oil-cooled and pressure lubricated. A standard downshift inhibitor reduces the possibility of engine overspeed should the operator improperly down-shift. Final gear reduction to the drive wheels is accomplished through a "sun geared" planetary axle drive. Fluid torque retarder braking systems are incorporated in nearly all models.

As noted above, trucks up to 85 ton capacity are almost always powered by diesel engines with power shift transmissions and torque converters. From 85 to 120 tons capacity, the diesel power can be transmitted to the drive wheels by either mechanical or electrical means. In the 85 ton class, Unit Rig* offers the smallest in its range of diesel-electric trucks. Other manufacturers offer a mechanical transmission. From 100 to 120 tons capacity, Wabco,* Terex,* Euclid,* Rimpull* and Dart* offer mechanical transmissions, while Wabco,* Unit-Rig,* and Kamatsu* manufacture electric wheel trucks. The high efficiency and low maintenance of an electric drive system offset its higher initial cost at about 100 tons capacity. The electric wheel drive dominates the market at this level. At the 85 ton level, the electric wheel drive can compete only in deep pits where maintenance on mechanical transmission trucks is unusually high.

Trucks in excess of 120 tons capacity are all powered by diesel-electric power trains. Power is supplied to the drive wheels via "sun geared" planetaries driven by independent electric motors, usually mounted within the wheel assemblies. Electric current is supplied to the motors by means of diesel-driven generators or alternators. Dynamic braking is possible with electric wheel trucks.

Although General Electric* dominates the field of electric wheel drives for the trucking industry, other manufacturers are offering competition. Unit Rig* has designed its own electric wheel, the W-100*, which is specially made by Reliance* and is used to power the Lectra Haul* 130 to 140 ton trucks. Euclid* has designed its own alternator and traction motor system for the R-210 truck. Terex* offers the EMD systems on all their electric trucks and both Unit Rig* and Wabco* use Electro-Motive Division* (EMD) electrical systems on their 200 ton and over trucks.

* Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

The EMD of General Motors* has been in the electric traction motor business for many years. Over 200,000 EMD D-79* traction motors have been built over the years. This is the motor used in the 170 to 200 ton size truck. They do not lend themselves to mounting in the wheel cavity and they are consequently mounted as shown in Figure 9. This has the disadvantage of not being able to make use of the wheel cavity space. Access for maintenance is more complicated. However, there are some distinct advantages:

- Drive motor capacity is not limited by wheel and tire dimensions, as is the case with wheel motors.

- Reduced heat buildup between motor, brakes and tires by removing the traction motor from the wheel cavity.

- Improved dynamic retardation characteristics.

According to General Electric,* more than 4,000 wheel motors are in operation. As shown in Figure 9 their motor mounts directly in the center of the hub, with a planetary final drive at the inboard side of the wheel.

The Reliance* motor has its electrical armature mounted away from the center of the two tires, which allows a larger diameter frame. Final drive is also by planetary drive, as shown in Figure 10.

General Motors* uses two traction motors, mounted inside of the rear axle, driving a planetary final reduction drive inside the wheel hub through a pinion/bullgear, as shown in Figure 11.

Euclid* also uses a "plug-in" motor, shown in Figure 12, which is mounted outside the hub on their 120 ton electric trucks.

Komatsu* offers only their largest truck with an "electric wheel" drive shown in Figure 13.

Each manufacturer claims certain advantages over other systems, but it is not the intent of this report to make comparisons or balance trade-offs. The different systems are shown simply to illustrate what is presently available.

* Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

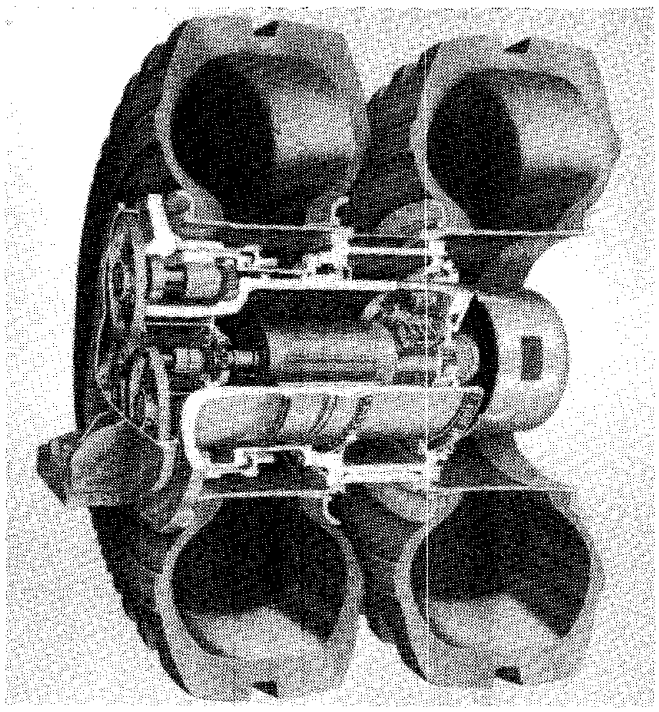


FIGURE 9. - Motorized wheel for off-highway vehicles -- General Electric* design.

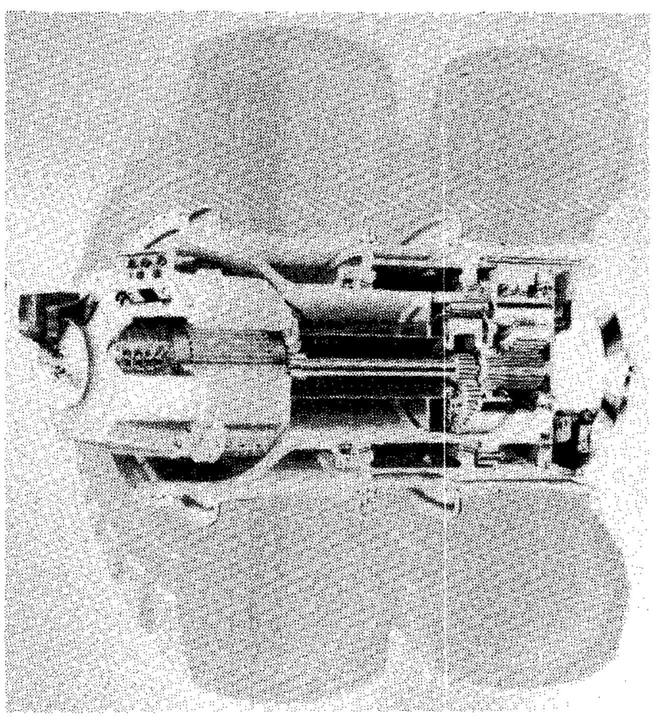


FIGURE 10. - Traction wheel - Reliance* electric design.

* Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

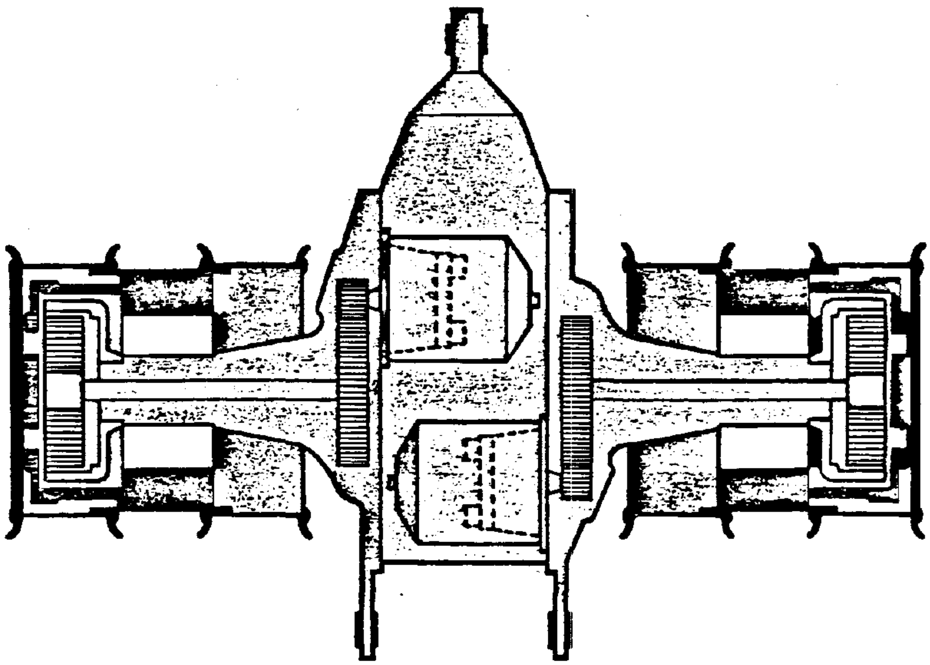


FIGURE 11. - Traction motor - General Motors.*

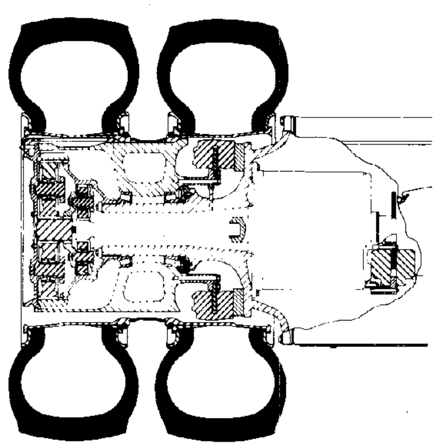


FIGURE 12. - Euclid* - "plug-in" wheel motors.

* Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

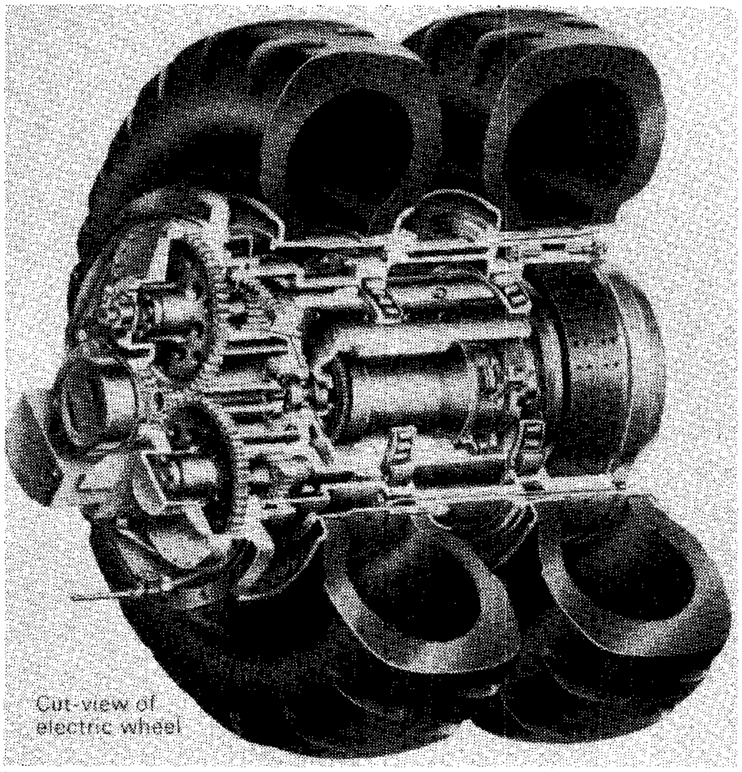


FIGURE 13. - Kamatsu* - wheel motor.

8.3 Problems Associated with Development of Permissible Electric Wheel Motors

The break-off point between mechanical and electrical systems is at about an 85 ton payload level. Generally speaking, mechanical drive trucks predominate below this level and diesel electric trucks above it.

Basically, the motorized drive wheel system consists of a dc generator, an exciter, two or four motorized wheels (depending upon application), a blower to provide cooling for generator and wheels, and the associated control equipment. The power source for the wheel can be an on-board diesel engine in the 500 to 2000 hp range. The dc series wound motor, with its inherent characteristics of trading torque (amperes) for speed (voltage) makes it ideal for vehicle application. At very low speeds, the motor produces high torque. As torque decreases, speed increases, and the tradeoff continues until the maximum motor speed is reached. A dc generator is normally used with horsepowers up to 1000, while a main alternator with rectifier set is used above that because the generator size would be too unwieldy.

* Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

The key to the application of electric drive systems is heat dissipation. Heat buildup is proportional to the steepness and length of the grade and road rolling resistances. Both positive and negative grades generate heat. During dynamic braking, used on down grades, the traction motors are converted to generators, with their output dissipated as heat in the air-cooled resistor banks. A blower motor is used to cool the braking grids.

If operated in a gassy mine, these wheel motors will be limited to a maximum surface temperature of 302°F. None of the wheel motors discussed above are classed explosionproof. A major redesign would be necessary, followed by MSHA certification. During dynamic braking, the heat generated would increase the temperature of the motor well above the limit. Cooling by air is impractical in the tight fit inside of a wheel hub. Water cooling is possible, but would be difficult, complex, and expensive. With the General Motors* wheel motor, which is mounted outside the hub and the Euclid* "plug-in" design, an explosion proof electric motor would be more feasible. However, none of these designs are in the size range expected to be used in oil shale mining.

Diesel-electric generators, in the size range needed for electric wheel motors, are not available in explosionproof configuration. At present, only the Caterpillar 3406 TA* engine is certified. Certification of the 3408 TA* is expected. The Cummings 1710* (800 hp) engine has been tested and found capable of meeting the requirements of Part 32. Efforts aimed at Part 36 certification for this engine are underway.

In Europe, however, engine-generator packages in the range up to 1200 hp have been built to comply with rules and regulations that govern the offshore oil industry, refineries, chemical plants and other hazardous areas. These requirements, however, are not the same as the U. S. Mining requirements. The two European companies directly known are Pyroban,* located in Shoreham-by-Sea, England and Rognon,* located in Chauny, France. There are other companies offering similar equipment.

Figure 14 illustrates one such engine. It should be noted that the shown generator set is designed as a "dry" system, incorporating heat exchangers, flame arrestors, spark arrestors and water jacketing. It does not use a water scrubber.

* Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

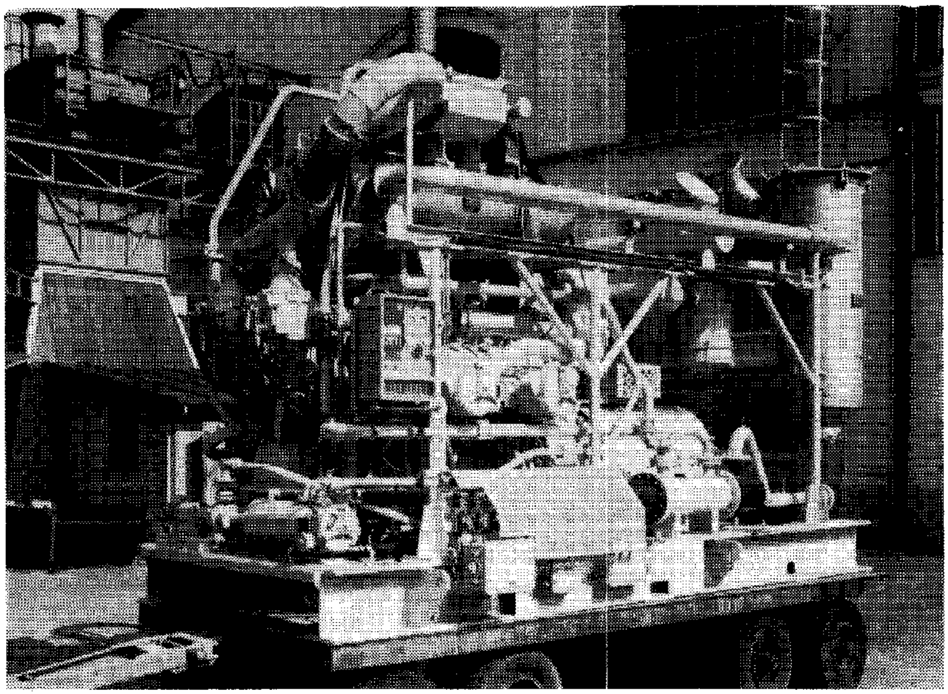


FIGURE 14. - Rognon* flameproof diesel generator.

The dynamic retarding grid box assembly dissipates retarding energy. It consists of a set of resistors, which are cooled by fans. Depending on the grade, these resistors can become very hot (on locomotives in hardrock mines the grid has been seen to glow red). Presently, this grid is not designed for gassy mines, and a major redesign would be needed to comply. However, most oil shale mines will operate fairly level haul roads and other methods of retardation may be more suitable.

8.4 Conclusions

- Of all the mines we have surveyed, none are presently considering electric wheel motor trucks.
- The vehicle size projected (50 to 85 ton range) is readily available in mechanical drive configurations, by all manufacturers.

* Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

- No manufacturer surveyed either makes or plans to offer permissible electrical wheel motor trucks to the oil shale industry.

- The electric wheel motors presently available would require major redesign to be suitable for operation in gassy mines.

- Presently, no certified diesel-electric generator package suitable for 50 to 85 ton trucks (500 to 800 hp) is available.

- Cooling of the wheel motors (waste heat) in the confined space of a wheel hub would present a major problem.

- Cooling of the retardation grid would require major redesign or a totally different approach.

- For trucks up to 85 tons, economic studies generally favor mechanical drive systems.

- Advantages of electric wheel motors in intermediate size (85 to 120 ton) trucks are considerable in deep pits with steep haulageways. Oil shale mines are expected to be relatively level.

At the present time, the use of wheel motors appears to be unlikely in oil shale mines. There are no indications that MSHA Approval and Certification Branch will be faced with wheel motor approvals for oil shale mining in the foreseeable future.

9. PERMISSIBLE BATTERIES AND ELECTRIC STARTING SYSTEMS

This section presents the results of investigations into two related areas of concern regarding future electrical systems in oil shale mines. These areas are:

a. Permissible batteries

b. Permissible electric starting systems.

Questions addressed include: What types of permissible batteries are currently available? What types of permissible batteries are likely to be needed in future oil shale mines? What constraints and problems exist regarding availability and use of permissible batteries on oil shale mining equipment (e.g., physical size and electrical capacity requirements, availability, maintenance and ventilation problems)? What is the potential demand for electric starting systems? What problems exist in making electric starting systems permissible?

It should be noted at this time that:

a. MSHA specifically prohibits the use of electric starting systems on permissible diesel-powered equipment.

b. The use of permissible batteries is not presently contemplated by oil shale mine operators.

Thus, the problems discussed below are those which *may* arise at some time in the mid- to long-term future. Some will require additional research and development before actual use becomes possible. However, problems in neither area appear to present immediate impediments to the developing oil shale mining industry.

9.1 Permissible Batteries

The type of batteries of interest to this program are heavy duty, lead-acid storage batteries. These batteries are similar to conventional, molded-case automobile batteries, in basic design, but are larger in terms of physical size and electrical capacity. Manufacturing techniques and basic designs for individual lead-acid battery cells are well developed. The requirements for construction of a *permissible* lead-acid storage battery relate primarily to mechanical assembly and electrical protection of groups of these individual lead-acid cells. This subsection reviews the applicable MSHA regulations and presents information gathered from battery and equipment manufacturers regarding battery specifications. Problems associated with the use of batteries in oil shale mines are discussed and conclusions concerning future battery uses are drawn.

9.1.1 Applicable Regulations

MSHA requirements for approval of permissible batteries are found in 30 CFR 18.44 and 18.63. These sections read as follows:

§18.44 Battery boxes and batteries (exceeding 12 volts).

(a) A battery box (tray), including the cover, shall be made of steel the thickness of which is to be based on the total weight of the battery and tray, as follows:

Weight	Thickness
2,000 lb maximum	3/16 in.
2,001-4,500 lb	1/4 in.
Over 4,500 lb	5/16 in.

Materials other than steel that provide equivalent strength will be considered.

(b) Battery-box covers shall be lined with a flame-resistant insulating material, preferably bonded to the inside of the cover, unless equivalent protection is provided.

(c) Battery-box covers shall be provided with a means for securing them in closed position.

(d) Battery boxes shall be adequately ventilated. The size and locations of openings for ventilation shall prevent access to cell terminals.

(e) Battery cells shall be insulated from the battery-box walls and supported on insulating material. Insulating materials that may be subject to chemical reaction with electrolyte shall be treated to resist such action.

(f) Drainage holes shall be provided in the bottom of each battery box.

(g) Cell terminals shall be "burned" on. Bolted connectors (two-bolt type) may be accepted on end terminals.

(h) Battery connections shall be so designed that battery potential will be minimized between adjacent cells, and total battery potential shall not be available between adjacent cells.

(i) Cables within a battery box shall be protected against abrasion of the insulation.

(j) Each wire or cable leaving a battery box on storage-battery-operated equipment shall have short-circuit protection in an explosion-proof enclosure as close as practicable to the battery terminals. A protective device installed within a nearby explosion-proof enclosure will be acceptable provided the exposed portion of the cable from the battery box to the enclosure does not exceed approximately 36 inches in length; in addition, special care shall be taken to protect each wire or cable from damage.

(k) A diagram showing the battery connections between cells and between trays shall be submitted. The number, type, rating, and manufacturer of the battery cells shall be included in specifications.

§18.63 Tests of battery boxes.

Battery boxes will be tested at MSHA's discretion to determine the adequacy of ventilation, electrical clearances, insulation, and suitability for the intended service. Such tests will be conducted at the site of manufacture of assembly, or on MSHA's premises.

Batteries approved as permissible to date have been primarily used to power traction and hydraulic pump motors on underground coal mining equipment (such as, shuttle cars, scoops, personnel carriers). Voltages range up to 250V and individual battery assemblies typically weigh several thousand pounds. Lighter batteries operating at lower voltages (6-48V) are most likely to be used in conjunction with diesel-powered equipment in oil shale mines. Although Section 18.44 does not apply to 6 and 12V battery assemblies, it is reasonable to *assume* that similar requirements regarding mechanical and electrical protection, ventilation, drainage, insulation, and cell arranagement would apply for these systems, as well.

MSHA certifies battery assemblies, i.e., arrangements of individual cells packaged and protected in accordance with Section 18.44. Certification is granted to the assembler of the battery package. In most cases, this is the battery manufacturer. However, some equipment manufacturers buy cells and assemble their own battery packages and, thus, become the holders of the certification for that particular battery assembly.

As a final note on the certification procedure, it should be mentioned that battery certification is not tied to a particular use or application. A battery assembly certified for use on a shuttle car could be adapted for use on some other equipment type without voiding the certification.

9.1.2 Availability of and Demand for Permissible Batteries

The storage battery industry is composed of a large number of manufacturers, making both permissible and nonpermissible battery assemblies.* Makers of both types of batteries were contacted in the course of this investigation in order to gather information on:

a. The characteristics of currently available permissible battery assemblies.

b. The characteristics of batteries typically used on large pieces of diesel-powered equipment of the types contemplated for use in oil shale mines.

In addition, equipment manufacturers were contacted in an effort to discover the types of batteries planned specifically for use in oil shale operations.

Battery manufacturers supplying information included:

a. Surrette Storage Battery Company, Inc.**

b. Exide, Inc.**

c. Keystone Battery, Inc.**

d. Electro-Lite Battery Manufacturing Co.**

e. Gates Energy Products, Inc.**

f. Kersey Manufacturing Co.**

g. Piqua Battery, Inc.**

h. C&D Battery Co.**

Equipment manufacturers and others contacted included:

a. Euclid, Inc.**

b. Caterpillar Tractor Co.**

c. Cummins Engine**

d. Unit Rig **

e. McJunkin Corp**

f. Ingersol-Rand, Co.**

g. M.E.D.C., Ltd.**

As noted above, batteries certified as permissible to date are commonly used in coal mine haulage and transport applications. Table 3 lists the characteristics of a line of batteries

*The 1982 Coal Age Magazine Buyer's Guide (September issue) lists 31 suppliers of storage batteries.

**Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

TABLE 3. - Permissible Battery Characteristics

Kersey * Machine	Battery Used			6 hr Rate Amp hr	Dimension (in.)			No. Trays Used	Pound Weight /Tray
	Voltage	Cells	Plates		W	L	H		
PAST-12	128	64	19	495	39	47	19	2	3600#
PAST-14	128	64	19	495	39	47	19	2	3600#
PAST-20/24	128	64	19	765	40	46	23.5	2	4320#
Brute 123	128	64	31	1275	39	72	23	2	7175#

Source: Ben Harbage, Senior Electrical Consultant, Kersey Manufacturing Co.*

manufactured by Kersey Manufacturing Co.* for use on battery-powered tractors and scoops in coal mines. Figure 15 shows a permissible battery (with the cover removed) installed in a two-man personnel carrier called the "Mineabout" manufactured by McJunkin Corp.*

These batteries are generally charged and discharged in alternating 6-8 hr periods, with the charging operation carried out while the vehicle is idle. An alternative method involves leaving a discharged battery at a charging station, in exchange for a freshly charged battery assembly.

The most important electrical rating for this type of battery is expressed in terms of ampere hours (AH) measured at a specified hourly rate. This figure measures the ability of the battery to sustain a constant current drain for the specified time period. For example, the 495 AH rating of the first two batteries in Table 12 indicates that these batteries can sustain a current drain of 82.5A (495 ÷ 6) for a period of 6 hr.

As noted above, batteries typically used with diesel-powered equipment are physically smaller and generally operate at lower voltages, than the permissible batteries described above. Table 4 lists the characteristics of several 6 and 12V batteries manufactured by Surrette Storage Battery Co.* for use

* Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

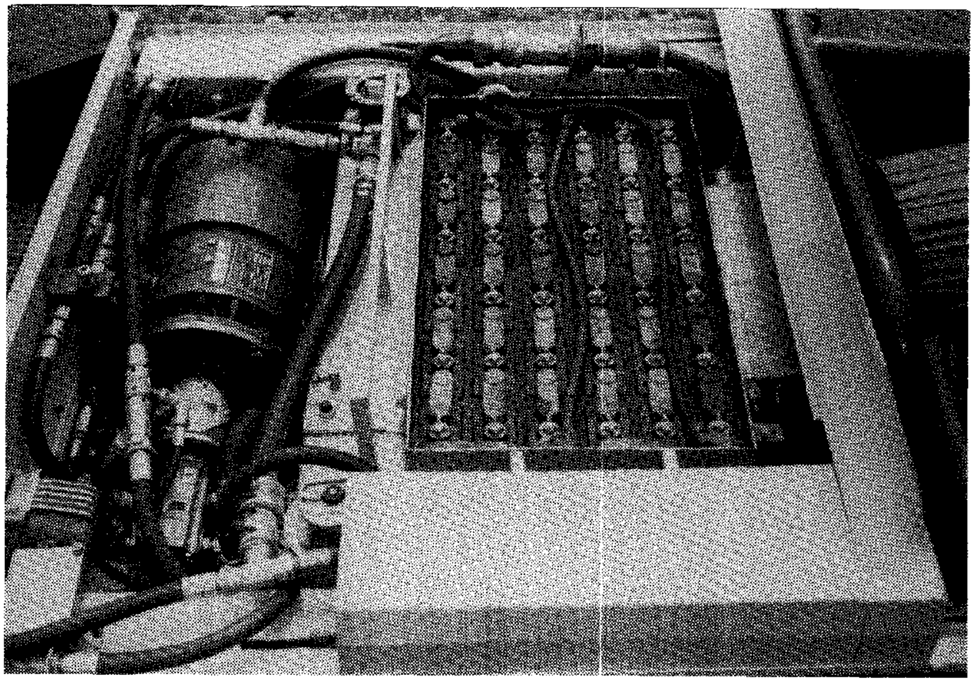


FIGURE 15. - Permissible battery (cover removed) installed in two-man personnel carrier. Source: McJunkin Corp.*

in commercial and diesel applications. These batteries are intended to be used on vehicles with "on board" charging systems (i.e., an alternator driven by the diesel engine supplies charging current to the battery when the engine is operting.) They are designed to deliver large amounts of current in relatively short periods of time when supplying power to start internal combustion engines.

The most important electrical ratings for these battery types are the reserve capacity and the cold cranking capacity. The reserve capacity, expressed in minutes, measures the ability of the battery to supply power for operating the vehicle (NOT including starts) in the event of a charging system failure. The cold cranking capacity measures the starting ability of the battery under cold temperature conditions. It is defined as the discharge load in amperes which a battery can sustain for 30 sec at 0°F and not fall below 1.2V per cell (7.2V for a 12V battery).

*Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

TABLE 4. - Commercial and diesel (non-permissible) battery characteristics
Source: Surrette Storage Battery Co.*

Classification	Volts	Plates per cell	20 hr rate in ampere hours	Reserve capacity in minutes	Cold cranking cap. (0°F) in amp	Net weight wet (approx.) in lbs	Dimensions in inches		
							L	W	H
Diesel	6	35	316	506	1580	125	22-11/16	7-1/8	9-1/2
Diesel	6	39	342	547	1710	130	20-1/2	8-3/4	9-1/2
Diesel	6	41	385	616	1925	141	25-1/2	7-1/2	9-1/2
Diesel	6	93	406	650	2151	148	20-1/4	9-15/16	9-3/4
Diesel	6	51	466	778	2423	170	20-1/4	11	9-3/4
Commercial	6	13	105	160	485	40	9-1/16	7	8-7/8
Diesel	6	15	130	215	515	50	10-1/8	6-7/8	9-1/8
Diesel	6	17	149	270	775	58	11-3/4	7-1/16	9-3/8
Diesel	6	19	168	285	775	65	13	7-1/8	9-3/8
Extra heavy duty	6	21	165	310	735	65	13	7-1/8	9-3/8
Diesel	6	21	193	305	875	70	13-7/16	7-1/16	9-3/8
Diesel	6	25	230	385	900	80	16-5/16	7-1/16	9-3/8
Extra heavy duty	6	27	221	430	920	80	16-5/16	7-1/16	9-3/8
Commercial	12	9	62	100	325	48	10-1/4	6-3/4	8-15/16
Commercial	12	9	62	100	325	48	10-3/4	6-3/4	8-13/16
Commercial	12	9	62	100	325	50	19-5/16	4-1/4	8-3/4
Commercial	12	11	75	125	400	54	11-3/4	6-3/4	9-1/8
Commercial	12	13	93	135	405	63	13-1/2	6-3/4	9-3/8
Diesel	12	19	165	285	775	135	20-1/4	8-3/4	9-3/4
Diesel	12	21	193	310	825	148	20-1/4	9-15/16	9-3/4
Extra heavy duty	12	27	221	430	920	165	20-1/4	11	9-3/4
Diesel	12	25	230	368	920	165	20-1/4	11	9-3/4
Diesel	12	25	230	368	900	164	20-1/2	11	9-1/2
Extra heavy duty	12	27	221	430	920	165	20-1/2	11	9-1/2

* Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

Batteries used on diesel-powered equipment in oil shale mines are most likely to be of the types described in Table 13. Smaller pieces of equipment will utilize a single 6 or 12V battery, while larger vehicles may require two or more batteries. For example, Euclid* utilizes two 12V batteries wired in series to power an electric start system on 50 ton trucks. They also offer an optional four-battery, 12V system on 85 ton trucks, but report that there is little or no demand in the field for this option.**

9.1.3 Potential Problems Associated with the Use of Permissible Batteries in Oil Shale Mines

Potential problem areas related to the use of permissible batteries in oil shale mines are:

a. Sizes and capacities required

b. Availability of batteries in permissible form

c. Maintenance problems

d. Vibration problems

e. Ventilation problems associated with the charging operation.

From the information gathered in this program, the following conclusions can be drawn regarding these potential problem areas:

a. Sizes and Capacities Required - The sizes and capacities of batteries required for diesel-powered equipment are generally *smaller*, both physically and electrically, than batteries currently certified by MSHA for use in permissible areas of gassy coal mines. A multitude of standard sizes and capacities are available, and the battery manufacturing industry is capable of supplying "custom-designed" battery assemblies and packages for special applications.

*Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

**As discussed in the next section, electric starting systems are standard on 50 ton (approximately 600 hp) and smaller trucks. Air starting systems are standard on 85 ton (approximately 800 hp) and larger trucks. Electric starting is available as an option on some 85 ton trucks and air starting is available as an option on 50 ton trucks. Electric starting is not offered on 100 ton, and larger, trucks.

b. Availability of Batteries in Permissible Forms - Currently available permissible batteries are not well suited to the possible applications expected in oil shale mines. However, it is felt that battery assemblies suited to these applications could be constructed in accordance with MSHA requirements if a demand for such batteries develop.

c. Maintenance Problems - Proper maintenance is important to the safe operation of any battery system. Considering the relatively smaller size and capacity requirements, as well as the general operating conditions in oil shale mines, maintenance problems should be no more severe (and, perhaps, less so) than corresponding problems in coal mines. These problems include maintaining proper electrolyte level, cleaning battery tops and terminals, inspecting for damaged cells, maintaining proper insulation on conductor and other metal surfaces, and monitoring specific gravity readings for indications of battery deterioration.

d. Vibration Problems - Loose hold down clamps, or operating a vehicle over rough terrain can cause early failure of batteries. The active material (a heavy deposit of black lead-like material) is loosened from the plates and builds up as sediment in the water eventually causing a short. Also the separator may shift, allowing the plates to touch, causing the (+) plate to contact the (-) plate and the cell to lose its stored energy.

e. Ventilation Problems Associated with the Charging Operation - is complicated by the fact that MSHA does not allow the charging of batteries in areas of a mine where permissible equipment is required. The charging operation causes the battery to generate hydrogen which if allowed to accumulate, may pose a fire or explosion hazard. Batteries in coal mines are charged in a separate split of ventilating air which flows over the battery and directly into the return. Ventilation openings in the battery box allow the hydrogen to dissipate and be carried to the return in non-hazardous concentrations.

The smaller battery size requirements, taken in conjunction with the much larger size of the mine openings in oil shale operations, should drastically reduce the hazards associated with "on-board" charging systems, relative to the coal mine model. Careful attention to battery location could virtually eliminate this hazard. For instance, placement of the battery in the air stream generated by engine cooling fans would, in effect, provide a forced-air ventilation system for the battery assembly. Another possible source of ventilation is the air drawn into the intake manifold when the engine (and charging system) are operating. Known rates of hydrogen liberation for particular battery assemblies could be used in selecting a location to eliminate the hazards associated with this problem. Additional factors influencing battery location are protection from mechanical damage and easy access to perform the maintenance operations mentioned above.

Conclusions

Several oil shale operators have indicated interest in using battery assemblies on some pieces of diesel-powered equipment, such as front end loaders, load haul dumps, and 50 to 85 ton trucks. Permissible forms of these batteries could be made available for such use. With proper attention paid to battery assembly location, it would seem that MSHA could approve these systems without introducing additional hazards into oil shale mines.

9.2 Permissible Electric Starting Systems

Battery assemblies for electric starting systems (ESS) on diesel powered equipment could be applicable in oil shale mining. Much of the diesel powered equipment used at the face is intended for mobility. In a non-gassy mine it may be desirable to consider ESS on smaller pieces of equipment (that is, load haul dumper, front end loader). Several equipment manufacturers and oil shale operators have indicated interest incorporating ESS on permissible machinery.

This subsection reviews MSHA regulations, policy and concerns regarding potential development of a permissible ESS. The discussion includes the relative merits of air versus ESS and the potential demand for permissible ESS.

Generalized conclusions are drawn and specific areas requiring additional research before a satisfactory system can be developed are noted.

9.2.1 Applicable Regulations

ESS are addressed in 30 CFR 36.21, which reads:

> §36.21 Engine for equipment considered for certification.
>
> Only equipment powered by a compression-ignition (diesel) engine and burning diesel fuel (see §36.2(i)) will be considered for approval and certification. The starting mechanism shall be actuated pneumatically, hydraulically, or by other methods acceptable to MSHA. Electric starting shall not be accepted. Engines burning other fuels or utilizing volatile fuel starting aids will not be investigated.

MSHA Approval and Certification Center personnel were contacted to discuss MSHA's present position on ESS. Recent Part 36 changes (allowing Part 18 electrical equipment or diesel equipment) invited comments from industry which requested MSHA lift the ban on ESS. The comments indicated several possible advantages which may be gained by utilizing the ESS. However, MSHA's concerns regarding potential hazards with these systems were not addressed. Thus, the ban remains in effect.

MSHA's specific questions relating to permissible ESS include:

a. Charging - How should charging of the battery, which would presumably be done while the machine is operating, be regulated to avoid hazards resulting from the charging process?

b. Battery - How should the battery be ventilated? What maintenance practices should be followed and how can the hazards resulting from poor maintenance be avoided?

c. Starter Motor - How can protective devices for the starter motor circuit be specified so as to avoid the hazards which would result from their failure to open in the event of a short circuit fault?

In addition, MSHA personnel indicated other questions that need to be addressed, such as:

a. In non-permissible applications, are air-starts or electric-starts preferred, and why?

b. How do other countries address the problem of air versus ESS?

c. How do other industries handle this problem?

d. Does anyone allow the charging of batteries in hazardous areas, and, if so, what precautions are required?

A complete investigation of these areas is beyond the scope of this program. However, some of these topics are briefly discussed below.

9.2.2 Relative Merits of Air and ESS

Electrical starts are frequently used in non-permissible applications of diesel powered equipment (e.g., trucks with capacities of less than 50 ton). This is true especially when smaller engines with limited horsepower capacities are used by operators with limited access to sources of compressed air.

Advantages of utilizing ESS include:

a. High stored energy density of lead acid batteries, relative to alternative types of energy storage systems

b. Compact physical size of ESS for small engines (50 to 250 hp)

c. Familiarity of ESS to operating and maintenance personnel

d. Long cranking and storage times.

Proponents of ESS cite additional advantages to mine operators:

a. Power would be available to permit use of certified headlights when the engine is not running.

b. Jump starting could be made available contingent upon certified parts

c. An increase in space since the compressor tanks, valves, motor and piping would be eliminated

d. Power take-off could be incorporated on the machine

e. Eliminating bleed-down of pressure on weekends and overnights

f. Eliminating the potentially hazardous practice of transporting high pressure vessels (used for restarting).

Disadvantages of ESS (ignoring, for now, permissibility problems) are primarily related to the battery. As the size of the ESS increases, so does the battery weight, cost and maintenance. Larger ESS are necessary to provide adequate power for initial starting of large engines particularly in cold weather. As the temperature decreases, so does the battery efficiency - during colder weather (below 0°F) the battery will not accept a charge due to high internal resistance. The battery operates in an ever-increasing state of discharge until a failure occurs.

Large equipment manufacturers (Euclid)* cite excessive battery size as a primary motive for converting to air starting systems. ESS are standard equipment on 50 ton, (approximately 600 hp) and smaller trucks. Air starting systems are standard on 85 ton (approximately 800 hp) and larger trucks. Air starting is available as an option on 50 ton trucks and similarly electric starting is available as an option on some 85 ton trucks. Electric starting is *not* available on 100 ton or larger trucks.

Euclid*, Unit Rig* and other very large equipment manufacturers indicate that their customers prefer air starts. Advantages cited include:

a. Air starting systems are maintained at a lower cost by eliminating the need for most batteries and downtime

b. Air starting permits a lighter duty battery charging circuit for accessories

c. Air starting reduces the high amperage requirements and maintains full power for fast effective starting under extreme temperature weather conditions

d. Air starting systems weigh up to 50 percent less than electric starting systems

*Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

e. Longer performance life under rugged weather and terrains

f. Easy repairs with no specialized training for maintenance and upkeep

g. Air starters can be turned over continuously, even stalled out, without any danger of burning out

h. Air starters are completely enclosed permitting engine repair without interference to the starting system

i. Power sources are readily available - air, natural gas or inert gases.

j. An air start option includes a positive lubrication system that automatically lubricates the starter and prevents freeze-ups.

The disadvantages the manufacturers mentioned pertained to the shorter cranking times inherent with air systems. The disadvantages referred to by proponents of ESS (i.e., pressure bleed-off, inconvenience with jump starting, ...) were categorized as problems/nonproblems that could be solved by an improved system design.

A schematic of a typical industry air starting system is depicted in Figure 16.

9.2.3 Problems Associated With Permissible ESS

The problems associated with permissible ESS are similar to those problems associated with permissible batteries. MSHA has additional concerns pertaining to protective devices used in starter motor circuits. This concern is based on the possibility that as battery capacity deteriorates with age, terminal corrosion, etc., current capacity may decline to levels below the interruption ratings of protective devices provided. A short circuit in the system has the potential to result in uninterrupted current flow creating a fire hazard.

This problem could be approached by incorporating a protective device limiting not only the magnitude of current flow, but time that starting current could flow without interruption. A

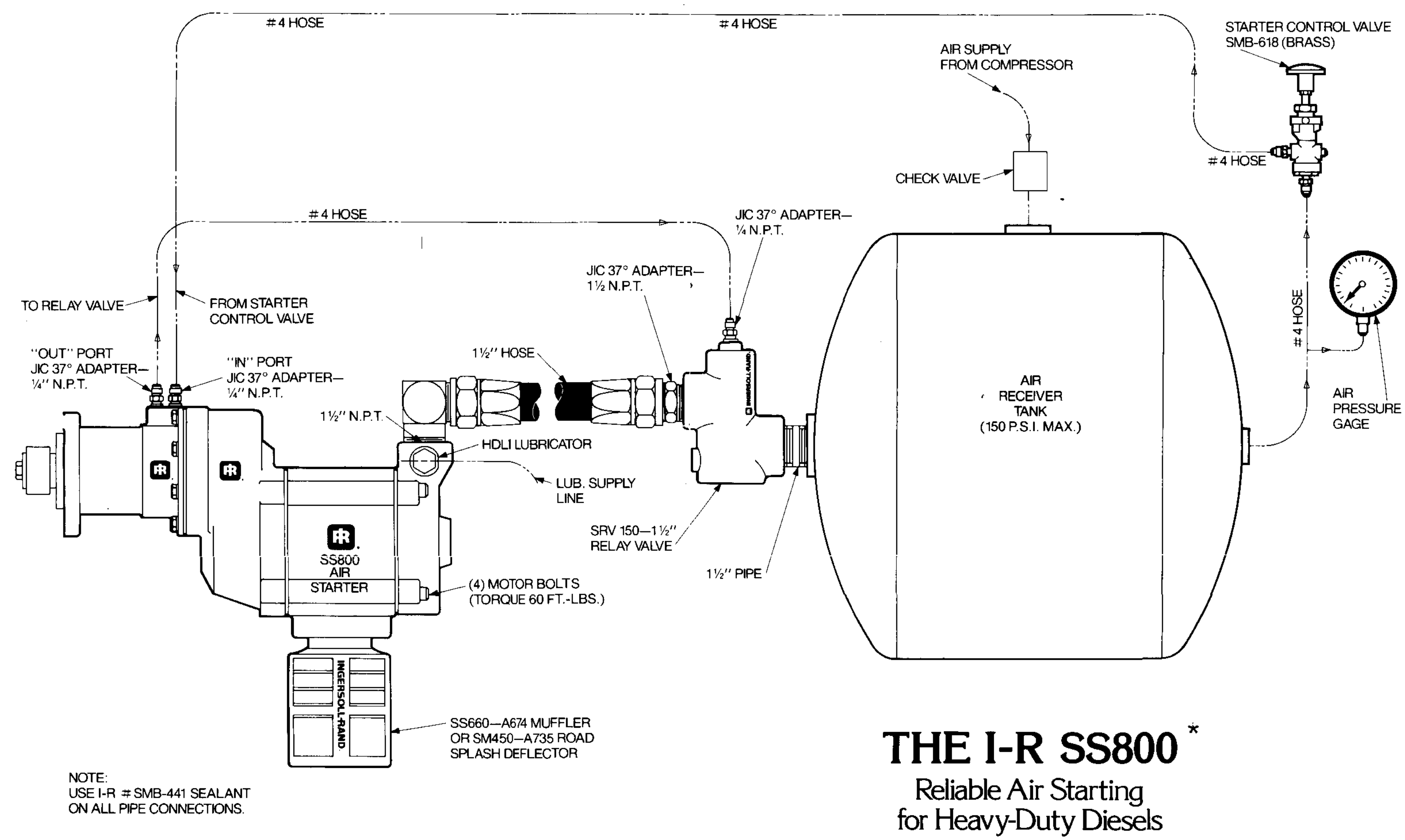


FIGURE 16. - Schematic of an air start system. Source: Ingersol-Rand Co.*

*Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

high capacity current flow in excess of a few seconds would cause interruption devices to operate. Installing an interlock with the ignition switch allows operators to reset protective devices by turning off the ignition switch and trying again. Such systems are common in automotive applications to protect starter motor from burnout caused by excessive periods of winter cranking starts. A short circuit current of this type would exist for a few seconds before being interrupted, regardless of magnitude of current flow.

At this time, no United States manufacturers are known to be developing a permissible ESS. However, a British company, M.E.D.C., Ltd.,* has developed an ESS which they consider fail-safe and flameproof. This system was documented in a paper by directors of M.E.D.C., Ltd.* Since this paper may not be readily available, it is reproduced in Appendix B of this report. Major features of the M.E.D.C. system are:

a. Use of a sealed, maintenance-free automotive-type battery

b. Use of stainless steel battery terminals to retard corrosion

c. Sensitive ground fault and short circuit protective devices

d. Interlocks and indicating lights to warn of abnormal system operation.

One United States equipment manufacturer has expressed interest in utilizing this system.

9.2.4 Conclusions

The following conclusions can be drawn from the previous discussion:

a. Air starting systems are more advantageous when used with large (>600 hp) engines. Smaller equipment (e.g., pneumatic drills) utilizing compressed air for other purposes may also be fitted with air starters in preference to electric starters, particularly where no space limitations exist.

* Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

b. ESS are more advantageous when used with small equipment types where space limitations exist.

c. There is a demand for permissible starting systems from the manufacturers and operators of presently available permissible diesel powered equipment.

d. There is likely to be a demand for permissible electric starts from oil shale operators using permissible diesel equipment. Permissible ESS will probably be desired on all but the largest equipment types currently under consideration.

e. It should be possible to design and fabricate a permissible ESS which would adequately meet MSHA's concern and provide a degree of safety equivalent to currently accepted air starting systems.

The battery location considerations discussed in the previous subsection, and the electrical protection of starting motor circuits discussed above, are areas which warrant research and development.

10. INTRINSICALLY SAFE INSTRUMENTATION AND APPLICABILITY OF EXISTING TEST STANDARDS

This section presents an analysis of the applicability to oil shale mine conditions of five existing test standards used to evaluate intrinsically safe instrumentation and control devices. The five standards considered are:

a. Section 18.68 of Title 30

b. National Fire Protection Association 493

c. Underwriters' Laboratories 913

d. American National Standards Institute/Instrument Society of American RP 12.6

e. International Electrotechnical Commission Publication 79-3.

Suggestions are also made regarding possible modifications needed to intrinsically safe devices, approved under NFPA 493 or UL 913 for use in National Electric Code Class I, Division I, Hazardous Locations, in order to adapt such devices for use in oil shale mines. The unforeseen slowdown in oil shale mine development discussed earlier in this report severely hampered this effort. Actual oil shale mine operating conditions remain, at this time, subjects of much speculation. Monitoring systems are still under consideration by several operators, but far less has been accomplished by way of system design and specification of particular components than had been envisioned when this study began.

One regulatory development has recently occurred which may ease the concerns which many operators expressed regarding design and specification of monitoring systems acceptable to MSHA for their oil shale operations. Due to the potential impact on oil shale electrical installations, a brief discussion of this procedure is included in this report.

10.1 Analysis of Existing Standards

The five standards mentioned above are discussed below. Following the discussion of each, conclusions are drawn regarding their applicability to oil shale operations.

10.1.1 Section 18.68 of Title 30

Definitions concerning intrinsic safety are found in Section 18.2. They read as follows:

> "Incendive arc or spark" means an arc or spark releasing enough electrical or thermal energy to ignite a flammable mixture of the most easily ignitable composition.
>
> "Intrinsically safe" means incapable of releasing enough electrical or thermal energy under normal or abnormal conditions to cause ignition of a flammable mixture of methane or natural gas and air of the most easily ignitable composition.

Section 18.68 - Tests for Intrinsic Safety - is divided into three parts. The first part (18.68(a)) sets general requirements for intrinsically safe circuits and/or components. It reads:

> (a) General:
>
> (1) Tests for intrinsic safety will be conducted under the general concepts of "intrinsically safe" as defined in Subpart A of this part. Further tests or requirements may be added at any time if features of construction or use or both indicate them to be necessary. Some tests included in these requirements may be omitted on the basis of previous experience.
>
> (2) Intrinsically safe circuits and/or components will be subjected to tests consisting of making and breaking the intrinsically safe circuit under conditions judged to simulate the most hazardous probable faults or malfunctions. Tests will be made in the most easily ignitable mixture of methane or natural gas and air. The method of making and breaking the circuit may be varied to meet a particular condition.
>
> (3) Those components which affect intrinsic safety must meet the following requirements:
>
> (i) Current limiting components shall consist of two equivalent devices each of which singly will provide intrinsic safety. They shall not be operated at more than 50 percent of their ratings.

(ii) Components of reliable construction shall be used and they shall be so mounted as to provide protection against shock and vibration in normal use.

(iii) Semiconductors shall be amply sized. Rectifiers and transistors shall be operated at not more than two-thirds of their rated current and permissible peak inverse voltage. Zener diodes shall be operated at not more than one-half of their rated current and shall short under abnormal conditions.

(iv) Electrolytic capacitors shall be operated at not more than two-thirds of their rated voltage. They shall be designed to withstand a test voltage of 1,500 volts.

(4) Intrinsically safe circuits shall be so designed that after failures resulting from this first failure, the circuit will remain intrinsically safe.

(5) The circuit will be considered as intrinsically safe if in the course of testing no ignitions occur.

The second part (18.68(b)) addresses low-energy battery-powered equipment. It reads:

(b) Complete intrinsically safe equipment powered by low energy batteries:

(1) Short-circuit tests shall be conducted on batteries at normal operating temperature. Tests may be made on batteries at elevated temperature if such tests are deemed necessary.

(2) Resistance devices for limiting short-circuit current shall be an integral part of the battery, or installed as close to the battery terminal as practicable.

(3) Transistors of battery-operated equipment may be subjected to thermal "run-away" tests to determine that they will not ignite an explosive atmosphere.

(4) A minimum of 1,000 make-break sparks will be produced in each test for direct current circuits with consideration given to reverse polarity.

(5) Tests on batteries shall include series and/or parallel combinations of twice the normal battery complement, and the effect of capacitance and inductance, added to that normally present in the circuit.

(6) No ignition shall occur when approximately 1/2 in. of a single wire strand representative of the wire used in the equipment or device is shorted across the intrinsically safe circuit.

(7) Consideration shall be given to insure against accidental reversal of polarity.

The third part (18.68(c)) specifies additional requirements for equipment and devices powered by line sources. It reads:

> (c) Line-powered equipment and devices:
>
> (1) Line-powered equipment shall meet all applicable provisions specified for battery-powered equipment.
>
> (2) Nonintrinsically safe components supplying power for intrinsically safe circuits shall be housed in explosion-proof enclosures and be provided with energy limiting components in the enclosure.
>
> (3) Wiring for nonintrinsically safe circuits shall not be intermingled with wiring for intrinsically safe circuits.
>
> (4) Transformers that supply power for intrinsically safe circuits shall have the primary and secondary windings physically separated. They shall be designed to withstand a test voltage of 1,500 volts when rated 125 volts or less and 2,500 volts when rated more than 125 volts.
>
> (5) The line voltage shall be increased to 120 percent of nominal rated voltage to cover power line voltage variations.
>
> (6) In investigations of alternating current circuits a minimum of 5,000 make-break sparks will be produced in each test.
>
> (d) The design of intrinsically safe circuits shall preclude extraneous voltages caused by insufficient isolation of inductive coupling. The investigation shall determine the effect of ground faults where applicable.
>
> (e) Identification markings: Circuits and components of intrinsically safe equipment and devices shall be adequately identified by marking or labeling. Battery-powered equipment shall be marked to indicate the manufacturer, type designation, ratings, and size of batteries used.

These requirements are, for the most part, self-explanatory. However, several points merit particular comment:

a. There are no specific packaging requirements. However, MSHA reserves the right to add further tests or requirements "if features of construction or use or both indicate them to be necessary."

b. Spark tests are required only in mixtures of methane or natural gas and air.

c. There are no provisions for approval of circuits or devices <u>without</u> spark ignition testing. MSHA has the discretion to waive tests based on previous experience. However, other standards discussed below contain provisions providing for approval of equipment meeting certain design specifications without spark ignition testing. Such provisions are found in other standards discussed below.

d. There are no provisions for adequacy tests. However, in Section 18.69 MSHA reserves the right to "verify the adequacy of equipment for its intended service." This provision applies to all equipment approved or certified under Part 18, including intrinsically safe devices and components approved under Section 18.68.

e. There are no specific maximum temperature standards in Section 18.68.

f. Transistors may be subjected to thermal "run-away" tests to determine whether or not they will ignite methane/ air mixtures. Other standards provide that no surfaces exposed to flammable or combustible material will, under normal or fault conditions, exceed the auto ignition temperature of the specific hazardous material.

Applicability to Oil Shale

Section 18.68 requirements have been successfully applied to guard against hazards found in underground coal mines. Therefore, it must be concluded that, insofar as similar oil shale mine hazards are concerned, these requirements offer an adequate level of protection.

However, certain hazards found in oil shale mines are not addressed by this standard. No provisions for testing in explosive mixtures other than methane are made. Carbon monoxide (CO) and hydrogen sulfide (H_2S), known to exist in some oil shale mines, are classed as Group C atmospheres by the National Electric Code and are generally more easily ignited than Group D atmospheres, which includes methane. Although H_2S and CO may not occur in explosive concentrations in oil shale mines, other gases may also be encountered by instruments used to monitor underground retorts.

The lack of maximum surface temperature standards also raises questions in light of the combustibility of oil shale dust. The limitation imposed on all Part 18 electrical equipment (150°C) may not provide adequate protection here since that limitation applies to equipment operating under normal conditions. Intrinsically safe equipment is supposedly safe under both normal and abnormal (fault) conditions. Thus, if Section 18.68 is used to approve intrinsically safe devices for use in oil shale mines, additional precautions should be taken to guard against accumulation of dust on surfaces which may exceed 150°C under fault conditions.

10.1.2 National Fire Protection Association 493/ Underwriters' Laboratories 913

In the course of this evaluation, it was found that NFPA 493 and UL 913 are essentially identical standards, Thus, no effort will be made to discuss both. A summary of NFPA 493 can be found in Electrical Instruments in Hazardous Locations, Third Edition, by Ernest C. Magison (21). This reference includes an extensive presentation of principles related to intrinsic safety, as well as other forms of protection for equipment operating in hazardous locations.

This discussion follows the organization of UL 913. This standard is much longer and more detailed than Section 18.68. A brief description of the requirements found under each of the main headings is presented below. The full texts are readily available from UL or NFPA.

10.1.2.1 UL 913 - Intrinsically Safe Apparatus and Associated Apparatus for use in Class I, II, and III, Division I, Hazardous Locations

General - This section discusses the scope and purpose of the standard. A glossary is provided which defines fault, intrinsically safe circuit, normal operation, and other terms. General requirements for apparatus and circuit evaluations are also provided. These requirements state that the energy available in hazardous locations shall not be capable of igniting the specified atmosphere during normal or fault conditions by arcing or thermal means. Sources of sparks considered are:

a. Discharge of capacitive circuits

b. Interruption of inductive circuits

c. Intermittent making and breaking of resistive circuits

d. Hot wire fusing.

Sources of thermal ignition considered are:

a. Heating of wires

b. Glowing of filaments

c. High surface temperatures of components.

Construction - Specific creepage and clearance distances are required. Provisions are made for proper use of ground barriers and encapsulation.

Field Wiring Connections - This section sets requirements for separation of terminals and wirings. Separate enclosures or partitions within common enclosures must be used to protect intrinsically safe circuits from contact with nonintrinsically safe circuits.

Internal Wiring - Minimum requirements for insulation of wiring are set. Shielding of wires is required if necessary to segregate intrinsically safe wiring from nonintrinsically safe wiring.

Protective Components - This section contains detailed requirements for the construction of transformers, damping windings, current-limiting resistors, blocking capacitors, shunt protective components, and shunt diode barriers. Encapsulation or housings are required to protect such components under all conditions of service.

Miscellaneous Components - Derating of components (to 2/3 of normal ratings) is required. Failure modes for semiconductors are addressed. Plug-in components and boards are allowed, but must not be interchangeable with nonidentical boards or components in the same equipment. Specifications for relays and batteries are included. The requirements for batteries are very detailed.

Apparatus for Class II and Class III Locations - This section includes additional requirements for intrinsically safe apparatus or circuits exposed to combustible dust (Class II) or easily ignitable fibers or filings (Class III).

Performance - This heading includes requirements for performance and testing procedures which will be used in the evaluation of circuits and apparatus. Included are:

a. Maximum temperature requirements and test procedures to verify compliance

b. A comparative procedure for determining spark ignition capability. Circuits which can be readily assessed do not have to be spark tested if they comply with certain specified levels of voltage, current, inductance, and capacitance

c. Test procedures for evaluation of transformers, resistors, barriers and other protective components

d. A dielectric voltage-withstand test to verify insulation integrity

e. Mechanical tests to insure the integrity of all partitions protecting circuits and components

f. A battery ejection drop test

g. A dust-tight enclosure specification and test procedure

h. A spark ignition test procedure. This procedure allows for testing of all atmospheres (Groups A, B, C, and D). It provides for verification of the spark test apparatus both before and after the test procedure is used to evaluate a circuit or component.

Manufacturing and Production Tests - This section requires additional tests for transformers.

Marking - Minimum marking requirements include:

a. Identification of apparatus

b. Hazardous location class and group

c. Operating temperatures

d. Maximum voltages

e. Installation, operation and maintenance procedures

f. Color coding of terminals and plugs (if necessary)

g. Battery specifications.

Appendix A - An appendix which contains additional general information is provided.

10.1.2.2 Applicability to Oil Shale

Unlike Section 18.68, UL and NFPA standards are not intended to apply to specific industries. Rather, they address hazards specified in the various classes, divisions, and groups contained in Article 500 of the National Electric Code. Thus, to properly use these standards, one must know what hazards will be encountered in the location of interest.

Certain hazards in oil shale remain undefined (for example, the combustibility of oil shale dust). Moreover, the National Electric Code, upon which these standards are based, specifically states that installation in underground mines are not covered by the various provisions. However, in the past, MSHA has identified certain conditions in mining where application of the provisions found in the NEC provide an adequate level of safety. It is felt that, as the hazards found in oil shale mines become more specifically defined, MSHA could similarly apply the provisions of UL 913 (or NFPA 493) to provide an adequate level of safety regarding the use of intrinsically safe equipment.

Stated another way, MSHA could substitute the provisions of UL 913 for the provisions of Section 18.68 in evaluating intrinsically safe equipment for oil shale mines without reducing the degree of safety provided. In fact, the broader scope of UL 913 which addresses hazardous atmospheres other than methane, makes this standard potentially more well-suited to oil shale conditions than Section 18.68. However, all other applicable provisions of Part 18 (such as the adequacy requirement of Section 18.69 and provisions addressed to mineworthiness of all equipment) should also apply to equipment approved as intrinsically safe under UL 913.

10.1.3 American National Standards Institute/ Instrument Society of America RP 12.6

ISA RP 12.6 is a relatively short standard specifically addressing the installation of circuits and apparatus already known to be intrinsically safe. Its provisions are designed to (21):

a. Insure that the installation conforms to the limiting parameters and requirements upon which approval was based

b. Prevent the interconnection of several intrinsically safe systems in a manner not contemplated during approval

c. Prevent the intrusion of nonintrinsically safe energy levels into approved circuits

d. Prevent power system faults and other occurrances from making the intrinsically safe circuit ignition capable.

ISA RP 12.6 is not comparable to UL 913, NFPA 493, or Section 18.68 in that it does not provide for testing and approval of devices as intrinsically safe. It is intended to be used in conjunction with these, or similar, standards. Thus, its applicability to oil shale mining is limited to the possible role of supplementing one of the other standards discussed. However, UL 913 and NFPA 493 contain many of the same provisions as ISA RP 12.6, and their general applicability is not dependent on supplementation by this, or any other, standard.

10.1.4 International Electrotechnical Commission Publication 79-3

IEC 79-3 describes in detail a spark test apparatus for use in evaluating intrinsically safe circuits. This apparatus has been adopted for use by UL, NFPA, and other international testing organizations.

In 1977, the IEC published requirements for intrinsically safe systems in Publication 79-11. However, according to Magison (21) the primary contribution of IEC to intrinsic safety has been its influence on other documents, such as NFPA 493. Magison goes on to say that "at present IEC requirements are of no specific value to manufacturers or users of intrinsically safe apparatus."

10.2 Suggested Modifications to Devices Approved Under UL 913 or NFPA 493

One expressed goal of this study is to perform an evaluation of design and packaging modifications necessary to adopt, for use in oil shale mines, intrinsically safe instruments and devices already accepted as being suitable for NEC Class I, Division I, Hazardous Locations. Performance of this task has been severely hampered by a lack of knowledge regarding actual oil shale mine operating conditions, and by the lack of development by oil shale operators of designs and specifications for monitoring systems, instrumentation, and other applications requiring such equipment. However, based on the knowledge which does exist, and on the above analysis of standards such as UL 913 and NFPA 493, certain conclusions can be drawn:

a. Equipment approved for use in Class I, Division I, Hazardous Locations, "should be tested in Group C and Group D atmospheres before" being accepted for use in oil shale mines. This requirement may be overly conservative in some mining situations. However, it seems prudent to take this precaution unless, or until, additional information is available on gases likely to be encountered in oil shale mines.

b. Equipment should be constructed so as to prevent the buildup of oil shale dust on heated surfaces. As noted above, UL 913 sets a maximum temperature standard that would restrict the temperature of component surfaces to a level below the auto ignition point of the subject material. However, this point has not yet been established for oil shale dust in an operating mine.

c. An adequacy test should be required. UL 913 does not require that the device approved be adequate for its intended purpose. Yet, overall safety in an oil shale mine may depend not only on the inability of the device itself to ignite hazardous materials, but on the ability of the device to perform its intended function.

d. Location, mounting, and protection of intrinsically safe devices intended for use on or with other types of equipment (for example, instrumentation on trucks and loaders) should be evaluated in light of the intended use. Without specific applications, it is impossible to say that the addition of a hose clamp here, or support bracket there, will provide ample protection for a device under any and all conditions. The intrinsically safe characteristic of such devices is assured by the tests performed under UL 913, but location, mounting, and protection of the device on a particular machine should be considered in the approval process for that particular machine.

10.3 MSHA Approval of Mine-Wide Monitoring Systems

A particular concern of oil shale operators (noted earlier in this report) is the nonavailability of MSHA-approved components for use in the complex monitoring systems planned for some oil shale mines. A recent regulatory development may offer a solution to this problem.

On June 21, 1982, MSHA instituted a new procedure designed to simplify and expedite the processing of applications for evaluation of Mine-Wide Monitoring Systems (MWMS) and for classification of sensors and barriers used in such systems. This procedure is specifically intended for use with "complex systems with performance specifications within recognized limits of safety." At least two companies have, at this time, received MSHA acceptance for MWMS.

An application package for this simplified procedure is reproduced in Appendix C of this report. This package includes instructions for use of the procedure, drawing and specification requirements, and application letter forms. It is available to interested persons from the MSHA Approval and Certification Center.

11. REFERENCES

1. Russell, Paul L., "Oil Shale," Mining Engineering, Vol. 33, No. 1, pp. 29-42, January 1981.

2. Shale Country, September 1981, October 1981, January 1982, April 1982.

3. Murray, Keith D. (Ed.), Guidebook to the Energy Resources of the Piceance Creek Basin, Colorado, 1974.

4. Bank, Walter, "Review of Health and Safety Problems Unique to Mining and Processing Oil Shale," April 1974.

5. "Explosibility of Carbonaceous Dusts," RI 6597, 1965.

6. "Methane Absorption in Oil Shale and its Potential Mine Hazard," RI 8243, 1977.

7. Richmond, J.K., et al., "Explosion Hazards in Gassy and Non Gassy Oil Shale Mines," 14th Oil Shale Symposium, Denver, CO, April 1981.

8. Richmond, J.K., et al., "Fire and Explosion Properties of Oil Shale, Part II," 13th Oil Shale Symposium, Colorado School of Mines, Golden, Colorado, April 1980, pp. 193-207.

9. Randle, Allen C., "Union Oil Company of California's Parachute Creek Shale Oil Program," presented at AMC International Mining Show, Las Vegas, NV, October 11-14, 1982.

10. Mining Cable Engineering Handbook, the Anaconda Company, 1977.

11. IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems, IEEE Standard 142-1972/ANSI C114.1-1973.

12. Titus, C.H., "Evaluation and Feasibility Study of Isolated Electrical Distribution Systems in Underground Coal Mines," BuMines OFR 39-72, April 17, 1972.

13. Dolinar, Kevin D., "Improved Ground Fault Protection System for Low-and Medium-Voltage Trailing Cables," Lee Engineering Division, Consolidation Coal Company, Sept. 1980.

14. Personal communication with William Savatt, MSHA Approval and Certification Center.

15. Section 18.68, Title 30, Code of Federal Regulations.

16. National Electric Code, 1981, ANSI/NFPA 70.

17. "Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1, Hazardous Locations," Underwriters' Laboratories Standard No. 913.

18. "Intrinsically Safe Apparatus for Use in Division 1 Hazardous Locations, 1978," National Fire Protection Association 493.

19. "Installation of Intrinsically Safe Instrument Systems in Class I Hazardous Locations," Instrument Society of America, RP12.6.

20. International Electrotechnical Commission Publication 79-3.

21. Magison, Ernest C., Electrical Instruments in Hazardous Locations, Third Edition, Instrument Society of America, 1978.

22. Personal communication and literature from the Caterpillar Tractor Company.

23. Personal communication and literature from the Cummins Engine Company.

24. Literature from the General Motors Corporation.

25. Personal communication and literature from Pyroban Ltd.

26. Personal communication and literature from Rognon SA.

27. Personal communication from Union Oil of California, Energy Mining Division.

28. Personal communication from Exxon Colony Project.

29. Personal communication from Occidental Oil.

30. Personal Communication from C-b Project.

31. Personal communication from the Phillips Petroleum Company.

32. Personal communication from White River Shale Project.

33. Personal communication from Sohio Mining Division.

34. Personal communication from Paraho.

35. Literature from Atlas Rear Dump Trailers.

36. Personal communication and literature from the Kress Corporation.

37. Personal communication and literature from Euclid, Inc.

38. Personal communication and literature from Wabco, Inc.

39. Literature from Unit Rig.

40. Literature from Kamatsu.

41. Literature from General Electric Corporation.

42. Literature from Reliance Electric Corporation.

43. Burton, A.K., "The Past and Present of Truck Haulage."

44. USBM Contract No. JO113070, "Explosion-Proofing Large Diesel Vehicles for Oil Shale Mining," Twin Cities Research Center, December 1981.

45. Discussions and meetings with Colorado Mining Association.

46. Memo to F.W. Felegy, District Manager, Health and Safety District E from John Nagy, Project Coordinator, Dust and Ventilation. Subject-Explosibility of Oil Shale Samples from the Anvil Points Mine, Rifle, Colorado, December 18, 1967.

47. Thimons, Edward D., R.P. Vinson, F.N. Kissell, "Forecasting Methane Hazards in Metal and Nonmetal Mines," U.S. Department of the Interior, Bureau of Mines, Report of Investigations NO8392, 1979.

48. C. and D.M. Blythe, "Electrical Systems for Vehicles Used in Underground in Miscellaneous Mines," Paper given to British Gypsum Ltd., to Manufacturing Electrical Design Consultants, Ltd., ca. 1981.

APPENDIX A

INDUSTRY CONTACTS

APPENDIX A - INDUSTRY CONTACTS

A. Government Agencies

1. Formal Meetings

   a. Mine Safety and Health Administration

      1. Denver Safety and Health Technology Center

      2. Metal and Non-metal Rocky Mountain District Office

      3. Metal and Non-metal Rocky Mountain Sub-district - Denver

      4. Metal and Non-metal Rocky Mountain Sub-district - Grand Junction

      5. Approval and Certification Center

   b. Department of Interior
      United States Geological Survey
      Office of the Oil Shale Supervisor

2. Telephone Contacts

   a. Occupational Safety and Health Administration

   b. Research Organizations

      1. U.S. Bureau of Mines

         a. Pittsburgh Research Center

         b. Denver Research Center

         Department of Energy

      2. a. Carbondale Research Center

         b. Laramie Energy Technology Center

      3. Sandia National Laboratories

4. Lawrence Livermore National Laboratory
5. Gulf Research
6. Los Alamos National Scientific Laboratory
7. Denver Research Institute
8. University of Colorado
9. University of Utah
10. Chevron Research Company
11. Colorado School of Mines Research Institute
12. Phillips Petroleum Company

c. Mining Companies

1. Mobil Oil Corporation
2. Occidental Oil Shale Incorporated
3. Exxon Company, U.S.A.
4. Tosco Corporation
5. Cliffs Engineering, Incorporated
6. Rio Blanco Oil Shale Company
7. Union Oil Company of California
8. Sohio Shale Oil
9. Superior Oil Company
10. Chevron Shale Oil
11. Phillips 66
12. White River Shale Project
13. Equity Oil
14. Paraho

15. Multi-Minerals

16. Southern Indiana Shale Oil

17. Geokinetics, Incorporated

d. Union Contacts

1. Oil Chemical and Atomic Workers

2. International Brotherhood of Electrical Workers

e. Other Contacts

1. Friends of the Earth

APPENDIX B

ELECTRICAL SYSTEMS FOR VEHICLES USED UNDERGROUND IN MISCELLANEOUS MINES

CEDAV®

ELECTRICAL SYSTEMS FOR VEHICLES USED UNDERGROUND IN MISCELLANEOUS MINES

PAPER GIVEN TO:
BRITISH GYPSUM LTD
BY C. AND D.M. BLYTHE
DIRECTORS OF:
M.E.D.C LTD

BACKGROUND HISTORY.

In the past a few fires have occurred in miscellaneous mines underground, whilst these could be put down to various reasons, the main causes appear to have been either directly/indirectly electrical failure or electrical faults, being caused by damaged cable or components or a combination of both, which have resulted in fires,some on the batteries, although the majority have been fuel fires.

Battery fires have been caused by short circuits, causing a flash that has ignited the hydrogen in the batteries, resulting in a "Mini Explosion" This type of fire spreads quickly through the machine or vehicle, resulting in damaging fumes in the airways of the workings, and total burn out of the machine.

A similar type of fault on the electrical system could also cause an ignition of the fuel oil. Again a very large pollution in the workings could occur which would be poisonous to personnel in the vicinity. Such problems have caused great concern to the Health & Safety Executive, because human life is at stake.

The Health & Safety Executive now decided that no more electrc starting of machines would be permitted and insisted that starting of machines must be:-

1. Hydraulic

2. Pneumatic

3. or Spring Starting.

Although these systems of starting are perfect in theory, they cause many problems for the Maintainance Engineers in the mines, e.g. failure of systems, expensive repair costs, loss of production, more down time. Economics alone demanded a re-think was needed.

M.E.D.C. Ltd. were approached by British Gypsum, to see if we could produce a design for Fully Safe Electrical System which would meet the requirements of the Health & Safety Executive, alternatively could we carry out feasiblity study of a complete Fail Safe System for the use of Electric starting on vehicles.

In light of past history on electric starting this would be no easy project. After careful consideration, M.E.D.C. Ltd. decided that it could produce a system which would not only satisfy the Health & Safety Executive but would be in advance of their requirements, and could possibly permit Fail Safe Electric starting of vehicles.

After many consultations with British Gypsum Engineers, and vehicle manufacturers e.g. G.H.H. Stergrade, Volvo and Lloyds tractors for Fords, it was decided that we could design a system which would be suitable for all types of a machines, and acceptable to Health & Safety Executive.

After preparing basic layout drawings and getting our ideas on paper, I made a visit to the Health & Safety Executive, and discussed the proposed system fully with both the Deputy Senior Electrical and Mechanical Inspector of Mines. The Inspectors agreed to us producing a system to try out, to be tested by their inspectors in the field, the future of electric starting would depend on their report.

THE STUDY AND DESIGN.

After studying machine electrics, we came to the conclusion that the majority of machines worked on the "Bare Earth Return System," which could not be made safe. We therefore decided that initially we must use a starter motor, alternator, heaters, switches, lights etc. with a fully insulated return.

We next considered the batteries. After much research and discussion with battery manufacturers, we concluded that the A.C. Delco maintainance free range of batteries were the most suitable, for the following reasons.

1/ Completely maintainance free (No topping up)

2/ Very good shelf life.

3/ Very good performance and life cycle.

4/ Had a built in flame arrestor. (This ensures that if there is a fire or ignition near the battery, the flame arrestor would stop a "back fire" into the battery and igniting the hydrogen in the battery casing.)

5/ Stainless steel terminals. (Corrosion resisting)

The Health & Safety Executive requirements needed a suitable housing for the battery. Any hydrogen given off from the enclosure must be evacuted almost instantly. Fuses had to be fitted directly to the battery terminals, a battery isolator switch fitted in the same enclosure, and wired to allow charging from the alternator with the machine running, yet also to allow for static charging in workshops.

We also had to consider the battery housing being suitable for fitting to machines, could we achieve a standard design, unfortunately this cannot be achieved due to various machines having different battery chambers, however, these chambers can be modified to meet the requirements.

We then went on to earth leakage and short circuit protection. Both of these systems required a very quick response time, and trip before either a spark, or fusing of a single strand of wire could occur. We resolved this problem by using electronic detection and continuous monitoring of both positive and negative lines. The electronic detectors operate the coil of the electro-mechanical relays controlling the heavy duty switching circuits which in turn control the solenoids contactors etc.

If an earth fault or short circuit develops on either positive or negative lines, the electrical power for the entire system with exception of the lighting circuits are automatically switched off, an audible and visual alarm is switched on, and the engine shuts down.

The earth leakage unit and short circuit protection unit, the contactors for the starter motor and fuel solenoid the starter motor relay, the earth leakage relays, a manual overide switch and fuses for lighting circuits and all terminals for ancillary equipment are housed in one panel. On the door of the panel are 5 indicators, 1 audible alarm and 3 push buttons. These are:-

INDICATORS.

Earth Leakage - Safe

Earth Leakage - Fail 1

Earth Leakage - Fail 2

Short Circuit - Trip

Manual Overide - Blue

Common Audible Alarm

PUSH BUTTONS.

Earth Leakage Reset

Earth Leakage Test

Short Circuit Reset

A manual overide has been fitted to allow the defeat of the system in an emergency only. For instance if an electrical fault occurred on a machine or a vehicle at the face, and the vehicle had to move to allow for shot firing, an Engineer can open the panel, operate a key switch allow the engine to be started and the machine moved to a safe area. The blue indicator would be illuminated and the audible alarm will sound as long as the system is defeated.

A door interlock switch is fitted, so when the system is defeated, the door which has to be opened to operate the key switch, cannot be fully closed, and both the visual and audible alarms continue.

This interlock has been fitted so that machine operators cannot drive around with a faulty machine, the machine to be driven in this state by authorised personel only. An electrically operated solenoid is fitted on the fuel system, therefore if either a short circuit or earth leakage fault occurs, this solenoid is de-energised. This solenoid switches off the fuel valve, and the engine automatically shuts down.

In the engine starting system, there is a pilot circuit, by turning the engine starter switch on, the contactor coils are energised which in turn, supplies power to the starter motor and fuel solenoid.

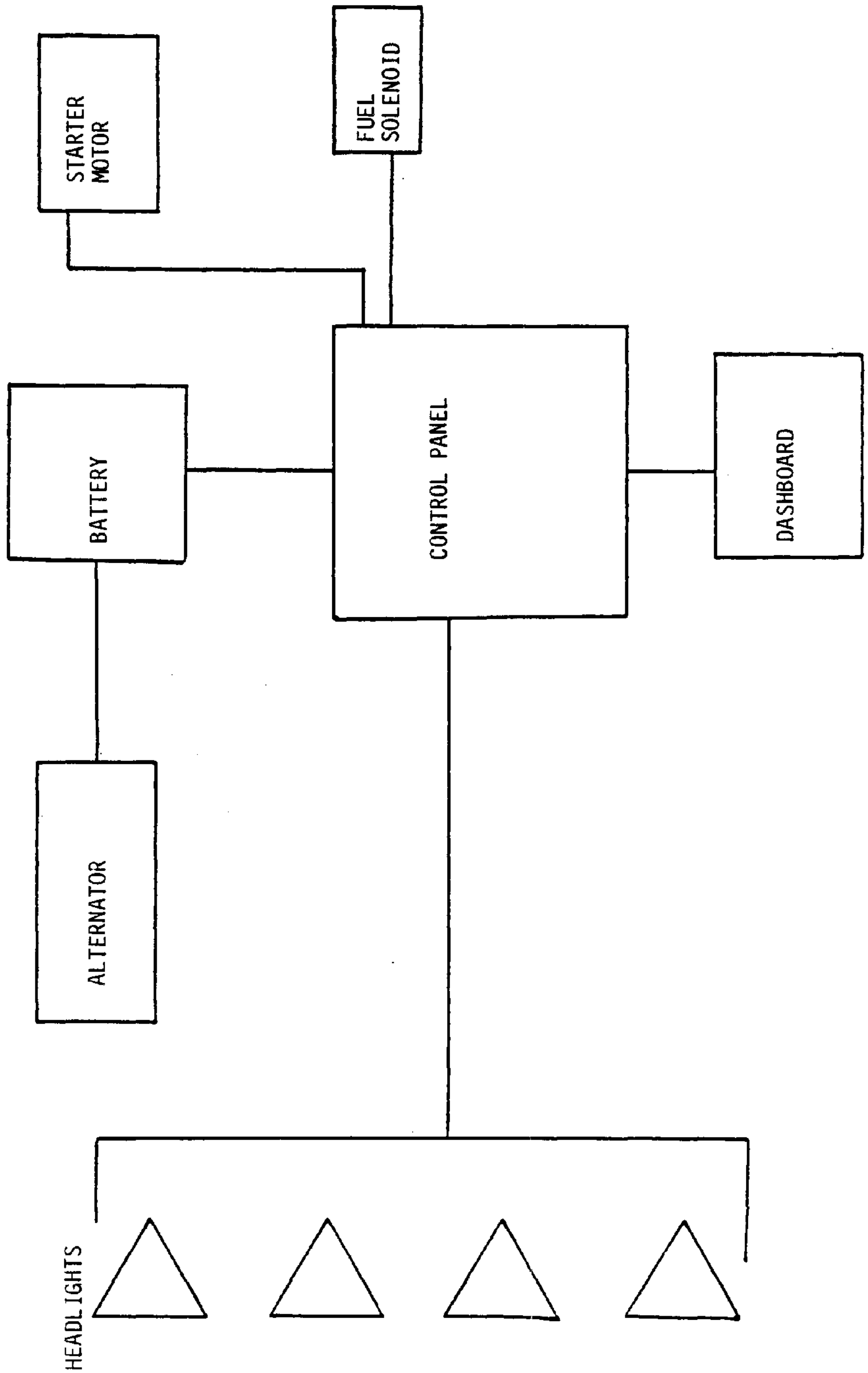
The wiring used on the vehicles are heavy duty cables on the starter motor circuit and cables of suitable rating for other equipment. Mechanical protection is achieved by Plastic covered steel flexible conduit and Armourflex cables. These are terminated via glands and covered by P.V.C. sleeves, so that all terminals are completely covered.

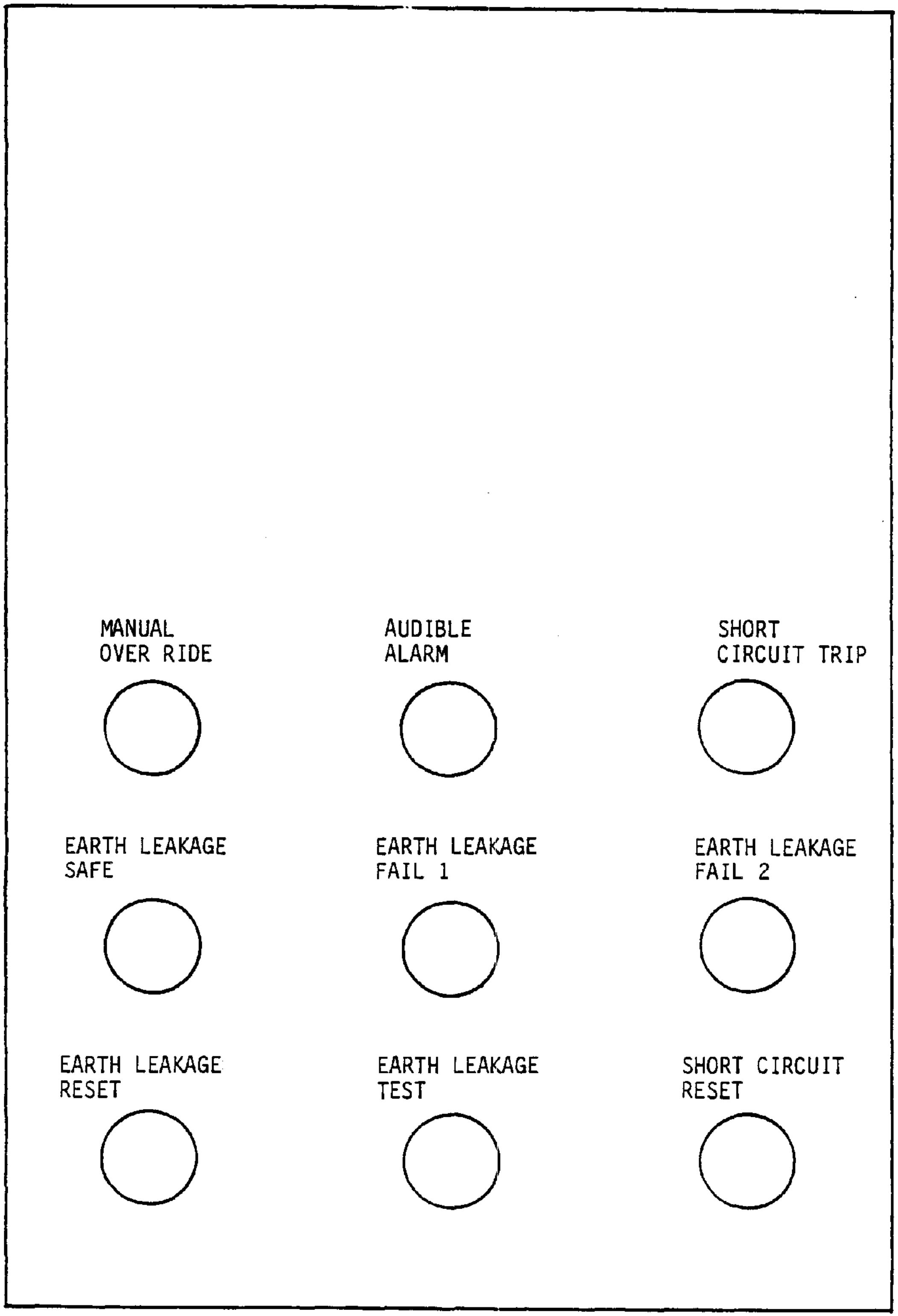
Cables are clipped to the structure of the vehicle, so that the chances of cables getting damaged are reduced.

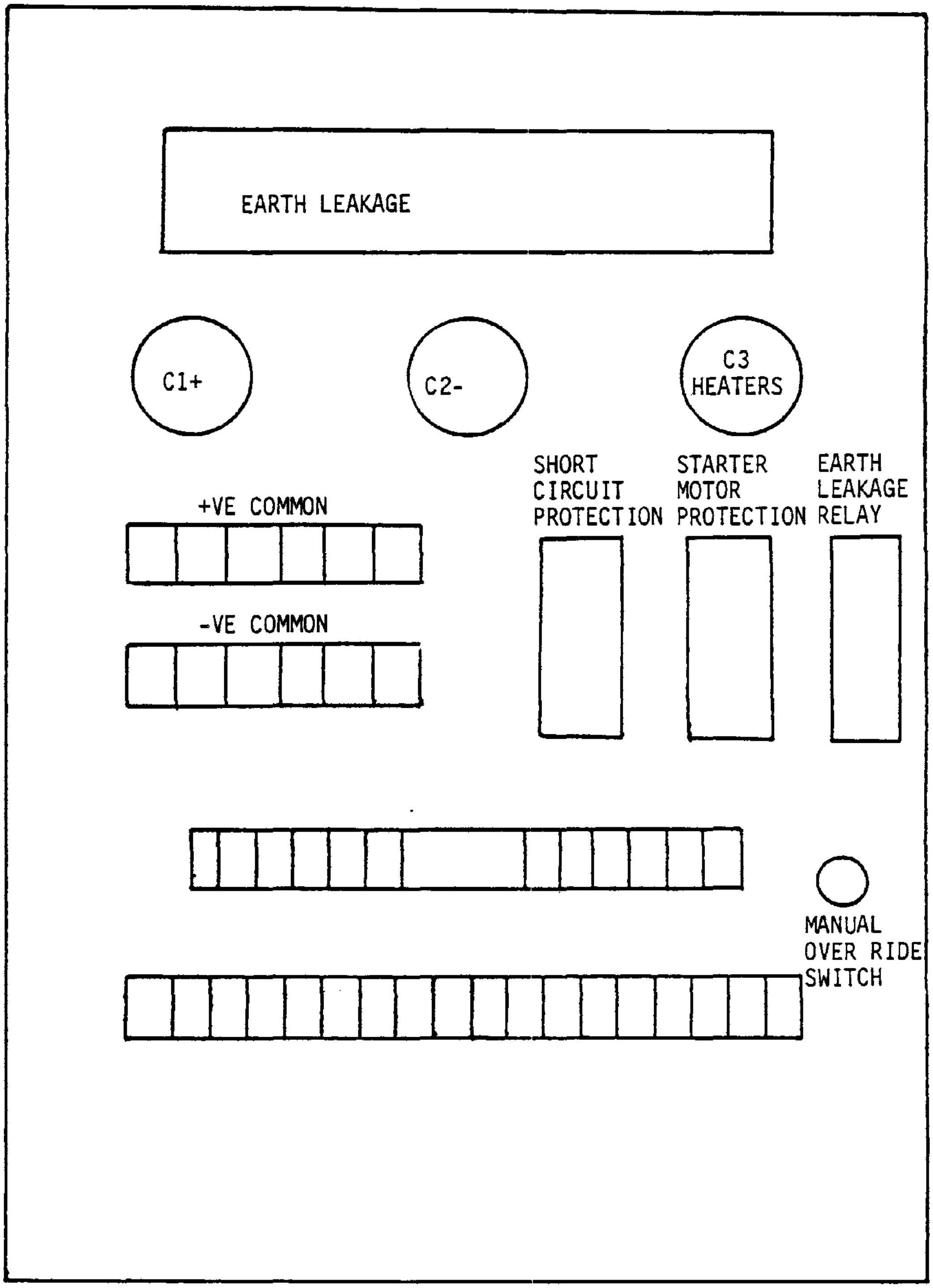
The enclosure both for the battery and earth leakage control panel are manufactured from ⅛" steel plate cladding on angle iron frames. This is to give a good mechanical strength, against possible damage i.e. anything falling onto the units.

The lighting fittings used are, in fact, flameproof, but these have been used purely for their physical strength.

The lighting circuit is fitted with a selector switch i.e. Headlights on at front. Tail lights at back. Headlights on at back Tail lights at front. All four Tail lights for when machine is parked and off position.


STARTER MOTOR
FUEL SOLENOID
BATTERY
CONTROL PANEL
DASHBOARD
ALTERNATOR
HEADLIGHTS


MANUAL
OVER RIDE
AUDIBLE
ALARM
SHORT
CIRCUIT TRIP
EARTH LEAKAGE
SAFE
EARTH LEAKAGE
FAIL 1
EARTH LEAKAGE
FAIL 2
EARTH LEAKAGE
RESET
EARTH LEAKAGE
TEST
SHORT CIRCUIT
RESET


EARTH LEAKAGE
C1+
C2-
C3
HEATERS
SHORT CIRCUIT PROTECTION
STARTER MOTOR PROTECTION
EARTH LEAKAGE RELAY
+VE COMMON
-VE COMMON
MANUAL OVER RIDE SWITCH

E/L TECHNICAL DESCRIPTION

The earth leakage unit may be divided into five individual sub-circuits.

1/ Oscillator

2/ D.C. restorer

3/ Comparator

4/ Monostable

5/ Trip circuit

1/ OSCILLATOR

This is a conventional operational amplifier astable multivibrator. A 1.1. mark space is used for this application. The frequency of the oscillator is approximately 370 HZ.

2/ D.C. RESTORER

This is included to ensure that the base of the square wave is clamped to a known voltage.

3/ COMPARATOR

This circuit uses an operational amplifier in its open loop mode to act as a comparator. A reference voltage of 5v and a portion of the square wave are applied to the comparator inputs. When the magnitude of the square wave exceeds the magnitude of the reference voltage the comparator output is a 370 HZ square wave. When the leakage current reaches the tripping level, the voltage across the leakage resistance is no longer high enough to bias the comparator and hence the comparator output is the reference voltage.

4/ MONOSTABLE

This unit is put in circuit to overcome the problem of natural capacitance between the battery and case.

5/ TRIP CIRCUIT

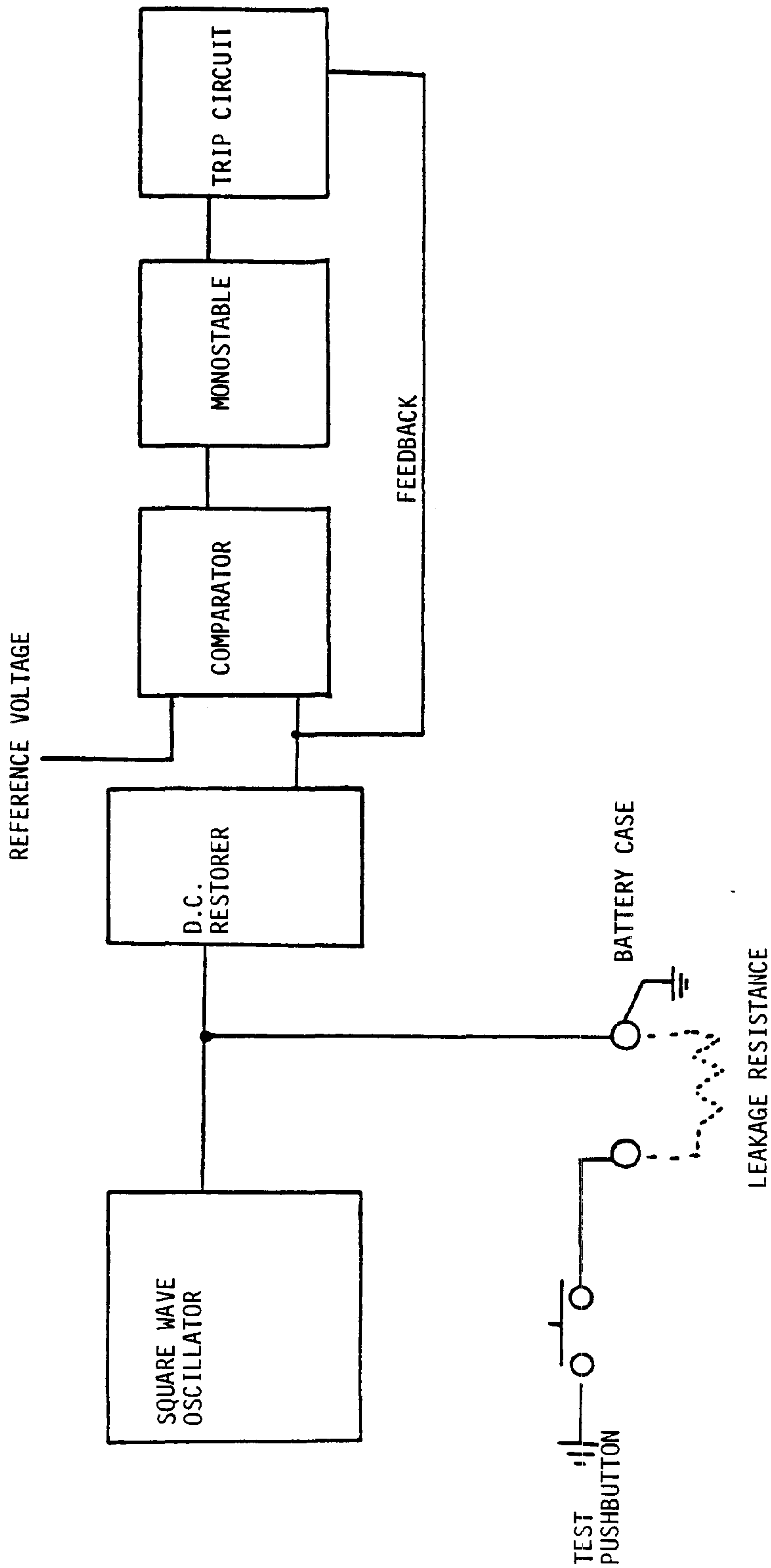
When the circuit is safe, pulses from the comparator, pulse each half of the transformer alternatively, this charges a capacitor which in turn turns on a transistor which operates the relay and gives an output between terminals 6& 12.

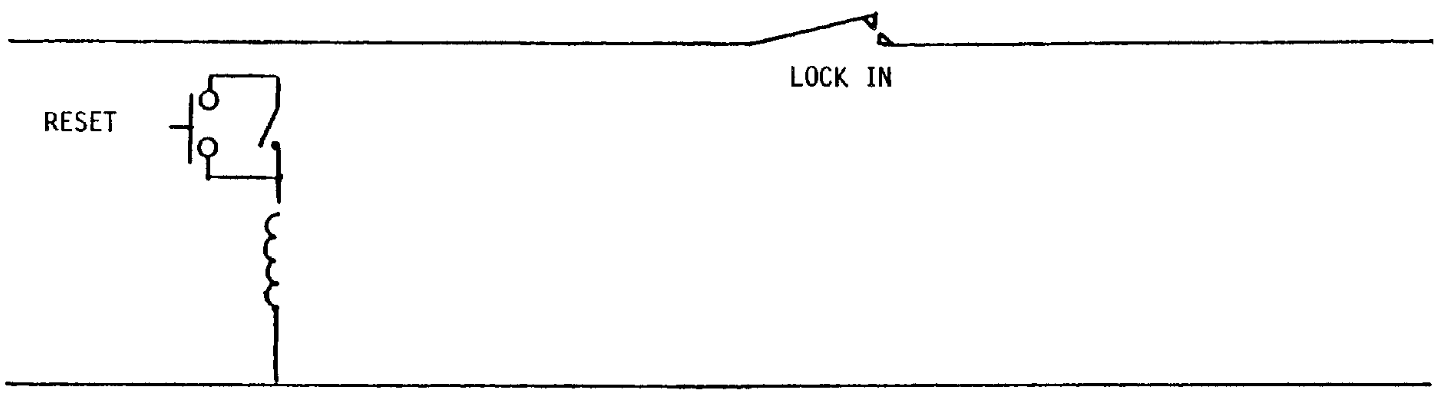
When a fault occurs the output comparator is the 5v reference voltage hence the transformer is no longer pulsed and the relay de-energises.

SHORT CIRCUIT PROTECTION

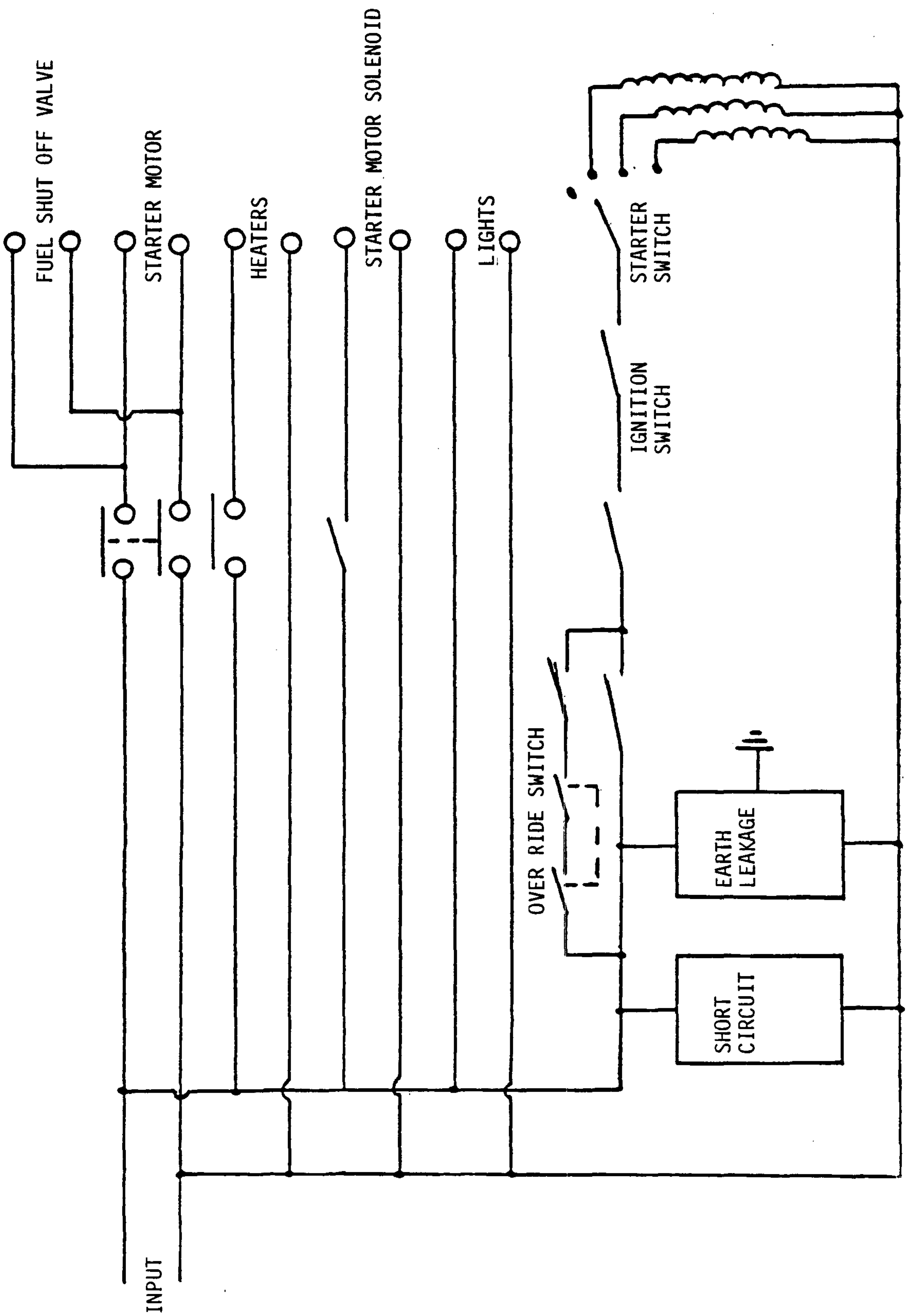
This unit is designed to sense a short circuit within the system.
When power is first applied the unit is de-energised in the fault condition, after re-setting the unit a pair of retaining contacts are closed, also provided for series insertion in some other part of the circuit is another set of contacts.

If a short circuit occurs the voltage across the unit will be reduced and the circuit will trip, opening both sets of contacts and so making it necessary to reset the unit before the system can be operated again.


TRIP CIRCUIT
MONOSTABLE
FEEDBACK
COMPARATOR
REFERENCE VOLTAGE
D.C. RESTORER
BATTERY CASE
LEAKAGE RESISTANCE
SQUARE WAVE OSCILLATOR
TEST PUSHBUTTON



SHORT CIRCUIT PROTECTION


FUEL SHUT OFF VALVE
STARTER MOTOR
HEATERS
STARTER MOTOR SOLENOID
LIGHTS
STARTER SWITCH
IGNITION SWITCH
OVER RIDE SWITCH
EARTH LEAKAGE
SHORT CIRCUIT
INPUT

TESTING OF THE SYSTEM PRIOR TO STARTING OF THE MACHINE.

Before starting the engine, the following procedure Must be carried out.

When the battery is "Switched On" all Fail indicators are illuminated and the audible alarm will sound.

However, the Blue indicator, which is for the manual overide Must not be illuminated.

1/ Reset the short circuit protection unit by means of the reset push button, the amber indicator will then go out, if the indicator remains on a short circuit fault is present. This fault must be cleared before anything further is done.

2/ Reset the earth leakage unit, the red indicator will go out, and the green safe indicator will illuminate, also the audible alarm will stop. If by pressing the reset, the red light remains on, this proves either an earth fault, or that the battery requires charging, therefore the necessary steps have to be taken.

3/ Test the earth leakage by means of the teat push button, this automatically puts a fault condition on the system, illuminating all fail indicators and sounding the audible alarm.

4/ Reset the earth leakage, if only the green safe indicator is illuminated the system can be started, if any other indicators are illuminated and the audible alarm is sounding you have a fault condition, so maintainance must be carried out.

Let us assume that this proceedure has been carried out and everything is healthy, the vehicle is now ready for starting.

STARTING.

Turn on the key operated ignition switch, position 1 switches on the fuel valve. Turn to position 2, this starts the starter motor. Once the engine has started the ignition switch should be released, as per on a car, and this returns to position 1 by spring return.

I stated that if the earth leakage indicators are still illuminated after pressing the reset push button, it means either an earth fault on the system or the battery needs charging.

We have designed a system of monitoring the battery output, this by the use of high brightness Light Emitting Diodes. If the battery was fully charged a Green L.E.D. will illuminate, but if the battery was low a Red L.E.D. will illuminate.

We consider that this system of monitoring the battery very useful to engineers when testing the system. For example if the system shows an earth leakage fault, and will not reset, the engineer will see at once if it was the battery which required charging, if so, he will be able to charge the battery, without having to check the system for faults that are not there.

* Reference to specific equipment (or trade names or manufacturers) does not imply endorsement by the Bureau of Mines.

APPENDIX C

U.S. DEPARTMENT OF LABOR MEMORANDUM
MINE-WIDE MONITORING SYSTEMS

U. S. Department of Labor

Mine Safety and Health Administration
Industrial Park Boulevard
RR 1, Box 201B
Triadelphia, West Virginia 26059

June 21, 1982

TO ALL INTERESTED PARTIES

SUBJECT: MINE-WIDE MONITORING SYSTEMS

Gentlemen:

The Mine Safety and Health Administration's Approval and Certification Center will accept applications for Mine-Wide Monitoring System (MWMS) Evaluations and Sensor Classifications and Barrier Classifications. This package contains application forms and instructions for the evaluation of MWMS, and for sensor and barrier classification for use on MWMS's. These evaluations or classifications are not applicable for use on other systems, approvals, acceptances or investigations. The enclosed application instructions are intended to provide a simple procedure whereby complex systems with performance specifications within recognized limits for safety can be expeditiously processed.

Applications for MWMS evaluation and sensor or barrier classification should contain the information itemized on the attached application instructions. Insufficient information will result in application cancellation.

MSHA reserves the right to require the submittal of additional information, such as detailed schematics and specifications, or actual equipment prior to the issuance of MWMS acceptance or a sensor or barrier classification.

For further information contact Ken Sproul at the Approval and Certification Center. Telephone No. (304) 547-0400.

APPLICATION INSTRUCTIONS FOR MINE WIDE MONITORING SYSTEM EVALUATION

An application letter for a Mine Wide Monitoring Systems Evaluation should contain the following information.

1. The company name, address, telephone number and the name of the company representative.

2. A company assigned code number - an arbitrary six-digit numerical code assigned by the submitting company for company identification purposes.

3. The date.

4. The functional block diagram and/or specification(s) of the Mine Wide Monitoring System including drawing number(s) and revisions. The functional block diagram should contain the necessary interconnection information to insure compliance with the conditions as outlined on the MWMS drawing(s) and specification(s) requirements.

5. The installation and maintenance - inspection manual used by the installer and maintained at the installation site, to insure that each MWMS is installed and maintained in accordance with the conditions stipulated in the application. The installation and maintenance inspection manual should contain as a minimum the following information:

   1. Form Number/Date.
   2. Characteristics to be inspected and/or tested, with limits.
   3. Method of testing or inspection.
   4. Results of testing or inspection.
   5. Signature/Date.

6. Sign the application letter.

MINE WIDE MONITORING SYSTEM

Drawing and Specification Requirements for use of Simplified Processing Procedures

Drawing(s) and specification(s) submitted for a Mine Wide Monitoring System should indicate that:

A. All interfaces to any data transmission line contain circuitry limiting the Data Transmission Line voltage to a maximum of 60 volts per conductor to ground.

B. All outstations are either blue or red in color and are located in intake air.

*Blue outstations may monitor sensors located in areas where equipment is required to be permissible.

*Red outstations are not connected to any circuits entering or located within areas where equipment is required to be permissible.

C. All blue outstations have MSHA power circuit (P.C.) classified input barriers installed in the data transmission line and that the barrier voltage classification is greater than or equal to the highest power circuit voltage being monitored.

D. All blue outstation inputs from power circuits or sensors requiring external power for operation have an MSHA classified power circuit (P.C.) barrier whose voltage classification is greater than or equal to the maximum voltage of the circuit monitored, or supplied to the barrier, or being supplied to the sensor for operation.

E. All outputs of power circuit (P.C.) barriers (inputs to blue outstations) are 120 volts/or less.

F. All sensors in areas where equipment is required to be permissible have a MSHA classification label. (The classification label shall designate an alphabetical classification for the sensor and the label shall be attached to the sensor or, when necessary for inspection purposes, in close proximity to the sensor. i.e. An oil level sensor label could be on the oil tank at the point of cable entry.)

G. Cables from MSHA classified sensors terminate in a MSHA classified barrier of the same classification. MSHA classified barriers are located at a blue outstation(s).

H. Cables from MSHA classified barriers that terminate in explosion-proof enclosures located in areas where equipment is required to be permissible, comply with the following conditions:

(1). The modification of existing permissible electrical equipment and circuitry within the permissible electrical equipment shall be documented by the operator under an acceptable Field Modification Application.

(2). Cable termination (data transmission line from a blue outstation) within MSHA certified enclosures are to a barrier with a classification that matches the classification of the barrier at the blue outstation. A P.C. barrier with a voltage rating greater than or equal to the voltage input to the enclosure is required when power circuits are monitored or power is obtained from within the MSHA certified enclosure.

(3). All cables leaving an MSHA certified enclosure and terminating in a sensor must meet the following conditions:

A. The sensor has a classification label.

B. The cable is shielded and the shield grounded at the MSHA certified enclosure.

C. The sensor classification has the same letter classification as a barrier located within the MSHA certified enclosure and connected to each individual sensor cable. A barrier classification label shall be located on the exterior of the MSHA certified enclosure and in close proximity to each and every barrier cable entrance.

D. Connections to the data transmission line shall be between the data transmission line classified barrier and the P.C. barrier when a P.C. barrier is required.

(4). Physical isolation is provided within an MSHA certified enclosure by means of an insulated or grounded metallic shield around all barriers and cables.

I. All sensors whose cable passes through an area where permissible equipment is required, have a MSHA classification label and interface with a blue outstation through a MSHA classified barrier of the same classification.

J. Barriers or barrier enclosures are attached to the blue outstation and are so labeled that barrier outputs identify the type of sensor to which the barrier cable is connected, i.e., CO sensor, CH_4 Sensor, Anemometer.

K. All cables entering blue outstations from the P.C. barriers, and all cables connecting a classified barrier with a classified sensor, and all cables connecting the blue outstation with non-classified sensors are shielded with the shield connected to ground at the outstation.

L. Grounding techniques for outstations and barriers are employed using no less capacity than a No. 12AWG Wire.

M. All blue outstations shall contain a MSHA evaluation label with the conditions of use as specified by MSHA.

N. MWMS components and circuits (except under the conditions outlined in (O)) underground automatically deenergize upon loss of mine ventilation. Manual deenergization from a centralized surface control area is acceptable. Manual reenergization of each individual underground outstation is required.

O. Fire detection circuits that monitor conveyor belts or conveyor belt entries meet the conditions specified by 30 CFR, Part 75.1103, including the capability to monitor for 4 hours upon loss of mine power. Exception: circuits shall deenergize either manually or automatically upon loss of mine ventilation, unless the power supply and circuits have been accepted by MSHA as intrinsically safe. Such circuits must be manually reenergized at each individual underground outstation.

P. Detailed installation and maintenance instructions are supplied to all purchasers or users of these systems, installation inspection checklist(s) must be included.

Q. Restrictions of use and modification of the system are explained to purchasers or users of these systems.

APPLICATION INSTRUCTIONS FOR BARRIER VOLTAGE (P.C.) OR ALPHABETICAL CLASSIFICATION

Complete the application for barrier evaluation form (MSHA - 15) as follows: (See sample Enclosure No. 1.)

1. Enter the company name and return address in the spaces provided. Include the name of the representative to be contacted if additional information is needed.

2. Enter the telephone number of the company representative, including area code, in the space designated "Telephone No.".

3. Enter the company assigned code number in the space designated "Company Assigned Code No." (Arbitrary six-digit numerical code assigned by the submitting company for company identification purposes.)

4. Enter the date in the space designated "Date."

5. Enter the manufacturer's descriptive name for the barrier in the space designated "Nomenclature."

6. Enter the name of the company that manufactures the barrier in the space designated "Manufacturer."

7. Enter the manufacturer's assigned part number or model number of the barrier in the space designated "Part/Model No."

8. Enter the barrier classification requested (See Table 1 for alphabetical classification or enter the P.C. Voltage classification requested) in the space designated "Class Requested."

9. Enter the highest voltage level (Nominal plus tolerances) that will be available at the output terminals of the barrier in the space designated "Maximum Output Voltage."

10. Enter the highest current value (Nominal plus tolerances) that will be available at the output terminals of the barrier in the space designated "Maximum Output Current."

11. Enter the barrier rated voltage. Barrier rated voltage shall meet or exceed 250 volts.

12. If applicable, enter the approval agency and the referenced published standard under which the device has been evaluated, in the space designated "Approval Agency." Applications referencing approval agencies should include a copy of the applicable standard, the address of the approval agency, and a copy of the test report.

13. Draw the electrical schematic of the basic barrier design in the space designated "Electrical Schematic or Drawing Reference(s)."

14. The statement shall be completed by having an authorized representative sign in the space labeled "Original Signature" and filling in the title and company name in the appropriate spaces on the application. The individual signing the application shall be an authorized representative of the company, who can bind the company to the conditions stipulated in the application letter.

The Barrier Classification Application Letter (MSHA - 15) shall be submitted in duplicate for each type barrier being evaluated. If applicable, a copy of the test report of the approval agency which previously evaluated the subject barrier is to be submitted with the application letter. Any drawing or specification sheet being submitted as documentation for the barrier classification shall comply with the following:

a. All drawings(s) have a title block, a title, a number assigned, a date, and be legible.

b. Pencil or ink notations not appear on drawings being submitted for documentation.

c. Drawings show the date of the latest revision.

d. All drawings include a note "Do Not Change Without Approval of MSHA" which is included on all drawings reproduced by the applicant.

e. All drawings be in English.

15. All applications for barrier classification shall be submitted with a barrier. The barrier will be returned by MSHA upon completion of the investigation.

TABLE 1

CLASS	VOLTS (Output)	CURRENT (Max)	CAPACITANCE (Max)	INDUCTANCE (Max)
A	5V	3A	5 mf	100 uh
B	5V	1A	5 mf	1 mh
C	10V	3A	60 uf	100 uh
D	10V	1A	60 uf	1 mh
E	12V	3A	30 uf	100 uh
F	12V	1A	30 uf	1 mh
G	15V	1.25A	15 uf	300 uh
H	20V	0.7A	7 uf	1 mh
I	20V/10V	0.7A/0.1A	1 uf	800 uh
J	25V	0.3A	3 uf	10 mh
K	30V	0.1A	1 uf	15 mh
L	18V	1.0A	10 uf	1 mh

APPLICATION LETTER
Barrier Classification
for use on
Mine Wide Monitoring Systems

Chief, Approval and Certification Center
Industrial Park Boulevard
RR #1, Box 201B
Triadelphia, West Virginia 26059

COMPANY NAME & ADDRESS
____
Attn: ________________________
____
____

DATE ____________________________
Company Assigned Code No. ____________________

TELEPHONE NO. ______________

GENTLEMEN:

We are requesting an evaluation of a barrier to be used on Mine Wide Monitoring Systems.

BARRIER SPECIFICATIONS

1. Nomenclature ______________________
2. Manufacturer ______________________
3. Part/Model No. ____________________
4. Class Requested ___________________
5. Maximum Output Voltage ____________
6. Maximum Output Current ____________
7. Barrier Input Voltage Rating ______
8. Approval Agency ___________________

FOR MSHA USE ONLY

ELECTRICAL SCHEMATIC OR DRAWING REFERENCE(S):

I ______________________________, ______________________________ attest that
(Original Signature) (Title)

______________________________ will maintain signed inspection records
(Company)

traceable to each unit on which we affix a classification label, to insure that it meets all the safety requirements listed above.

APPLICATION INSTRUCTIONS FOR SENSOR CLASSIFICATION

A. Complete the application for sensor evaluation form (MSHA-16) as follows: (See sample Enclosure No. 2.)

1. Enter the company name and return address in the spaces provided. Include the name of the representative to be contacted if additional information is needed.

2. Enter the telephone number of the company representative, including area code, in the space designated "Telephone Number."

3. Enter the assigned company code number in the space designated "Company Assigned Code No." (Arbitrary six-digit numerical code assigned by the submitting company for company identification purposes.)

4. Enter the date in the space designated "Date."

5. An authorized representative of the company shall sign in the appropriate space labeled "Original Signature." The individual signing the application shall be an authorized representative of the company who can bind the company to the conditions stipulated in the application letter.

6. Enter the manufacturer's descriptive name for the sensor in the space designated "Nomenclature."

7. Enter the name of the company that manufactures the barrier in the space designated "Manufacturer."

8. Enter the manufacturer's assigned model number of the sensor in the space designated "Model No."

9. Enter the sensor classification(s) requested in the space designated "Class Requested." Sensor classification(s) should be consistent with the specifications of the barrier classification(s) to which it will be connected. (See Table 1.)

10. Enter the sum total of all the capacitance (nominal values plus tolerances) contained in the sensor in the space designated "Maximum Total Capacitance." If the sensor has no capacitance, indicate with "N/A" or "None."

11. Enter the sum total of all the inductance (nominal values plus tolerances) contained in the sensor in the space designated "Maximum Total Inductance." If the sensor has no inductance, indicate with "N/A" or "None."

12. Enter the ohmic value of the lowest rated resistor (nominal value less tolerance) of the sensor circuitry in the space designated as "Minimum Resistor Ohmage."

13. Enter the wattage rating of the lowest wattage rated resistor (nominal value less tolerance) of the sensor circuitry in the space designated as "Minimum Resistor Wattage."

14. Enter a brief description of the basic sensor design (i.e., manufacturer's specifications, circuit design, internal components, etc.) in the space designated "Brief Description of Design." If electrical schematic, layout design, or parts lists are necessary, the drawing number(s) shall be referenced under the "Brief Description of Design."

15. The application letter shall be completed by having an authorized representative sign in the space provided for original signature and filling in the title and company name in the appropriate spaces. The individual signing the application shall be an authorized representative of the company who can bind the company to the conditions stipulated in the application letter.

B. Complete the application for Active Chemical/Hot Filament/or MSHA Pre-Accepted Sensor evaluation form (MSHA - 17) as follows: (See sample Enclosure No. 3.)

1. Enter the company name and return address in the spaces provided. Include the name of the representative to be contacted if additional information is needed.

2. Enter the telephone number of the company representative, including area code, in the space designated "Telephone No."

3. Enter the assigned company code number in the space designated "Company Assigned Code No." (Arbitrary six-digit numerical code assigned by the submitting company for company identification purposes.)

4. Enter the date in the space designated "Date."

5. An authorized representative of the company shall sign the appropriate space labeled "Original Signature." The individual signing the application shall be an authorized representative of the company who can bind the company to the conditions stipulated in the application letter.

6. Enter the manufacturer's descriptive name for the sensor in the space designated "Nomenclature."

7. Enter the name of the company that manufactures the sensor in the space designated "Manufacturer."

8. Enter the manufacturer's assigned model number of the sensor in the space designated "Model No."

9. Enter the sensor classification(s) requested in the space designated "Class Requested." Sensor classification(s) should be consistent with the specifications of the barrier classification(s) to which it will be connected. (See Table 1.)

10. Enter the sum total of all the capacitance (nominal values plus tolerances) contained in the sensor in the space designated "Maximum Total Capacitance." If the sensor has no capacitance, indicate with "N/A" or "None."

11. Enter the sum total of all the inductance (nominal values plus tolerances) contained in the sensor in the space designated "Maximum Total Inductance." If the sensor has no inductance, indicate with "N/A" or "None."

12. Enter the ohmic value of the lowest rated resistor (nominal value less tolerance) of the sensor circuitry in the space designated as "Minimum Resistor Ohmage."

13. Enter the wattage rating of the lowest wattage rated resistor (nominal value less tolerance) of the sensor circuitry in the space designated as "Minimum Resistor Wattage."

14. Enter the MSHA assigned investigation number (IA, MM, etc.) where the sensor was previously accepted by MSHA. If the sensor was not previously accepted by MSHA, enter "N/A" or "No" in the space designated previously evaluated.

15. Enter a brief description of the basic sensor design i.e., manufacturer specifications, circuit design, internal components, etc. in the space designated "Brief Description of Design." If the sensor was previously evaluated, explain any modification to the previously evaluated design.

16. The application letter shall be completed by having an authorized representative sign in the space provided for original signature and filling in the title and company name in the appropriate spaces. The individual signing the application shall be an authorized representative of the company who can bind the company to the conditions stipulated in the application letter.

C. The sensor evaluation application letter (MSHA - 16 or MSHA - 17) shall be submitted in duplicate for each type sensor being evaluated. Any drawing being submitted as documentation for the sensor evaluation shall comply with the following:

1. All drawing(s) have a title block, a title, a number assigned, a date, and be legible.

2. Pencil or ink notations not appear on drawings being submitted for documentation.

3. Drawings show the date of the latest revision.

4. All drawings include a note "Do not Change without Approval of MSHA" which is included on all drawings reproduced by the applicant.

5. All drawings be in English.

D. All applications for sensor classification must be submitted with a typical sensor. The sensor will be returned by MSHA upon completion of the investigation.

APPLICATION LETTER
Sensor Classification for use on Mine Wide Monitoring Systems

Chief, Approval and Certfication Center
Industrial Park Boulevard
RR #1, Box 201 B
Triadelphia, West Virginia 26059

COMPANY NAME & ADDRESS

____

Attn: ______________________

____

____

TELEPHONE No. ______________________

DATE: ______________________

Company Assigned Code No. ______________________

GENTLEMEN:

We are requesting an evaluation of a Sensor Assembly to be used on Mine Wide Monitoring Systems.

I ______________________, attest to the following:
(Original Signature)

1. No power source is connected to or within the sensor, except through the MSHA Classified Barrier.
2. Chemical or hot filament components do not exist in this sensor.
3. All motors are brushless type.
4. Light-emitting diodes are the only illuminating devices.

SENSOR SPECIFICATIONS

1. Nomenclature ______________________
2. Manufacturer ______________________
3. Model NO. ______________________
4. Class Requested ______________________
5. Maximum Total Capacitance ______________________
6. Maximum Total Inductance ______________________
7. Minimum Resistor Ohmage ______________________
8. Minimum Resistor Wattage ______________________

FOR MSHA USE ONLY

BRIEF DESCRIPTION OF THE DESIGN: ______________________

____

____

I ______________________, ______________________ attest that
(Original Signature) (Title)

______________________ will maintain signed inspection records trace-
(Company)
able to each unit on which we affix a classification label, to insure that it meets all the safety requirements listed above.

APPLICATION LETTER

Active Chemical/Hot Filament/or MSHA Pre-Accepted Sensor Classification
for use on
Mine Wide Monitoring Systems

COMPANY NAME & ADDRESS

____

ATTN: ______________________

____

____

TELEPHONE No. ______________

Chief, Approval and Certification Center
Industrial Park Boulevard
RR #1, Box 201B
Triadelphia, West Virginia 26059

DATE: ____________________

Company Assigned Code No. ______________________

GENTLEMEN:

We are requesting an evaluation of an Active Chemical/Hot Filament Sensor to be used on Mine Wide Monitoring System.

I ________________________________, attest to the following:
(Original Signature)

1. No power source is connected to or within the sensor, except through the MSHA Classified Barrier.
2. All motors are brushless type.
3. Light-emitting diodes are the only illumination devices.

SENSOR SPECIFICATIONS

1. Nomenclature ____________________
2. Manufacturer ____________________
3. Model Number ____________________
4. Barrier Class Requested ____________________
5. Maximum Total Capacitance ____________________
6. Maximum Total Inductance ____________________
7. Minimum Resistor Ohmage ____________________
8. Minimum Resistor Wattage ____________________
9. Previously Evaluated ____________________

FOR MSHA USE ONLY

BRIEF DESCRIPTION OF THE DESIGN: ____

____

I ________________________________, ______________________________ attest that
(Original Signature) (Title)

________________________________, will maintain signed inspection records trace-
(Company)

able to each unit on which we affix a classification label, to insure that it meets all the safety requirements listed above.

Enclosure No 1

APPLICATION LETTER
Barrier Classification
for use on
Mine Wide Monitoring Systems

Chief, Approval and Certification Center
Industrial Park Boulevard
RR #1, Box 201B
Triadelphia, West Virginia 26059

COMPANY NAME & ADDRESS
DLM Inc.
Attn: Ms. Bonnie Lee
228 Victor Street
Scotch Plains N.J. 07076

TELEPHONE NO. 201-233-6823

DATE 4-22-83
Company Assigned Code No. 000001

GENTLEMEN:

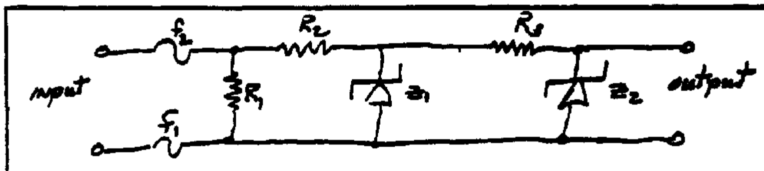
We are requesting an evaluation of a barrier to be used on Mine Wide Monitoring Systems.

BARRIER SPECIFICATIONS

1. Nomeclature IS. BARRIER
2. Manufacturer Stanz Ltd.
3. Part/Model No. 30-6193-001
4. Class Requested D
5. Maximum Output Voltage 10.0 volts
6. Maximum Output Current 945.0 ma.
7. Barrier Input Voltage Rating 400 volts
8. Approval Agency Int. Testing Labs.

FOR MSHA USE ONLY

ELECTRICAL SCHEMATIC OR DRAWING REFERENCE(S):



$f_1 + f_2$ — .945 ma @
R_1 — 50 ohms ½ watt
$R_2 + R_3$ — 100 ohms, ½ watt €
$z_1 + z_2$ — 10 volt, 10 watt, 500 volt Zener, @

I Ms. Bonnie Lee (Original Signature), Vice Pres. Eng. (Title) attest that

DLM Inc. (Company) will maintain signed inspection records

traceable to each unit on which we affix a classification label, to insure that it meets all the safety requirements listed above.

Enclosure No. 2

MSHA-16

163

APPLICATION LETTER
Sensor Classification
for use on
Mine Wide Monitoring Systems

COMPANY NAME & ADDRESS
Wherle Industry
Attn: Ken Wherle
202 Cooks Ave
Scotch Plains, N.J. 07076
TELEPHONE No. 900-579-0477

Chief, Approval and Certfication Center
Industrial Park Boulevard
RR #1, Box 201 B
Triadelphia, West Virginia 26059

DATE: May 28, 1982
Company Assigned Code No. 000471

GENTLEMEN:

We are requesting an evaluation of a Sensor Assembly to be used on Mine Wide Monitoring Systems.

I Ken Wherle, attest to the following:
(Original Signature)

1. No power source is connected to or within the sensor, except through the MSHA Classified Barrier.
2. Chemical or hot filament components do not exist in this sensor.
3. All motors are brushless type.
4. Light-emitting diodes are the only illuminating devices.

SENSOR SPECIFICATIONS

1. Nomenclature Liquid Level Detector
2. Manufacturer Wherle Industry.
3. Model NO. CK-172
4. Class Requested A, B, C
5. Maximum Total Capacitance N/A
6. Maximum Total Inductance N/A
7. Minimum Resistor Ohmage 1,000 ohms
8. Minimum Resistor Wattage 2 watts

FOR MSHA USE ONLY

BRIEF DESCRIPTION OF THE DESIGN: Output signal proportional to center arm of pot and position relative to the common leg. Center arm position adjusted by positive bouyancy float.

I Ken Wherle, Vice Pres. Eng. attest that
(Original Signature) (Title)

Wherle Industry. will maintain signed inspection records trace-
(Company)
able to each unit on which we affix a classification label, to insure that it meets all the safety requirements listed above.

Enclosure No. 3

MSHA-17

APPLICATION LETTER
Active Chemical/Hot Filament/or MSHA Pre-Accepted Sensor Classification
for use on
Mine Wide Monitoring Systems

Chief, Approval and Certification Center
Industrial Park Boulevard
RR #1, Box 201B
Triadelphia, West Virginia 26059

COMPANY NAME & ADDRESS
Leonard Monitoring Inc.
ATTN: Mr. Sam Leonard
1968 East Orange Ave.
Beach Haven West, N.J. 07079
TELEPHONE No. 201-233-6723

DATE: May 29, 1982
Company Assigned Code No. 000055

GENTLEMEN:

We are requesting an evaluation of an Active Chemical/Hot Filament Sensor to be used on Mine Wide Monitoring System.

I Sam Leonard, attest to the following:
(Original Signature)

1. No power source is connected to or within the sensor, except through the MSHA Classified Barrier.
2. All motors are brushless type.
3. Light-emitting diodes are the only illumination devices.

SENSOR SPECIFICATIONS

1. Nomenclature Methane Monitor
2. Manufacturer Finn Inc
3. Model Number Silver Edge-316
4. Barrier Class Requested C
5. Maximum Total Capacitance 45 μF
6. Maximum Total Inductance N/A
7. Minimum Resistor Ohmage 150 ohms
8. Minimum Resistor Wattage 1 watt
9. Previously Evaluated MM-1886

FOR MSHA USE ONLY

BRIEF DESCRIPTION OF THE DESIGN: MM-1886 Design Modified to Allow 2 no 18 wires Tapped off pins M1 + M2 for connection to "C" Barrier.

I Sam Leonard, Vice Pres Sales attest that
(Original Signature) (Title)

Leonard Monitoring Inc, will maintain signed inspection records trace-
(Company)

able to each unit on which we affix a classification label, to insure that it meets all the safety requirements listed above.