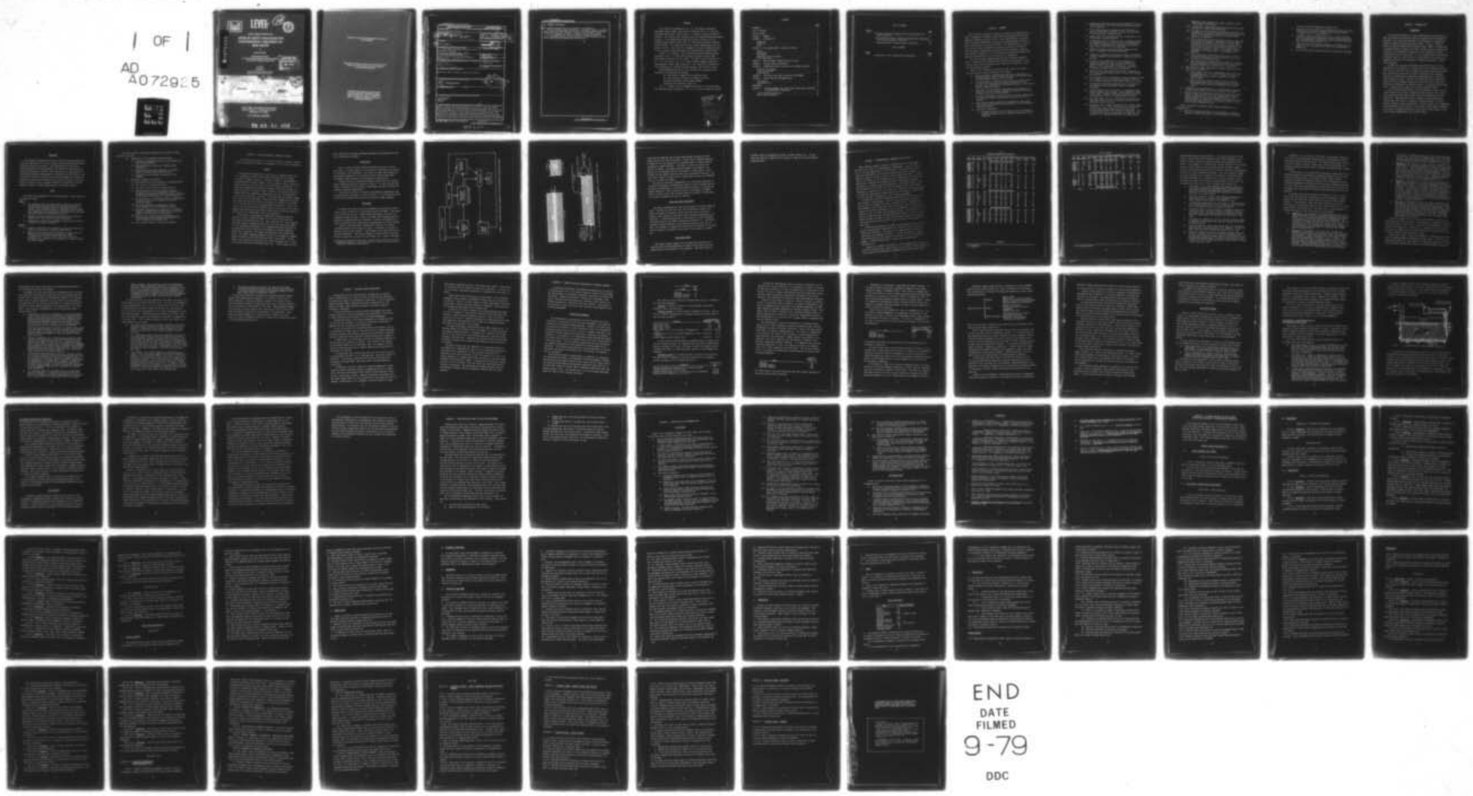
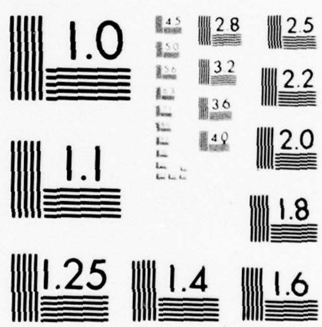
AD-A072 925 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS F/G 8/9
DEVELOP SAFETY PRACTICES FOR ELECTROKINETIC TREATMENT OF MINE W--ETC(U)
JUL 79 C E GREEN H0272005
UNCLASSIFIED WES-MP-GL-79-14 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

MISCELLANEOUS PAPER GL-79-14

DEVELOP SAFETY PRACTICES FOR ELECTROKINETIC TREATMENT OF MINE WASTE

by

Charles E. Green

Geotechnical Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

July 1979

Final Report

Approved For Public Release; Distribution Unlimited

Prepared for Office of the Assistant Director-Mining
Bureau of Mines, U. S. Department of Interior
Washington, D. C. 20241

Under Contract No. H0272005

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Miscellaneous Paper GL-79-14	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): (6) DEVELOP SAFETY PRACTICES FOR ELECTROKINETIC TREATMENT OF MINE WASTE	5. TYPE OF REPORT & PERIOD COVERED: (9) Final report. Oct 76-Jan 79
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): (10) Charles E. Green	8. CONTRACT OR GRANT NUMBER(s): (15) [redacted] H0272005
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U. S. Army Engineer Waterways Experiment Station, Geotechnical Laboratory, P.O. Box 631, Vicksburg, Miss. 39180	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: Office of the Assistant Director-Mining, Bureau of Mines, U. S. Department of Interior, Washington, D. C. 20241	12. REPORT DATE: (11) July 1979
	13. NUMBER OF PAGES: 72
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): (12) 77 p.	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

(14) WES-MP-GL-79-14

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electrokinetics
Mine wastes
Safety

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study was conducted to identify, evaluate, and develop procedures to minimize or eliminate safety hazards associated with the electrokinetic dewatering process, such as toxic and volatile gas emissions, electrical shock, accidental detonation of explosives, electrochemical corrosion of metal appurtenances, and possibly others. The identification, evaluation, and procedure development were based on pertinent literature, existing safety regulations, interviews with mine personnel, physical and mechanical properties of the electrokinetic dewatering process, (Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

038 100 alt

20. ABSTRACT (Continued).

and physical characteristics of the material to be dewatered.

The electrokinetic dewatering process is described in detail. Potential safety hazards are identified and evaluated. Procedures and/or safety regulations were developed to minimize or eliminate the potential hazards.

It is recommended that the electrokinetic dewatering process, when used in deep metal mines, be properly monitored to obtain additional information on other potential hazards that possibly exist.

FOREWORD

This report was prepared by the U. S. Army Engineer Waterways Experiment Station (WES), Geotechnical Laboratory (GL), P. O. Box 631, Vicksburg, Mississippi 39180, under U. S. Bureau of Mines Contract No. H0272005. The contract was initiated under the Advanced Mining Technology Program. It was administered under the technical direction of the Spokane Mining Research Center with Mr. Dick Sprute acting as Technical Project Officer. Mr. Monte Camp was the contract administrator for the Bureau of Mines. This report is a summary of the work completed as part of this contract during the period from October 1976 to January 1979.

Messrs. W. G. Shockley, Chief, Mobility and Environmental Systems Laboratory, and E. S. Rush, Chief, Mobility Systems Division (MSD), were general supervisors of the study. The MSD is now a division of GL, Mr. J. P. Sale, Chief. Mr. C. E. Green, Research Engineer, Mobility Investigations Branch, MSD, directed it. Mr. Green also conducted the field observations, directed the data analysis, and wrote the report.

Acknowledgements are made to the following for cooperation and assistance in conducting the program:

Mr. Dick Sprute, Spokane Mining Research Center

Dr. Dennis Kelsh, Professor at Gonzaga University

Star Mine Personnel, Hecla Mining Company

Henderson Mine Personnel, Amax, Inc.

COL J. L. Cannon, CE, was Commander and Director of the WES during the study and report preparation. Mr. F. R. Brown was Technical Director.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: SUMMARY

This study was conducted to identify, evaluate, and develop procedures to minimize or eliminate safety hazards associated with the electrokinetic dewatering process, such as toxic gas emissions, electrical shock, accidental detonation of explosives, electrochemical corrosion of metal appurtenances, and possibly others. The identification, evaluation, and procedure development were based on pertinent literature, existing safety regulations, interviews with mine personnel, physical and mechanical properties of the electrokinetic dewatering process, and physical characteristics of the material to be dewatered.

The electrokinetic dewatering process was described in general terms. Potential safety hazards were identified and evaluated. Procedures and/or safety regulations were developed to minimize or eliminate the potential hazards.

Based on the information obtained for this study, the following conclusions and/or safety regulations were drawn:

a. The electrokinetic dewatering process can be used safely in underground metal mines, provided pertinent existing and newly developed safety regulations are followed.

b. A limited number of laboratory tests shall be conducted prior to field use to determine the physical properties of the material to be dewatered and the expected results of the electrokinetic dewatering process.

c. The effect of electrokinetic dewatering can be enhanced by agitation, periodic current reversal, intermittent current application, and electrode arrangement.

d. The basic philosophy of miners is that the present safety regulations are as good as they possibly could be and still be feasible.

e. Most existing safety regulations pertaining to electricity, ventilation, and explosives should apply to the electrokinetic dewatering process.

f. New safety regulations:

   (1) Personnel working in the vicinity of the electrokinetic dewatering process shall be completely familiar with its operation.

(2) Smoking and open flames shall not be permitted in the immediate area where the electrokinetic dewatering process is in operation.

(3) Signs warning against smoking and open flame shall be posted so that they can readily be seen in areas around the electrokinetic dewatering area.

(4) Danger signs shall be posted around the perimeter of the electrokinetic dewatering area.

(5) An adequate volume of fresh air shall be supplied around the dewatering area to ensure that the concentration of any airborne contaminant does not exceed the threshold limit value listed for that contaminant.

(6) Whenever possible, the electrokinetic dewatering area shall be segregated from other operations.

(7) Combustible (hydrogen) gas indicators shall be installed wherever hazardous concentrations of combustibles may be present.

(8) Periodic visual inspections of the electrodes and electrical connectors shall be made to determine whether corrosion has taken place and if so to what extent. If the electrodes or electrical connectors are highly corroded, they shall be replaced.

(9) Fuses or other overcurrent devices shall be required in the output of power supplies ahead of the cables serving the electrodes.

(10) The rectifiers shall be connected to the alternating current (a-c) supply with a two-winding transformer to provide full isolation between a-c and direct current (d-c) sides.

(11) Electrokinetic dewatering systems shall be designed for the lowest voltage requirement needed for adequate dewatering.

(12) Treatment depths shall be limited to a manageable amount and/or treatment time extended. Where depths are necessarily large, treatment with layered electrodes shall be considered as a means of limiting potential levels.

(13) The area (stope, pit, etc.) in which the dewatering will take place shall be free of extraneous metals such as scrap cable, bars, and pipe.

(14) Rectifiers shall contain a requirement for ground current indicators, i.e., a high resistance device between both positive and negative leads and earth ground that activates with current flow (usually a neon lamp). Thus, if containment walls are conducting, the lamps will illuminate. An illuminated lamp would not mean that the

system is unduly hazardous but that a conductor exists from sludge to earth ground.

(15) A space must be maintained between electrodes and containment walls to reduce stray potentials.

(16) An expert in the electrokinetic dewatering procedure shall determine the location and spacing of the electrodes to be used. The selected spacing shall be verified during operation for adequacy.

(17) For a repetitively used installation, such as a sump, the area should be completely isolated and a safety relay installed on each entrance to the area. The relay shall be designed so that once the entrance is opened the current to the electrodes is shut off and manual reset of the relay is required. However, for a stope, a gate or barricade (with warning sign) in the manway raise is adequate.

(18) The electrokinetic dewatering process shall be discontinued when loading and blasting operations are in the vicinity of the dewatering area.

(19) The electrokinetic dewatering process shall be continued until the material has dried below its saturation point, thereby eliminating the possibility of liquefaction.

g. Mine Health and Safety Adminstration (MHSA) regulations that users should be aware of:

(1) Power supply outputs for electrokinetic application must be ungrounded, i.e., the electric output (DC) shall be floating with neither polarity connected to system (earth) ground.

(2) Control circuitry shall include a relay to interrupt power output, with lockout and manual reset provisions, if current between ground and equipment frame exceeds 5 amp.

h. Conditions are not precipitated in the electrokinetic process whereby the probability of serious accidents is increased.

i. The electrokinetic dewatering process can increase mining efficiency, in many cases ensure a safe working surface for the miners, reduce the size of the area required for surface tailings-ponds, and increase the amount of tailings that can be stowed underground; therefore, its ecological impact is positive for the environment and man.

Based on the above conclusions and/or safety regulations, it is recommended that:

a. When used in deep metal mines, the electrokinetic dewatering process be properly monitored to obtain additional information on other potential hazards that possibly exist.

b. Laboratory tests to determine gas emissions and other pertinent properties be conducted on material from any metal mines contemplating use of electrokinetics.

c. A computer model be prepared that could be used to determine electrode spacing and configuration, rate of dewatering, possible gas emissions, conductivity in and around the dewatering area, corrosion possibilities, etc.

d. Laboratory and field tests be conducted to determine the procedure to use for optimizing the effects of electrokinetic dewatering.

e. The newly developed safety regulations be adopted by the MSHA.

CHAPTER 2: INTRODUCTION

Background

In the mining industry it is well established that the disposal of waste by-products has presented difficult engineering and environmental problems. One of the major problems is the dewatering of tremendous volumes of material having high water content. The U. S. Bureau of Mines, through the Spokane Mining Research Center (SMRC), is addressing a research program to develop the widest possible choice of technically satisfactory, environmentally compatible, and economically feasible disposal practices for mine waste. It has concluded that the dewatering techniques that will achieve effective consolidation will produce the greatest dividends in the operation of disposal areas used to confine waste materials.

The SMRC has conducted considerable laboratory and pilot field experiments in electrokinetic consolidation of mill tailings processed from zinc and lead mines and on sludges from other industrial processes. Mill tailings are often used to backfill underground mine openings. Tailings are hydraulically transported underground with a relatively large quantity of water. Then the contained water must be removed to improve structural support capabilities and provide a firm base upon which men and equipment can effectively work in subsequent mining operations. Dewatering also reduces the volume of material stored.

During hydraulic backfilling, the electrokinetic process, and prolonged storage of tailings in underground mine openings after processing, certain potential safety hazards that need evaluation have been identified. These hazards include: dangerously high pressures occurring with liquefaction of dewatered slimes subsequent to electrokinetic treatment, toxic gas emissions, electrical shock in the immediate processing area, electric shock in other areas through highly conductive rock veins, accidental detonation of explosives, electrochemical corrosion of metal appurtenances, and possibly others.

Objective

Electrokinetic dewatering of wet soil and soil wastes basically involves the application of a direct current electrical potential between electrodes inserted into media. While laboratory and field tests clearly establish that electrokinetics is effective in dewatering and consolidating hydraulic backfill, they also point out the necessity of identifying potential safety hazards. Therefore, the objectives of this study were to identify, evaluate, and develop procedures to minimize or eliminate potential safety hazards such as toxic and volatile gas emissions, electrical shock, accidental detonation of explosives, electrochemical corrosion of metal appurtenances, and possibly others.

Scope

Two tasks were accomplished in this study program. These tasks are described as follows:

Task I:

a. An information base was established by reviewing literature and consulting with personnel from the mining industry to identify and investigate sources of potential hazardous conditions. This review included the compilation of the various soil compositions encountered and of the dewatering techniques developed during the electrokinetic process.

b. Federal, state, and industrial procedures were reviewed and tabulated to codify pertinent safety regulations.

c. Limited mine surveys were performed to determine the degree of awareness of existing regulations.

Task II:

a. Hazardous conditions were evaluated by using illustrative portrayals and qualitative technical dissertations.

b. Experts in mine safety and electrokinetic processes were interviewed to obtain detailed site-specific safety recommendations. Based on these interviews, plans and procedures were formulated and recommended to minimize health and safety hazards.

The study functions required to accomplish these tasks are summarized as follows:

<u>a</u>. Compilation of an information base containing:

(1) A review of laboratory and field electrokinetic dewatering applications;

(2) Pertinent Federal, state, and industry safety regulations;

(3) Interviews with industry personnel on existing safety philosophies and conditions; and

(4) A review of the historical literature of the industry.

<u>b</u>. Evaluation of data to ascertain:

(1) The characteristics and quantities of emitted gases;

(2) The toxicity of the gas emissions;

(3) Gas ignition and detonation characteristics;

(4) Possible areas of corrosion, either caused by electrolysis or by electromechanical reactions to equipment and facilities, that could cause a situation to deteriorate from a safe to an unsafe condition;

(5) The possibility of sustaining a fatal or debilitating electrical shock due to extraneous electrical conductive paths;

(6) Accidental detonation of explosives from d-c fields related to the electrokinetic process;

(7) Subsequent saturation and liquefaction of dewatered slimes (or unclassified tailings) and the potential hazards associated with use as backfill;

(8) Whether or not conditions are precipated in the electrokinetic process whereby the probability of serious accidents is increased; and

(9) The ecological impact to man and environment.

CHAPTER 3: THE ELECTROKINETIC DEWATERING PROCESS

A generalized description of the electrokinetic dewatering process along with appropriate figures is presented in the following paragraphs.

Theory

Electrokinetic dewatering is the process of removing water from soil by means of a direct current passed through the soil between electrodes inserted in the soil. Electric current is the movement of charged particles through a medium (such as copper or water) caused by a "force" pushing or pulling them along a path through the medium. If a negatively charged and a positively charged electrode are placed in a medium separated by a given distance, because of the physical nature of charged particles, negatively charged particles will be attracted (or pulled) to the positive electrode. At the same time, positively charged particles will be pushed away. These positively charged particles that are forced away from the positive electrode are attracted to the negative electrode, which is forcing away negative particles. Thus a current is set up with particles migrating from one electrode to the other. Negative particles are usually free electrons and the positive particles are positive ions (atoms which have lost electrons).

In the case of electrokinetic dewatering, the medium that the electric current is passed through is a soil mass and the positive particles are dissolved metal ions. Thus, when the pull of the negative electrode becomes stronger than the pull of the soil particles around it, the ion migrates through the soil dragging water molecules with it. The drag force can be controlled by changing the voltage difference between the electrodes. The bigger the difference, the stronger the force. The current generated depends directly on the number of charged particles present in the medium that are free to move about. As the number of free particles goes down, the current decreases until it goes to zero when relatively few particles are left. If the current is to be kept constant, the voltage differences between the electrodes will have to be continually increased.

Description

Prior to using the electrokinetic dewatering process on a full-scale basis, a limited number of electrokinetic dewatering tests should be conducted in the laboratory. The results of these tests along with the physical properties of the material should indicate what power requirements and procedure to use during field applications.

A typical one-line diagram (flow-chart) required for the electrokinetic dewatering process is shown in Figure 1. It must be noted that Figure 1 presents only the specific requirements and may be altered depending on specific applications.

Cross-sectional views of a typical electrokinetic dewatering setup using horizontal electrodes is shown in Figure 2. It must be noted that if vertical electrodes were used, the setup would change somewhat.

Electrodes

At present two basic electrode arrangements have been used effectively, either vertically or horizontally placed electrodes. The number of electrodes may vary for a given situation; however, the basic arrangement remains the same. Tests at the SMRC (1)* indicated that the horizontal configurations are preferable to vertical configurations in terms of fabrication and installation and generally give better results.

Basically, the horizontal configuration consists of a cathode (bottom electrode) and at least one anode. A perforated iron pipe is generally used for the cathode. (Other metals can be used, but iron is the most economical.) The pipe is wrapped in burlap cloth so that the water can enter the pipe and the fines (sands, etc.) cannot. The water

---

* Underlined numbers in parentheses refer to items in the list of references at the end of this report.

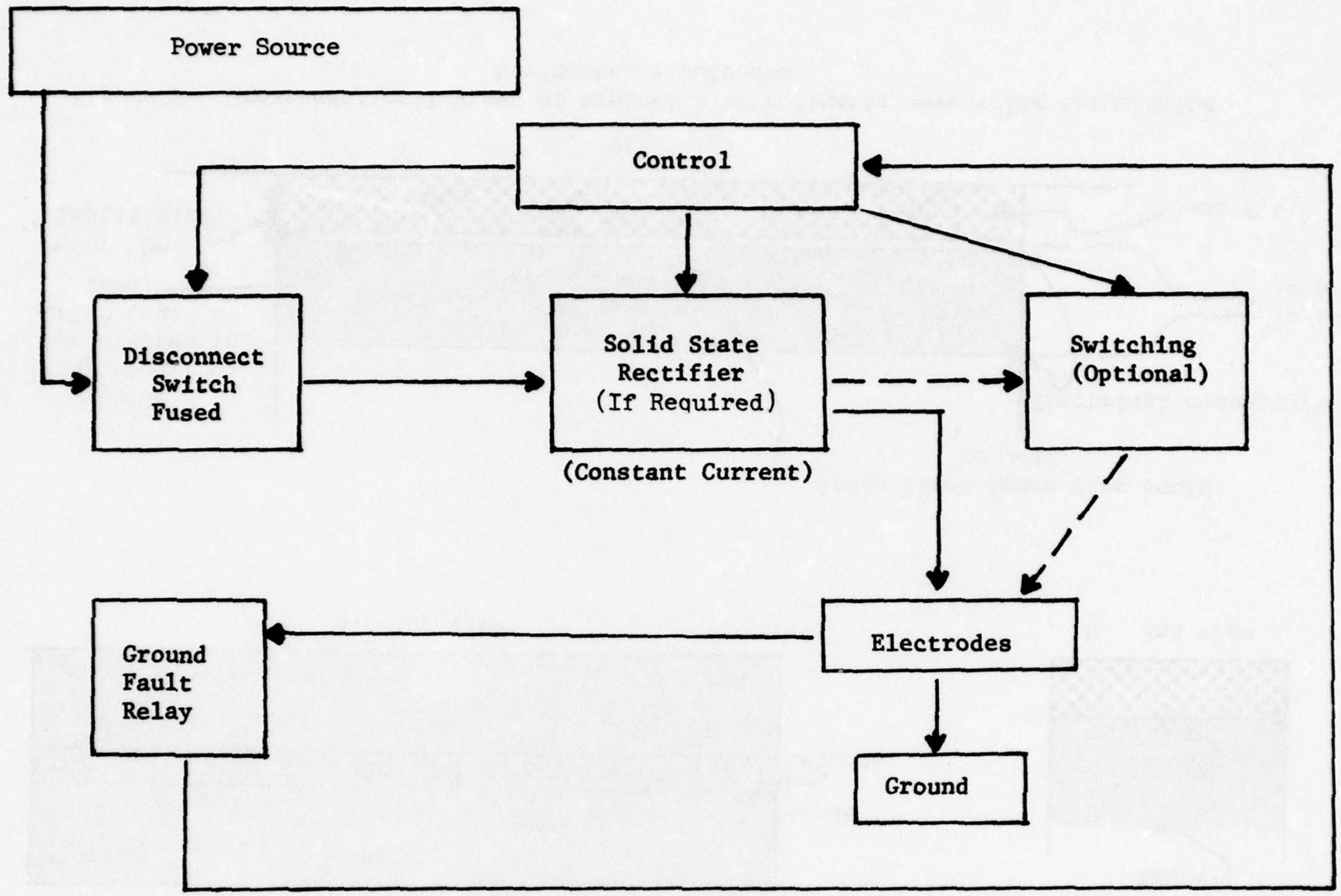


Figure 1. One-line electrical diagram for the electrokinetic dewatering process

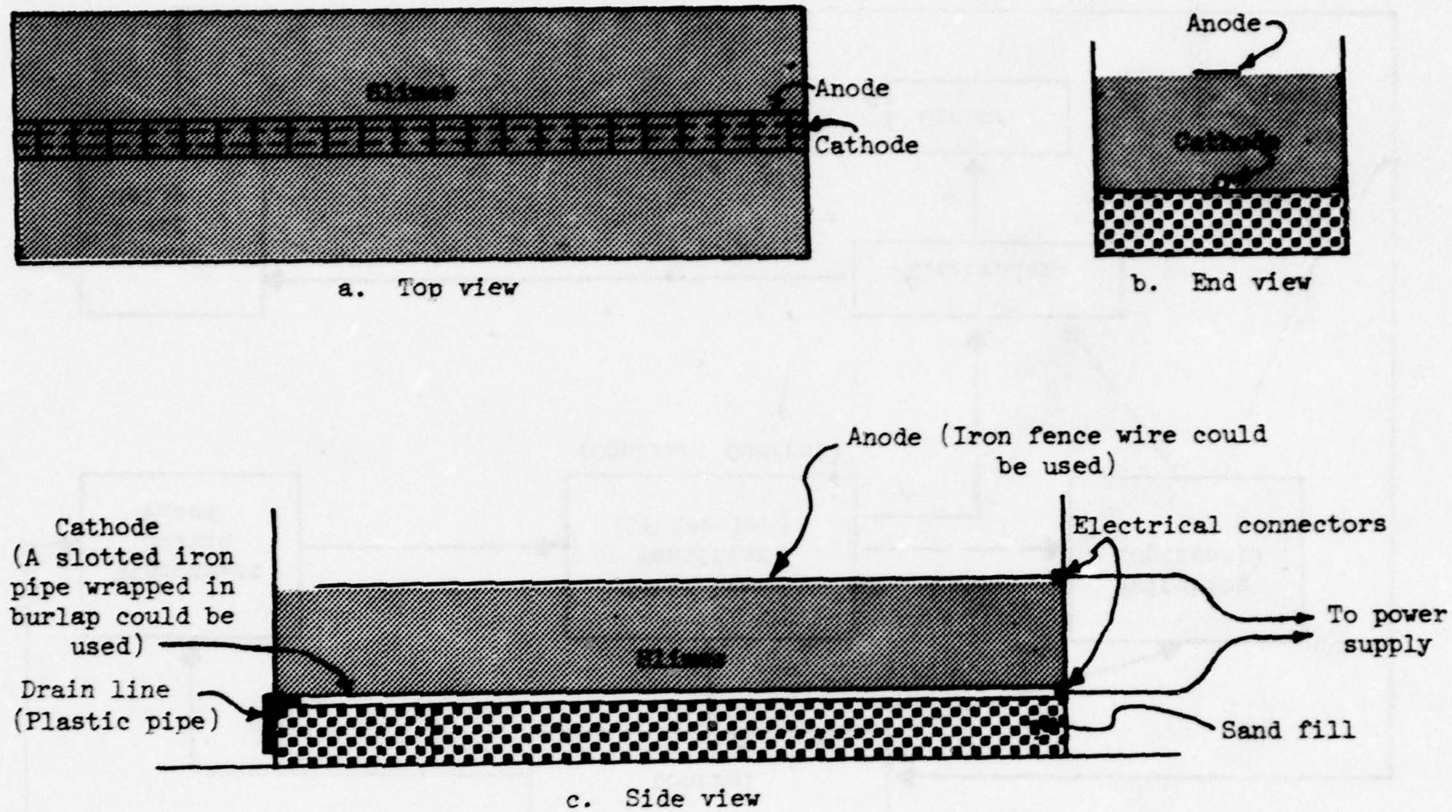


Figure 2. Cross-sectional views of typical electrokinetic dewatering setup using horizontal electrodes

flows from the material into the pipe and through the pipe to a discharge point at one end of the pipe. A short piece of plastic pipe can be added to the iron cathode at the discharge point to reduce electric potential on exposed material. The anode or anodes can be any of a variety of things. The number required depends on the depth of the material to be dewatered and how the material is being placed. Reinforcing rod and hogwire both have been used successfully as anodes. The fence wire is easy to install but is usually good for only one treatment since it is anodic and erodes.

The vertical electrode configuration is a little more difficult to use than the horizontal configuration; however it may be better than the horizontal configuration in situations where the walls of a section are highly conductive. When using the vertical or horizontal configurations, it must be noted that as water enters the cathode, it might have to be drawn off against the force of gravity.

Power and Control Equipment

The power requirements for this process depend on specific applications. The SMRC (2) used 480 volts, 60 Hz alternating current (AC), which was changed into direct current (DC) with static rectifiers; however, motor generator units may be more convenient depending on the situation. A detailed description of the power and control equipment used successfully by the SMRC is presented in Reference 2. The control equipment required depends on the dewatering procedure that will be used. For example, no repeat-cycle timer would be required if the power was not going to be switched from one pair of electrodes to another, etc.

Power Application

The amount of power applied and its application procedure for effective and efficient dewatering is based on the results from laboratory tests on the material to be dewatered. This may consist of constant current, intermittent current, current reversal, etc. In any case, the current is applied for as long as it takes to reach the desired dewatered state.

CHAPTER 4: ELECTROKINETIC DEWATERING APPLICATIONS

Many technical reports, articles, dissertations, etc., have been written on the subject of electrokinetic dewatering. To get an indication of the many applications of the process, of the various soil compositions encountered, and of possible associated health and safety hazards, a detailed review of much of this literature was made. In most cases, the authors did not present sufficient information to compile the various soil compositions encountered, and the dewatering techniques developed, or to mention any associated health and safety hazards. The major exceptions to this are the technical papers written by the SMRC. Therefore, a compilation of the various soil compositions encountered and of dewatering techniques developed during the electrokinetic dewatering tests at the SMRC is presented in the following paragraphs.

The SMRC has conducted considerable laboratory and field tests in electrokinetic consolidation of mill tailings processed from various mines as well as sludges from other industrial waste. Although the electrokinetic process has been used successfully outside the mining industry on various fine-grained soils, the compilation presented herein pertains to mill tailings from underground mines. The compilation is limited to SMRC work that has been published; however, it must be noted that at present the SMRC is conducting laboratory analysis on samples from other mines and the results of these tests will be published at a later date.

As previously mentioned, the SMRC has extensively tested electrokinetic consolidation of metal-mine mill tailings under a variety of laboratory conditions. The various soil compositions encountered in these tests are presented in Table 1. A brief description of these tests along with the test results is presented in the following paragraphs. A detailed description of these tests is presented in References 1-4.

Reference 3 presents the results of tests obtained with unclassified mill tailings from a single mine in Coeur d'Alene, Idaho, mining district along with electrokinetic equipment and procedures developed to

Table 1

Compilation of Soil Compositions Encountered

Test Number	Type Tests	Type Material	Iron Fe	Aluminum Al	Silicon Si	Lead Pb	Zinc Zn	Sulphur S	Manganese Mn	Magnesium Mg	Calcium Ca
			Material Composition, %								
			Bunker Hill Mine Tailings (Reference 4)								
70-98A	Lab	UC*	6.75	3.36	34.50	0.22	0.16	1.57	0.00	0.00	0.00
70-98B											
70-98C											
70-98D											
70-99A		C**	6.90	2.67	35.90	0.23	0.12				
70-99B											
70-99C											
70-99D											
			Galena Mine Tailings (Reference 4)								
70-97A	Lab	UC	22.40	7.13	18.40	0.00	0.00	0.86	0.00	0.00	0.00
70-97B											
70-97C											
70-97D											
71-03A		Slimes	20.50	3.61	17.00			0.83			
71-03B											
71-03C											
71-03D											
71-04A		C	23.00	1.34	16.90			0.96			
71-04B											
71-04C											
71-04D											
			Lucky Friday Mine Tailings (Reference 4)								
71-16A	Lab	UC	8.80	3.00	32.50	0.30	0.15	0.25	0.50	0.00	0.00
71-16B											
71-16C											
71-16D											
71-01A		Slimes	9.43	6.59	26.90	0.53	0.24	0.45	0.00		
71-01B											
71-01C											
71-01D											
71-06A		C	10.10	2.63	31.10	0.40	0.14	0.37			
71-06B											
71-06C											
71-06D											
			Star Mine Tailings (Reference 4)								
70-91A	Lab	UC	7.02	3.32	32.80	0.65	0.33	0.73	0.00	0.00	0.00
70-91B											
70-91C											
70-91D											
71-08A		Slimes	8.45	5.59	28.30	0.47	0.24	0.45			
71-08B											
71-08C											
71-08D											
71-07A		C	7.91	2.82	32.7	0.70	0.22	0.51			
71-07B											
71-07C											
71-07D											

(Continued)

* UC = Unclassified.

** C = Classified.

Table 1 (Concluded)

Test Number	Type Tests	Type Material	Material Composition, % Iron Fe	Aluminum Al	Silicon Si	Lead Pb	Zinc Zn	Sulphur S	Manganese Mn	Magnesium Mg	Calcium Ca
			Sunshine Mine Tailings (Reference 4)								
71-10A	Lab	Slimes	20.00	3.39	19.10	0.00	0.00	0.58	0.00	0.00	0.00
71-10B											
71-10C											
71-10D											
71-09A		C	20.60	1.89	20.10			0.41			
71-09B											
71-09C											
71-09D											
			A Coeur d'Alene, Idaho Mine Tailings Reference 1)								
1	LCM*	UC	8.04	3.60	32.49	0.33	0.16	0.00	0.87	1.08	0.03
2			8.30	3.54	31.74	0.36	0.25		0.87	1.10	0.03
3			7.18	2.33	31.56	0.28	0.19		0.35	1.22	0.04
4			7.05	2.01	32.40	0.25	0.20		1.88	0.02	0.74
5			8.61	3.03	32.38	0.40	0.25		0.87	1.21	0.03
70-10A	Lab		9.00	2.10	32.90	0.42	0.00		0.77	0.27	0.00
70-10B											
70-10C											
74-05			8.14	3.07	30.85	0.00	0.24	0.25	0.68	1.17	
74-07			20.62	2.65	20.00	0.00	0.02	0.01	1.79	1.22	
			Star Mine Tailings (Reference 2)								
1	Field	C	7.25	0.37	64.10	0.48	1.03	0.00	0.65	0.55	0.92

* LCM = Large concrete model.

optimize dewatering and densification. In initial planning for these tests, it was obvious that electrical power could be applied to mill tailings under a variety of conditions, some more advantageous than others. Some examples of variables were current density in the tailings slurry, current density at the electrode surface, periodic current reversal, intermittent application of potential, electrode configurations, and tailings slurry placement procedures. Due to the extensive number of tests conducted, only a summary of the results is presented herein. The simple application of continuous DC to electrodes placed in mill tailings will improve dewatering and densification, but the effect can be enhanced by some or all of the following modifications (3):

a. "Agitation of fill after dewatering is partially completed will greatly increase the ultimate amount of dewatering and densification while decreasing power consumption and time. Mechanical vibration also improved dewatering and densification, but to a lesser extent.

b. "Periodic reversal of current flow improves dewatering and densification and can reduce power consumption if the proper frequency and duration of reversal are used.

c. "Intermittent application of dc can result in improved dewatering and densification with little increase in time (if any), plus a significant reduction in power consumption.

d. "Slurries, having low water content at placement, dewater and consolidate best. Allowing tailings to dewater by natural percolation before applying dc improves dewatering and densification, saves power, and requires little additional total time.

e. "Placement and dewatering slurry in relatively shallow layers, as opposed to large bulk pours, improves ultimate dewatering and densification.

f. "Lead cathodes give better results than does iron but may be practical only if recovery after use is feasible. No improvements were noted when aluminum was substituted for iron.

g. "Either horizontal or vertical electrode placement gives good results. In either case, it is critically important that the drainage electrode (cathode) filters fine particles without blocking the drainage path. The water, once attracted to the cathode, must have a resistance-free flow path from the cathode to the collection drain."

Reference 4 is a follow-on of Reference 3 and presents laboratory test results in electrokinetic dewatering and consolidation of metal-mine mill tailings from five mines in the Coeur d'Alene, Idaho, district. Classified (coarse) tailings, slimes, and unclassified material were placed in plexiglass models, and d-c potential was applied until dewatering ceased.

In this report, it is shown that electrokinetic consolidation is an effective method for densifying and dewatering hydraulic mill tailings from five different mines in the Coeur d'Alene, Idaho, district. Although the method was generally effective for all materials studied, unclassified materials responded better than either classified tailings or slime. Flow rates were generally high during the first few hours of d-c application and dropped off abruptly when dewatering was 95 percent complete.

To validate the results presented in References 3 and 4, limited field tests and additional laboratory tests were conducted on unclassified tailing slurry from a metal mine in the Coeur d'Alene, Idaho, district. Five different field tests were conducted in 18-cu-yd (13.76-cu-m) concrete model stopes, 18-ft (5.49-m) long by 6-ft (1.83-m) deep by 56-in. (1422.2-mm) wide. Note that four to six truckloads of slurry were required to fill the stope for test purposes.

a. Test No. 1. The objectives of this two-phase test were (1) to assess the extent to which unclassified tailings would dewater alone, and (2) to measure the additional dewatering and densification that could be achieved with electrokinetics. Two horizontal electrodes were used for 116 hr, and DC was applied in the mode of 15 min on and 15 min off per 30-min cycle. Although most of the electrokinetic dewatering was complete in 48 hr, dewatering was continued at a slow but quite steady rate for the next 60 hr.

b. Test No. 2. The purpose of this test was to measure the effect of electrokinetics when applied to each load during the filling process. Power was applied only after each load had been allowed to dewater naturally for 20 hr or longer. Thus, the first treatment was on a single load, the second on two loads--a load of naturally dewatered material and a load of electrokinetically dewatered material, etc.--for four loads of tailings. Intermittent power was applied for a period of 3 to 5 hr to each of the first three loads, after first allowing the material to dewater naturally and then lightly agitating the top 3 in. (76.2 mm) with a garden rake. After the final load was placed and drained, power was applied for four days although dewatering was essentially complete after two days.

c. Test No. 3. The objective of this test was to evaluate the effectiveness of reversing current flow for a portion of each 30-min cycle. Power was applied with reversal for nearly five days (115 hr). During each 30-min cycle, current flowed in the forward direction (bottom electrode negative) for 20 min, was off for 1 min, flowed in the reverse direction for 8-1/2 min, and finally was off for 1/2 min. Except for unmonitored changes that may have occurred below the surface, benefits were small for power and time expended after 48 hr.

d. Test No. 4. The objective of this test was to evaluate and compare the performance of a vertical electrode system with other systems tested. The electrode arrangement for this test consists of 5 cathodes in the center and 14 anodes around the periphery. Electrokinetic treatment was applied after the third load and after the fifth load. Current was applied for 21 hr with current reversal 5 min during every 30-min period. At the termination of this test, water was still flowing; however, due to the unexpected slow dewatering and high power consumption, perhaps this test was not fully representative of vertical electrode performance.

e. Test No. 5. The purpose of this test was to demonstrate and evaluate the procedure of dividing the total fill in a stope into regions with the electrodes establishing boundary lines, thus permitting individual electrokinetic application to each zone for a selected portion of each 30-min cycle at different current densities, if desired. Two zones were established using three horizontal electrodes in this test. All power cycles were 30 min long, but various modes of applying power were used during this test.

After the completion of the previously described field tests some additional tests were conducted in the laboratory to determine if small-scale test results could be used to predict the effectiveness of electrokinetics when applied on a larger scale. Comparison of the laboratory tests and the larger scale test data indicate that laboratory tests can be used to predict field application results.

Additional laboratory tests were conducted on unclassified tailings from two additional mines, designated as mines A and B. The results of these tests showed that water content is an important property of unclassified tailings slurries, and although no detailed attempt to optimize concentrations was made, best results were obtained with slurries of 30:70 water-solids content (by weight).

In summary, the five large-scale tests performed on mill tailings have shown that electrokinetic dewatering can be an effective and economical means of densifying and consolidating hydraulic mill tailings. Results were in general agreement with the earlier tests performed in the laboratory (4) and confirm the desirability of making preliminary laboratory studies before attempting a field application of the technique. The following recommendations (4) concerning application to mining practice are:

a. "Horizontal electrodes are preferable to vertical configurations in terms of ease of fabrication and installation and, based on data reported here, give generally superior results. Subsequent mucking operations would not be hindered by the easily removed horizontal anodes near the surface of the densified fill, whereas the stubs of the vertical cathodes extending above the fill surface would be troublesome.

   "Vertical electrodes may be superior in situations where stope walls are highly conductive and the relatively slow drainage and high power cost reported in test 4 could certainly be improved by wrapping cathodes with only one layer of burlap rather than two.

b. "Particle segregation can be significantly reduced by using slurries of unclassified tailings with relatively low water content (for example 70 wt-pct solids). Such slurries are easy to pump, are most responsive to electrokinetic treatment, and by requiring less water, reduce the pumping and dewatering requirements per unit volume of densified fill. Every effort should be made to reduce water content to this level before lacing unclassified tailings underground.

c. "Intermittent power application (that is, 15 min on, 15 min off) can be an effective method of reducing resistivity build-up in cathode areas and is, therefore, an effective way of utilizing power. Two stopes could be dewatered simultaneously by intermittent dc, and this may be important if particular time periods must be used for electrokinetic application. Periodic current reversal can allow electrokinetic dewatering to proceed somewhat faster but at the expense of increased power consumption.

d. "In situations where fill placement results in significant particle segregation, a three-electrode system can be effectively utilized to concentrate electrokinentic application to the region where it is most needed; that is, the upper layer of slimes. This technique can also be advantageous when fast surface hardening is desired. Power can be restricted to the lower region after surface hardening is complete. The flexibility offered by this configuration, and the dewatering and densification achieved at modest power consumption in test 5, suggest that a horizontal arrangement of the three electrodes may be optimum in most backfill applications."

A full-scale field test was conducted by the SMRC at the Star mine, Burke, Idaho, at the 2000-ft (609.6-m) level. The test was performed in a stope approximately 3-1/2 ft (1.07 m) wide by 80 ft (24.38 m) long. A three-horizontal electrode system was selected for test purposes. This test showed that electrokinetics can be used underground in a safe and efficient manner. Dewatering and densification of settled slimes can be accomplished quickly and economically with modest consumption of electrical power. Test procedure changes (4) that could improve cost-effectiveness are as follows:

a. "The cathode drain pipe was probably extraneous, since water percolated rapidly through the coarse sand of the previous sandfill. Consequently, less expensive hogwire (or scrap metal) could have been used as cathode material instead of the pipe.

b. "If cribbing and sandwall were made watertight, or nearly so, and high enough to allow retention of sand and water while still permitting placement of enough fill in one pour, slimes would settle out near the sandwall, leaving coarse material at the other end of the stope. Electrokinetic treatment would then be required only for the settled slimes, since the coarse tailings drain well naturally. Consequently, much less effort and material would be required to utilize this technique in the stope.

c. "With sandwall and cribbing prepared as indicated in paragraph b., and a horizontal sandfill line with discharge ports similar to the installation used in this test, it should be possible to achieve a fairly uniform layer of slimes over the entire stope surface. If such were the case, electrokinetic treatment could be confined to the top 10 to 16 in. thereby reducing installation and energy costs. In addition, such an arrangement would permit placement of material with a greater fraction of slimes; for example, tailings directly out of the mill circuit with slimes added from a holding area.

d. "The electrode placed just below the slimes layer (middle electrode in this test) could be used for the bottom electrode in electrokinetically treating the subsequent sandfill placement, again reducing installation costs."

As previously mentioned, the SMRC has an ongoing research program dealing with electrokinetic dewatering. At present a field test is being conducted at a mine near Empire, Colorado. The results of this test along with the results of many laboratory tests on various materials are not available for publication at this time. Some procedural changes could come as a result of these tests, such as the "do's" and "do nots" given the physical properties of the material to be dewatered. Since these procedural changes will be published by the SMRC in the near future, it would be somewhat fruitless to discuss the procedures developed in the previously discussed test.

CHAPTER 5: EXISTING SAFETY REGULATIONS

Although there are no existing safety regulations for electrokinetic dewatering per se, there are some for other mining operations that would also apply to electrokinetic dewatering. A list of pertinent existing Federal safety regulations and state regulations for five states (Colorado, Idaho, Montana, New Mexico, and Utah) (5-10) are presented in Appendix A.

To get an indication of existing safety philosophies and conditions, personnel in the mining industry were interviewed. The results of these interviews are presented in the following paragraphs.

Underground mining is universally regarded as a hazardous occupation and has many problems. In nearly all operations underground, dampness and wet surroundings are encountered.

To get an indication of underground working environments, some of the problems that might occur are discussed in the following paragraphs. Drilling, blasting, dry mucking, loading and unloading cars, timbering, and ore crushing are dusty operations necessitating control measures.

In metal mines, the metals may constitute an exposure problem as in mining lead, zinc, arsenic, or mercury. The toxicity of the various ores generally depends on the absorption rate. For example, sulfide ores of lead and mercury are not readily absorbed and therefore have a relatively low toxicity.

In mining lead, zinc, and mercury ores, the silica mixed with the ore may exceed 90 percent of the mined material. Rigid dust control is indicated: wet drilling, wetting of muck piles and the work face, sprinkling of haulage ways, using water jets, and well-engineered ventilation.

In addition to the dust exposures, there are exposures to those injurious gaseous combustion products accompanying the use of explosives, the major ones being nitrogen dioxide, carbon monoxide, sulfur dioxide, and hydrogen sulfide. Approved explosives are designed with the proper oxygen balance so that production of toxic gases is held to a minimum. Nevertheless, it is necessary to provide control of those gases where explosives are used. The control may consist of ventilation or sufficient time for natural diffusion and absorption. At times, the use of personal respiratory protection is necessary for either gases or dusts.

Oxygen deficiency and naturally occurring gases, such as methane, hydrogen, carbon dioxide, and hydrogen sulfide, must be controlled by ventilation. The use of diesel engines in mines necessitates sufficient ventilation to control the minor amounts of aldehydes, carbon monoxide, and nitrogen dioxide present in the exhaust gas.

In general, the miners recognize the existing hazards associated with their occupation. They realize that most safety regulations are written to improve working conditions; therefore, most are readily accepted by the miners. Generally speaking, the experienced miners take the regulations very seriously, but it takes the inexperienced miner some time to get adjusted to the system.

The basic philosophy concerning existing safety conditions is: if everyone abides by the safety rules, the chances of a serious accident are greatly reduced; however, if someone fails to abide by the safety rules, it could affect not only the guilty party but also other miners working in the same area. Generally, the miners believe that the present safety conditions are as good as they possibly could be and still be feasible.

The major problem with the operation of a new process (such as electrokinetics) underground is that if it is a potential hazard and if the miners do not understand it, they naturally are afraid of it. Therefore, before any new process is put into operation in a mine, the miners working in the general area should be briefed on how the system operates and the results to expect. Although this briefing may require an hour or so of the miners' time, any fears they might have would be reduced or eliminated. The miners who are working directly with the electrokinetic process should be completely familiar with the total operation.

CHAPTER 6: IDENTIFICATION AND EVALUATION OF POTENTIAL HAZARDS

As previously mentioned, electrokinetic dewatering is the process of removing water from a soil mass by passing a direct current through the mass by means of electrodes; therefore, electricity is induced into the ground. Anytime electricity is induced into the ground, there exists a possibility of gas emissions, corrosion, stray current, accidental detonation of explosives, and other hazards. Discussions of each potential hazard, along with its evaluation, are presented in the following paragraphs.

Potential Gas Hazards

The characteristics and quantities of emitted gases due to the electrokinetic dewatering process are highly dependent on the physical properties of the material being dewatered. Because of the wide range in the physical properties of mine tailings on which the electrokinetic dewatering process could be used, it would be somewhat fruitless to try to predict the gas emissions for every case. Generally, the physical properties of the material will be determined during preliminary laboratory tests, which should be conducted prior to the use of the process on a full-scale basis. Once the physical properties have been determined, the expected characteristics and quantities of emitted gases can be determined. The primary characteristics, besides quantities of the gas emissions, that should cause concern are: (a) toxicity, (b) ignition, and (c) detonation.

The allowable airborne concentrations of substances is controlled by the American Conference of Governmental Industrial Hygenists (ACGIH). The ACGIH (11) has adopted threshold limit values (TLV's), which refer to the airborne concentrations and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect. The adopted TLV's for the previously mentioned gases are shown in the following tabulation:

Gases	
Name	TLV ppm
Hydrogen	--
Hydrogen sulphide	10
Hydrogen cyanide	10

The toxicity of the previously discussed gases (12) is discussed in the following paragraphs.

Hydrogen is nontoxic; however, it forms hydrogen cyanide and hydrogen sulfide that are toxic.

Hydrogen cyanide is colorless with a characteristic odor. The effects of various concentrations of hydrogen cyanide in air are given in the following tabulation.

Response	Concentration mg/litre	ppm
Immediately fatal	0.3	270
Fatal after 10 min	0.2	181
Fatal after 30 min	0.15	135
Fatal after 1/2 to 1 hr or later, or dangerous to life	0.12-0.15	110-135
Tolerated for 1/2 to 1 hr without immediate or late effects	0.05-0.06	45-54
Slight symptoms after several hours	0.02-0.04	18-36

As can be seen in the tabulation, hydrogen cyanide is highly toxic and can be fatal; however, its characteristic odor can be recognized by trained indiviuals at 2-5 ppm. The sense of smell is, however, easily fatigued; and there is a wide individual variation in the minimum odor threshold.

Hydrogen sulfide is colorless and has a distinct rotten egg odor. The physiological responses to various concentrations of hydrogen sulfide are given in the following tabulation.

Response	Concentration ppm
Maximum allowable concentration for prolonged exposure	20
Slight symptoms after several hours	70-150
Maximum concentration for 1 hr without serious consequences	170-300
Dangerous after exposure of 1/2 to 1 hr	400-700

Although the characteristic odor of the gas is detectable in concentrations as low as 0.025 ppm, it is distinct at 0.3 ppm, is offensive and moderately intense at 3-5 ppm, and marked but not intolerable at 20-30 ppm. The odor at higher concentrations does not become more intense, and above about 200 ppm the disagreeable odor appears less intense. Therefore, the possibility of exposure to high concentrations increases.

Ignition is the process of igniting. Before a mixture can ignite, a portion of the mixture must be heated to its ignition temperature. The ignition temperature may be defined as the minimum temperature at which rapid combustion becomes independent of external supplies of heat. This implies that in order to initiate flame a definite minimum volume of a gaseous mixture must be heated to its ignition temperature and held at this temperature for a sufficient time to enable flame to propagate away from the ignition source.

The investigation of ignition temperatures is extremely complicated, and the results obtained by various investigators may show wide disagreement because of different conditions. Some of the major factors that affect the ignition temperatures are: the percent of combustible in the mixture, the "lag" or time required at a given temperature to cause ignition, the percentage of oxygen present, the pressure on the mixture at the time of ignition, and the presence or absence of impurities, especially catalytic surfaces. It is apparent that the term "ignition temperature" is not a true physical constant, and reported values for a given combustible may vary widely. The ignition temperatures in air (13) for the previously discussed gases are shown in the following tabulation:

Name	Ignition Temperature °C
Hydrogen	572
Hydrogen cyanide	538
Hydrogen sulphide	292

The values shown in the above tabulation may vary somewhat depending on the previously discussed conditions.

Detonation is the process of exploding with sudden violence. In the past, confusion has arisen regarding the meaning of the terms "explosive limits," "flammable limits," and "limits of flammability." In the final analysis, these different expressions mean the same thing; therefore, for simplicity, the term "limits of flammability" will be used in discussing detonation characteristics of various gases. Limits of flammability are regarded as those limiting mixtures within which flame will propagate entirely through the mixture without regard as to whether pressure is produced.

Various factors that affect the limits of flammability are: the direction of flame propagation, the temperature and pressure of the mixture at the time of ignition, the percentage of water vapor present, and indirectly the source of ignition. The limits of flammability in air (13) of the previously discussed gases are presented in the following tabulation:

Gas	Limits of Flammability Percent by Volume	
	Lower	Upper
Hydrogen	4.0	74.2
Hydrogen cyanide	5.6	40.0
Hydrogen sulphide	4.3	45.5

As previously mentioned, the values above can vary depending on the atmospheric conditions.

It must be noted that in the previous discussion on gases, it was assumed that a single gas existed in the air. However, it is possible to calculate closely the limits of flammability of not only mixtures of combustible gases and vapors in air but also mixtures containing varying amounts of inert gases and air as would probably be the case during electrokinetic dewatering.

To eliminate or control the toxicity of hazardous gases, the first defense is to provide adequate ventilation to ensure that gas concentrations do not exceed the threshold limit values. This need for adequate ventilation applies not only to spaces around the equipment where the gases may originate but in all working areas in the immediate vicinity.

Combustible gases, mixed with air in proportions to give flammable mixtures, may be safe provided all sources of ignition are eliminated. The primary sources of ignition that may cause explosions can be classified as shown below:

Ignition sources	Matches	Open lights
		Matches and cigarette lighters
		Fires in boilers and water heaters
		Burning material; incinerators
	Sparks	Static electricity
		Electrical shorts and arcs
		Lightning
		Sparks from tools
	Heated materials	Glowing metals; hot cinders
		Overheated bearings
		Electric light filaments
		Spontaneous combustion

Most of the sources of ignition given above can be controlled by following the proper safety regulations.

Static electricity has caused many serious fires and explosions and is one of the most difficult hazards to control. It is more serious in dry atmospheres where the relative humidity is below 50 percent. Static electricity may be generated by friction, that is, by slipping belts, pulleys, revolving machinery, and by passage of solids, liquids, or gases at high velocity through small openings. It also may be generated by impact, pressure, cleavage, and induction. It may be partly or totally eliminated by the proper grounding of all machinery, pipes, and other equipment where charges may accumulate. Whenever practical, these is added safety in also maintaining the humidity above 50 percent.

As previously mentioned, most of the ignition sources are controlled by proper safety regulations; however, smoking should not be permitted in the area where the electrokinetic dewatering process is in operation. This should eliminate the use of matches and cigarette lighters in the general vicinity, thereby eliminating the possibility of gas ignition.

Ideally, the electrokinetic dewatering process would be segregated from other operations; however, in some cases this would be impossible.

Therefore, danger signs should be posted at a safe distance away from the process and also around the perimeter of the area being dewatered.

Another safety precaution to use where hazardous concentrations of combustibles may be present is to install combustible (hydrogen) gas indicators or recorders. The sampling locations should be chosen so that test mixtures may be taken periodically from different locations.

As previously mentioned, during the electrokinetic dewatering process some oxidation reactions may occur, gas may be formed, and a highly corrosive localized environment may be created near the anode. The chemical makeup of the tailings being dewatered and the material used as electrodes determine whether or not corrosion due to electrolysis will take place and, if so, to what extent.

Possible areas of corrosion that could cause a situation to deteriorate from a safe to an unsafe condition are the electrodes and the electrical connectors to the electrodes. In most cases, however, the electrodes are used for a short period of time and then abandoned or removed for reuse. Unless the environment was very highly corrosive, the corrosion that would take place would have no hazardous effect on the surrounding areas, i.e., there would be no stray currents induced. Periodic visual inspections of the electrode connectors should be made to determine whether corrosion has taken place and, if so, to what extent. If the electrodes or electrical connectors are corroded, they should be replaced rather than reused.

Other possible areas of corrosion due to oxidation are pipes, pumps, conduits, etc., used in the dewatering process. If stray currents cause metal equipment to become anodic, they could corrode. If extensive corrosion does occur, the equipment will have to be replaced. A visual inspection will indicate any corrosive action on the materials and equipment.

If the material being dewatered is determined to be overly acidic or basic, it can be chemically treated before being placed in the dewatering area to minimize any corrosive effects that might take place. It must be noted that the chemical treatment could possibly retard the rate of electrokinetic dewatering; therefore, care should be taken in selecting the chemical additives.

In summary, the only possible areas of corrosion, caused by either electrolysis or electrochemical reactions, that could cause a situation to deteriorate from a safe to an unsafe condition are the electrodes and electrical connectors to the electrodes. The possible hazard can be eliminated by periodically monitoring the stray current and visually inspecting the electrodes and connectors.

Electrical Hazards

Electric current flowing from a source, such as a battery, a generator, or a transformer, through power lines to electric equipment will always return to that source over whatever paths are available to it. These paths are always the paths of least resistance to current flow. They include additional conductors insulated from ground (such as electric cables), conductors not insulated from ground (such as rails), and the earth itself. If the supply or return conductor between the source and the load should be interrupted, as by the opening of a fuse, dangerously high ground currents may result in the earth-grounded system.

To help eliminate the possibility of ground current hazards during the electrokinetic process, the MHSA regulations include the following:

a. Power supply output for electrokinetic application must be ungrounded, i.e., the electric output (DC) shall be floating with neither polarity connected to system (earth) ground.

b. Control circuitry shall include a relay to interrupt power output, with lockout and manual reset provisions, if current between ground and equipment frame exceeds 5 amp.

In addition to the regulations, fuses or other overcurrent devices shall be required in the output of power supplies ahead of the cables serving the electrodes, and rectifiers shall be connected to the a-c supply with a two-winding transformer to provide full isolation between a-c and d-c sides.

The severity of electrical hazards generally increases with potential. Therefore, dewatering systems must be designed for the lowest voltage requirement needed for adequate dewatering. Treatment depths should be limited to a manageable amount and/or treatment time extended. Where depths are necessarily large, treatment with layered electrodes should be considered as a means of limiting potential levels.

Due to the remote possibility of inducing stray current in the areas surrounding the area being electrokinetically dewatered, there exists a possibility of sustaining a fatal or debilitating electric shock and/or accidental detonation of explosives. These two possibilities are discussed in detail in the following paragraphs.

Possibility of sustaining a fatal or debilitating electric shock

The maximum allowable electric shock that nearly all workers may be exposed to without causing serious harm is 40 volts. During the electrokinetic dewatering process, a power source capable of producing a much higher voltage is used, resulting in the remote possibility of sustaining a fatal or debilitating shock.

To control the current used in the electrokinetic process the following items must be considered:

<u>a</u>. The areas (stope, pit, etc.) in which the dewatering will take place must be free of extraneous metals such as scrap cable, bars, and pipe. Thus there will be only one conductor from the pit or stope and that is earth even if there are conductive veins in the area.

<u>b</u>. Rectifiers shall contain a requirement for ground current indicators, i.e. a high resistance device between both positive and negative leads and earth ground that activates with current flow (usually a neon lamp). Thus, if containment walls are conducting, the lamps will illuminate. An illuminated lamp would not mean that the system is unduly hazardous but that a conductor exists from sludge to earth ground.

<u>c</u>. A space must be maintained between electrodes and containment walls (particularly with horizontal electrodes) to reduce hazards of stray potentials. The space should be carefully determined by knowledgeable personnel. The selected spacing should be verified during operation for adequacy. Usually a space between electrode edge and adjacent walls equal to one-half the vertical distance between electrodes is adequate.

Figure 3 suggests a method for determining adequacy of spacing between electrodes and walls. Probes are installed as shown for measuring potentials along stope walls. This figure represents measurements to be made immediately adjacent to walls of a collection sump while applying electrokinetic treatment.

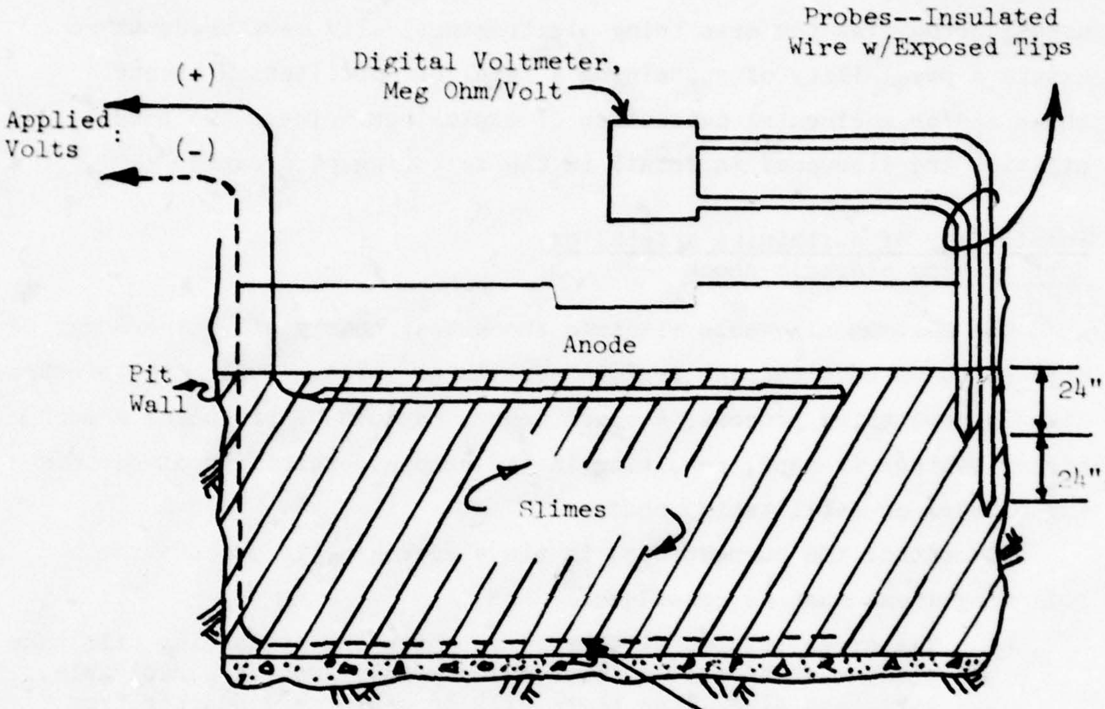


Figure 3. A suggested method of measuring wall potentials

To eliminate the possibility of sustaining a fatal or debilitating shock within the area being dewatered, the area should be completely isolated. For a repetitively used installation, such as a collection sump, a safety relay should be installed on each entrance into the area. The safety relay should be designed so that once the entrance (gate, door, etc.) is opened, the current to the electrodes is cut off. Once the current is cut off, manual reset of the relay shall be required. However, for a stope, a gate or barricade (with warning sign) in the manway raise may be more practical and adequate.

Accidental detonation of explosives

The possibility of the accidental detonation of explosives from d-c fields related to the electrokinetic dewatering process is remote; however, the possibility does exist. To get an indication of the amount of current required to detonate most commercial caps, the Blasters' Handbook (14) was reviewed. According to Reference 14, the maximum stray current that can be tolerated is 0.05 amp, or one fifth of the minimum firing current for commercial blasting caps (0.25 amp). This is in accordance with the recommendations of the Institute of Makers of Explosives.

If the present safety regulations pertaining to the storage of explosives and detonators are followed, there is no way to accidentally detonate the stored explosives. Therefore, the only time that accidental detonation is possible is during loading and blasting operations.

The first defense against this hazard is to control the current used in the electrokinetic dewatering process as previously discussed. Once the current is controlled, the hazard is eliminated; however, electric blasting operations in highly conductive ground (highly metallic rock formations and areas drawing water that might be slightly acidic or alkaline) warrant frequent tests for the presence of hazardous electric currents. When stray currents are found, they should be eliminated if not caused by natural phenomena.

It is highly improbable that the current can be completely controlled; therefore, during loading and blasting operations in the vicinity of the dewatering area, the electrokinetic dewatering process should be discontinued.

Other Hazards

A potential hazard associated indirectly with the use of the eletrokinetic dewatering process to dewater mill tailings is the possibility of subsequent saturation and liquefaction of the dewatered backfill. A brief discussion of the liquefaction process and the associated potential hazard is presented in the following paragraphs.

Evaluation of the possible occurrence and effects of settlement and liquefaction is important in all hazardous areas. Failures caused by liquefaction of saturated granular soils have been observed many times. An extensive list of slope failures caused by liquefaction has been given by Seed (15). Ambraseys and Sarma (16) have summarized a number of reports of liquefaction beneath horizontal ground surfaces.

The cause of liquefaction has been understood in a qualitative way, for many years. If a saturated sand is subjected to ground vibrations, it tends to compact and decrease in volume; if drainage is unable to occur, the tendency to decrease in volume results in an increase in pore water pressure; and if the pore water pressure builds to the point at which it is equal to the overburden pressure, the effective stress becomes zero, the sand loses its strength completely, and a liquefied state develops.

Liquefaction of a sand in this way may develop at any zone of a deposit where the necessary combination of in situ condition and vibratory deformation may occur. Such a zone may be at the surface or at some depth below the ground surface, depending only on the state of the sand and the induced motions.

However, liquefaction of the upper layers of a deposit may also occur, not as a direct result of the ground motions to which they are subjected but because of liquefaction in an underlying zone of the deposit. Once liquefaction develops at some depth in a mass of sand, the excess hydrostatic pressures in the liquefied zone will dissipate by flow of water in an upward direction. If the hydraulic gradient becomes sufficiently large, the upward flow of the water will induce a "quick" or liquefied condition in the surface layers of the deposit. Liquefaction of this type will depend on the extent to which the necessary hydraulic gradient can be developed and maintained; this in turn will be determined by the compaction characteristics of the sand, the nature of ground deformations, the permeability of the sand, the boundary drainage conditions, the geometry of the particular situation, and the duration of the induced vibrations.

It has been generally recognized that the susceptibility of a given soil to liquefaction will be determined to a high degree by its void ratio or relative density. For a cyclic loading condition, loose sands may liquefy, but the same material in a denser condition may not. Previous investigations (17) indicate that when the relative density (i.e., the state of compaction relative to the loosest and densest conditions possible into which a particular cohesionless soil can be placed) exceeds 70 percent, liquefaction will not occur. However, it must be pointed out that other factors, such as soil type, degree of saturation, intensity and duration of cyclic load, and initial confining pressure, also play an important role in the liquefaction phenomena. For liquefaction to occur, the material must be saturated.

For the electrokinetic process to be effective, the backfill material must be drained of "free" water before the process starts, i.e., the boundary must be such that the surface water can be drawn off and some of the water in the backfill can be drained by gravity. If the cathode used is a slotted pipe, it can be used as an effective gravity drain as well as a drain for the water removed by electrokinetic dewatering. The resulting fill will not be saturated, and the relative density should be higher than 70 percent of the maximum relative density; therefore, it is highly improbable that liquefaction can occur. Thus, no potential hazards are associated with the use of unclassified tailings as a backfill if the tailings are dewatered using the electrokinetic dewatering process.

Another possible hazard occurs if conditions are precipitated in the electrokinetic process, whereby the probability of serious accidents increases. As previously mentioned, the underground mining is considered a hazardous occupation, and the probability of serious accidents can be decreased by following set safety rules and regulations. The rules and regulations are developed to cover the various hazards associated with different mining processes; therefore, with the introduction of any new process into mine operations, new safety regulations must be developed.

The development of safety regulations for a new process, such as electrokinetic dewatering, is a progressive type operation, whereby the more the process is used, the more familiar the associated potential hazards become. To initially cover all the potential hazards of any new process is almost impossible; however, by following existing regulations and some newly developed regulations, conditions will not be precipitated in the electrokinetic process that will increase the probability of serious accidents.

CHAPTER 7: THE ECOLOGICAL IMPACT TO MAN AND ENVIRONMENT

"Generally most mines are located in rugged mountains with narrow creeks and gulches which provide insufficient ground area for surface disposal of mine waste. Inadequate tailings disposal has been a source of stream pollution, often lethal to plant and animal life, a disaster hazard when placed in dumps (recall the Aberfan, Wales, tragedy of 1966), and a real physical problem just to stow the tremendous volume of material. Tailings can be used as raw materials for product manufacture, such as making brick, but it is difficult to imagine sufficient consumption to appreciably reduce the need for disposal. Consequently, better design of tailing ponds, land reclamation and safer and more efficient methods of stabilizing wastes are required.

"Stowing underground in mined-out areas has been a mining practice for many years. The 'cut-and-fill' method uses hydraulically placed tailings slurries as the floor of a stope, thus allowing mining to proceed from the bottom to the top of an ore body. Any method of increasing the rate of dewatering, or the amount of consolidation and the shear strength of the settled material, would greatly improve the safety and efficiency of the method. Using 'cyclones' to separate the coarse particles from the slimes and placing the coarse fraction underground increases the settlement rate of slurries. However, ultimate strength of the backfill is reduced, and large surface tailings ponds are required for the slow-settling fine particles of the slimes. The ultimate strength of settled material, both underground and in the tailings dump, could be improved significantly if well-graded slurries containing both coarse and fine particles were used. The rate of production of backfill would also be increased, thereby improving mine efficiency." (3)

The electrokinetic dewatering process can be used to achieve dewatering, consolidation, and cementation of mine tailings. This process can:

a. Increase mining efficiency in many cases,

b. Ensure a safe working surface for the miners,

c. Reduce the size of the area required for surface tailings ponds, and

d. Increase the amount of tailings that can be stowed underground.

By reducing the size of the tailings ponds and stowing more of the tailings underground, the chances of stream pollution are reduced, thereby improving the surface environment. By ensuring a safe working surface for the miners, the underground environment is improved. Therefore, the ecological impact from use of the electrokinetic dewatering process is positive for the environment and man.

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on the information obtained for this study, the following conclusions and/or safety regulations were drawn.

a. The electrokinetic dewatering process can be used safely in underground metal mines provided pertinent existing and newly developed safety regulations are followed.

b. A limited number of laboratory tests shall be conducted prior to field use to determine the physical properties of the material to be dewatered and the expected results of the electrokinetic dewatering process.

c. The effect of electrokinetic dewatering can be enhanced by agitation, periodic current reversal, intermittent current application, and the electrode arrangement.

d. The basic philosophy of miners is that the present safety regulations are as good as they possibly could be and still be feasible.

e. Most existing safety regulations pertaining to electricity, ventilation, and explosives should apply to the electrokinetic dewatering process.

f. New safety regulations:

(1) Personnel working in the vicinity of the electrokinetic dewatering process shall be completely familiar with its operation.

(2) Smoking and open flames shall not be permitted in the immediate area where the electrokinetic dewatering process is in operation.

(3) Signs warning against smoking and open flame shall be posted so that they can readily be seen in areas around the electrokinetic dewatering area.

(4) Danger signs shall be posted around the perimeter of the electrokinetic dewatering area.

(5) An adequate volume of fresh air shall be supplied around the dewatering area to ensure that the concentration of any airborne contaminant does not exceed the threshold limit value listed for that contaminant.

(6) Whenever possible, the electrokinetic dewatering area shall be segregated from other operations.

(7) Combustible (hydrogen) gas indicators shall be installed wherever hazardous concentrations of combustibles may be present.

(8) Periodic visual inspections of the electrodes and electrical connectors shall be made to determine whether corrosion has taken place and, if so, to what extent. If the electrodes or electrical connectors are highly corroded, they shall be replaced.

(9) Fuses or other overcurrent devices shall be required in the output of power supplies ahead of the cables serving the electrodes.

(10) The rectifiers shall be connected to the a-c supply with a two winding transformer to provide full isolation between a-c and d-c sides.

(11) Electrokinetic dewatering systems shall be designed for the lowest voltage requirement needed for adequate dewatering.

(12) Treatment depths shall be limited to a manageable amount and/or treatment time extended. Where depths are necessarily large, treatment with layered electrodes shall be considered as a means of limiting potential levels.

(13) The area (stope, pit, etc.) in which the dewatering will take place shall be free of extraneous metals such as scrap cable, bars, and pipe.

(14) Rectifiers shall contain a requirement for ground current indicators, i.e., a high resistance device between both positive and negative leads and earth ground that activates with current flow (usually a neon lamp). Thus, if containment walls are conducting, the lamps will illuminate. An illuminated lamp would not mean that the system is unduly hazardous but that a conductor exists from sludge to earth ground.

(15) A space must be maintained between electrodes and containment walls to reduce stray potentials.

(16) An expert in the electrokinetic dewatering procedure shall determine the location and spacing of the electrodes to be used. The selected spacing shall be verified during operation for adequacy.

(17) For a repetitively used installation, such as a sump, the area should be completely isolated and a safety relay installed on each entrance to the area. The relay shall be designed so that once the entrance is opened, the current to the electrodes is shut off, and manual reset of the relay is required. However, for a stope, a gate or barricade (with warning sign) in the manway raise is adequate.

(18) The electrokinetic dewatering process shall be discontinued when loading and blasting operations are in the vicinity of the dewatering area.

(19) The electrokinetic dewatering process shall be continued until the material has dried below its saturation point, thereby eliminating the possibility of liquefaction.

g. Mine Health and Safety Adminstration (MHSA) regulations that users should be aware of:

(1) Power supply outputs for electrokinetic application must be ungrounded, i.e., the electric output (DC) shall be floating with neither polarity connected to system (earth) ground.

(2) Control circuitry shall include a relay to interrupt power output, with lockout and manual reset provisions, if current between ground and equipment frame exceeds 5 amp.

h. Conditions are not precipitated in the electrokinetic process, whereby the probability of serious accidents is increased.

i. The electrokinetic dewatering process can increase mining efficiency, in many cases ensure a safe working surface for the miners, reduce the size of the area required for surface tailings-ponds, and increase the amount of tailings that can be stowed underground; therefore, its ecological impact is positive for the environment and man.

Recommendations

Based on the above conclusions and/or safety regulations, it is recommended that:

a. When used in deep metal mines, the electrokinetic dewatering process be properly monitored to obtain additional information on other potential hazards that possibly exist.

b. Laboratory tests to determine gas emissions and other pertinent properties be conducted on material from any metal mines contemplating use of electrokinetics.

c. A computer model be prepared that could be used to determine electrode spacing and configuration, rate of dewatering, possible gas emissions, conductivity in and around the dewatering area, corrosion possibilities, etc.

d. Laboratory and field tests be conducted to determine the procedure to use for optimizing the effects of electrokinetic dewatering.

e. The newly developed safety regulations be adopted by the MSHA.

REFERENCES

1. Sprute, R. H. and Kelsh, D. J., "Limited Tests in Electrokinetic Densification of Mill Tailings," Report of Investigations No. 8034, 1975, Bureau of Mines, U. S. Department of Interior, Washington, D. C.

2. __________, "Electrokinetic Densification of Hydraulic Backfill--A Field Test," Report of Investigations No. 8075, 1975, Bureau of Mines, U. S. Department of Interior, Washington, D. C.

3. __________, "Laboratory Experiment in Electrokinetic Densification of Mill Tailings; Part 1, Development of Equipment and Procedures," Report of Investigations No. 7892, 1974, Bureau of Mines, U. S. Department of Interior, Washington, D. C.

4. __________, "Laboratory Experiments in Electrokinetic Densification of Mill Tailings; Part 2, Application to Various Types and Classifications of Tailings," Report of Investigations No. 7900, 1974, Bureau of Mines, U. S. Department of Interior, Washington, D. C.

5. Mining Enforcement and Safety Adminstration, "Metal and Nonmetal Mine Health and Safety, Underground Mine Standards," Mar 1974, U. S. Department of Interior, Washington, D. C.

6. Colorado Bureau of Mines, "Colorado Mining Laws, with Safety and Health Regulations," Bulletin No. 20, Jan 1971, Denver, Colo.

7. Idaho Department of Labor and Industrial Services, "Minimum Safety Standards and Practices for Mining and Mineral Industry," Safety Code 5, Jul 1976, Boise, Idaho.

8. Montana Department of Labor and Industry Workmen, "Safety and Health Standards for Metal and Nonmetallic Mining and Related Industries," Helena, Mont.

9. New Mexico State Inspector of Mines, "Mine Safety Code for All Mines," 1975, Santa Fe, N. Mex.

10. State of Utah, "Metal and Nonmetal Mine Health and Safety Standards," Salt Lake City, Utah.

11. "TLV's Threshold Limit Values for Chemical Substances in Workroom Air," adopted by American Conference of Governmental Industrial Hygienists for 1976.

12. <u>Industrial Hygiene and Toxicology; Vol II, Toxicology,</u> Interscience Publishers, 1963.

13. Industrial Hygiene and Toxocology; Vol I, General Principles, Interscience Publishers, Inc., 1958.

14. E. I. duPont de Nemours and Co., Inc., Blaster's Handbook, 15th ed., 1969.

15. Seed, H. B., "The Fourth Terzaghi Lecture: Landslides During Earthquakes Due to Liquefaction," Journal, Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol 94, No. SM5, Sep 1968.

16. Ambraseys, N. and Sarma, S., "Liquefaction of Soils Induced by Earthquakes," Bulletin of the Seismological Society of America, Vol 59, No. 2, Apr 1969.

17. Lee, K. L. and Seed, H. B., "Cyclic Stress Conditions Causing Liquefaction of Sands," Journal, Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol 93, No. SM1, Jan 1967.

APPENDIX A: EXISTING FEDERAL AND STATE SAFETY REGULATIONS PERTINENT TO ELECTROKINETIC DEWATERING

This Appendix contains a list of existing Federal safety regulations, and state safety regulations for five states (Colorado, Idaho, Montana, New Mexico, and Utah), which pertain to electricity, ventilation, and explosives. Although these regulations are for other mining operations, they also apply to electrokinetic dewatering in underground heavy metal mines. The reference numbers shown (Nos. 5-10) are listed at the end of the main text.

Federal Safety Regulations (5)

57.4 FIRE-PREVENTION AND CONTROL

General Surface and Underground

57.4-55 Transformer stations, pump rooms, compressor rooms and similar installations shall be in fire-resistant areas.

57.4-60 Power circuits should be de-energized in all areas on idle shifts or idle days except where power is required. Circuits which remain energized should be protected by fuses or circuit breakers of the correct type and capacity consistent with the power load on such shifts or idle days.

57.5 AIR QUALITY, VENTILATION AND RADIATION

Ventilation - Underground Only

57.5-26 Instruments should be provided to test the mine atmosphere quantitatively for carbon monoxide, nitrogen dioxide, and other gases that occur in the mine. Tests should be conducted as frequently as necessary to assure that the required quality of air is maintained.

57.6 EXPLOSIVES

General Use - Surface and Underground

57.6-123 Mandatory. When electric detonators are used charging shall be stopped immediately when the presence of static electricity or stray currents is detected, the condition shall be remedied before charging is resumed.

Underground Only

57.6-180 Explosives, detonators, and blasting lines should be isolated from sources of static electricity and stray currents and from extraneous electric contact.

57.6-181 Where electric blasting is to be performed, electric circuits to equipment in the immediate area to be blasted should be de-energized before explosives or detonators are brought into the area; the power should be turned on again until after the shots are fired.

57.12 ELECTRICITY

General - Surface and Underground

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

57.12-2 Mandatory. Electric equipment and circuits shall be provided with switches or other controls. Such switches or controls shall be of approved design and construction and shall be properly installed.

57.12-3 Mandatory. Individual overload protection or short-circuit protection shall be provided for the trailing cables of mobile equipment.

57.12-4 Power wires and cables should have adequate current-carrying capacity and should be protected from mechanical injury.

57.12-6 Distribution boxes should be provided with disconnect switches.

57.12-7 Mandatory. Trailing cable and power-cable connections to junction boxes shall not be made or broken under load.

57.12-8 Power wires and cables should be insulated adequately where they pass into or out of electrical compartments.

57.12-11 Mandatory. High-potential transmission cables shall be covered, insulated, or placed according to acceptable electrical codes to prevent contact with low-potential circuits.

57.12-13 Splices in power cables, including ground conductor where provided, should be:

(a) Mechanically strong with adequate electrical conductivity.

(b) Effectively insulated and sealed to exclude moisture.

(c) Provided with mechanical protection and electrical conductivity as near as possible to that of the original.

57.12-16 Mandatory. Electrical equipment shall be de-energized before work is done on such equipment. Switches shall be locked out or other measures taken which shall prevent the equipment from being energized without the knowledge of the individuals working on it. Such locks, or preventative devices shall be removed only by the persons who installed them or by authorized personnel.

57.12-17 Mandatory. Power circuits shall be de-energized before work is done on such circuits unless hot-line tools are used. Suitable warning signs shall be posted by the individuals who are to do the work. Switches shall be locked out or other measures taken which shall prevent the power circuits from being energized without the knowledge of the individuals working on them. Such locks, signs, or preventative devices shall be removed only by the person who installed them or by authorized personnel.

57.12-18 Mandatory. Principal power switches shall be labeled to show which units they control, unless identification can be made readily by location.

57.12-19 At least 3 feet of clearance should be provided around all parts of stationary electric equipment or switchgear where access or travel is necessary.

57.12-20 Mandatory. Dry wooden platforms, insulating mats, or other electrically nonconductive material shall be kept in place at all switchboards and power-control switches where shock hazards exist. However, metal plates on which a person normally would stand and which are kept at the same potential as the grounded, metal, non-current-carrying parts of the power switches to be operated may be used.

57.12-21 Mandatory. Suitable danger signs shall be posted at all major electrical installations.

57.12-22 Areas containing major electrical installations should be entered only by authorized persons.

57.12-23 Mandatory. Electrical connections and resistor grids which are difficult or impractical to insulate shall be guarded, unless protection is provided by location.

57.12-25 Mandatory. All metal enclosing or encasing electrical circuits shall be grounded or provided with equivalent protection. This requirement does not apply to battery-operated equipment.

57.12-26 Mandatory. Metal fencing and metal buildings enclosing transformers and switchgear shall be grounded.

57.12-28 Mandatory. Continuity and resistance of grounding systems shall be tested immediately after installation.

57.12-29 Electric equipment and wiring shall be inspected by a competent person as often as necessary to assure safe operating conditions.

57.12-30 Mandatory. When a potentially dangerous condition is found it shall be corrected before equipment or wiring is energized.

57.12-31 Electric motors, switches, and controls exposed to damaging dust or water should be of dusttight or watertight construction.

57.12-32 Inspection and cover plates on electrical equipment should be kept in place at all times, except during testing or repairs.

57.12-36 Mandatory. Fuses shall not be removed or replaced by hand in an energized circuit, and they shall not otherwise be removed or replaced in an energized circuit unless equipment and techniques especially designed to prevent electrical shock are provided and used for such purpose.

57.12-37 Mandatory. Fuse tongs or hotline tools shall be used when fuses are removed or replaced in high-potential circuits.

57.12-40 Mandatory. Operating controls shall be installed so that they can be operated without danger of contact with energized conductors.

57.12-41 Mandatory. Switches and starting boxes shall be of safe design and capacity.

57.12-54 Tools and supplies should be carried in the hands and not on the shoulders when men travel near bare power conductors.

Underground Only

57.12-82 Mandatory. Powerlines shall be well separated or insulated from waterlines, telephone lines, and air lines.

57.12-83 Power cables in shafts and boreholes should be fastened securely in such manner as to prevent undue strain on the sheath, insulation, or conductors.

57.12-84 Disconnecting switches that can be opened safely under load should be provided underground at all primary power circuits near shafts, levels, and boreholes.

57.12-85 Mandatory. Transformer stations shall be enclosed to prevent persons from unintentionally or inadvertently contacting energized parts.

State Safety Regulations

Colorado (6)

21. CABLES, ELECTRIC

1. High voltage electric power cables over six hundred fifty (650) volts shall be of a type that will give the best mechanical and

electrical characteristics of insulation, and of a type approved for the service intended.

2. Cables should have an outer covering that will best protect against any deterioration, prevent electrical shock and fires, and they shall be installed in an approved manner and guarded against damage from external sources.

5. Armored metallic cable (standard underground) may be used in most shafts and underground working places and under most operation conditions. Such armored cable shall be fastened at least at five (5) foot intervals with fittings that will not injure the cable.

6. Shielded nonmetallic sheathed cable may be used for high tension transmission underground when properly supported, grounded, and protected. All high tension cable for underground use shall be shielded or metallic armored.

7. Conduit nonmetallic sheath may be used for exposed and concealed wiring for buildings such as shops, offices and warehouses, but shall not be imbedded in masonry, concrete, fill or plaster. Flexible metal conduits may be used in the same places and under the same conditions.

9. Overhead high potential wires shall be installed on insulators of sufficient size and guarded to prevent contact with other circuits.

10. Underground power circuits shall be insulated in a permanent manner, and so located as to minimize the possibility of damage by mine water, falls of rock, ground movement, or other hazards.

11. When insulated wires instead of cable are used underground, they shall be supported rigidly on insulators at least every five (5) feet, and shall be spaced six (6) inches apart and two (2) inches from the surface over which they are installed.

12. Open wiring shall not be used in underground repair shops, compressor rooms, battery charging stations or pumping plants. Wiring for such use must either be in conduit or an approved cable type.

13. All power wires, except ground wires, shall be supported on or by well-installed insulators, and shall not touch combustible materials nor the back or sides of working places. Where such wires pass through

doors or bulkheads or where they cross other power circuits, they must be completely and properly insulated.

14. When rigid metal conduit is used, it shall be of a corrosion-resistant material, suitable for underground conditions.

16. Trailing electric power cables shall be connected to mobile equipment in such a manner as not to cause danger to the joints or terminal screws or fittings, and no energized trailing cable or other "live" cable shall be handled except with insulated tongs or hooks.

17. Trailing power cables must at all times be maintained in good repair, and all splices and joints must be covered with insulation equivalent to the original covering.

18. All electrical circuits shall be of ample capacity for the amount of current carried.

19. Power cables shall not be allowed to lie in water unless they are of a type specially constructed to properly function under water.

21. Trailing cable and power-cable connections to junction boxes shall not be made or broken under load.

23. High-potential power lines shall be installed as specified by an acceptable electrical code.

24. Guy wires of poles supporting high-potential conductors shall be equipped with insulators installed near the pole end.

38. DANGER SIGNS

1. Danger, no smoking or warning signs shall be posted at all locations where existing conditions or temporary hazards, which are not otherwise properly guarded, warrant their use.

2. Employers shall be responsible for the posting of all such necessary danger or warning signs, and such signs shall be posted where they will offer the most effective protection.

3. No employee or other person or persons shall remove, deface or destroy any danger or warning sign or interfere with any other safety device.

39. DANGEROUS CONDITIONS

1. In every case of any serious change of condition or occurrence which might tend materially to increase the hazards of properly carrying on work in any mill, excavation, mine or quarry, whether or not any personal injury has resulted, a report of such condition shall be immediately sent to the Commissioner of Mines by the employer.

41. DETONATORS

1. Detonators shall in all cases be stored at lease one hundred (100) feet from other explosives and from high potential electricity. They shall be kept in covered boxes and only taken out in such quantities as required for daily use.

50. ELECTRICAL EQUIPMENT

1. All electrical equipment shall be so constructed, installed, and maintained as to reduce the accident hazard so far as is reasonably possible.
2. All electrical equipment shall be installed in a manner to be readily and safely accessible to authorized employees for maintenance and repair. Such equipment shall be guarded by rails, wooden platforms, insulating mats, or other electrically nonconductive material wherever necessary.
3. Lighting arresters shall be installed and maintained in good condition. Cirecuit breakers or fuses of correct type and capacity shall be installed on all electrical equipment, including trailing cable, to protect against excessive loads or short circuits.
4. All electrical circuits and equipment which are used at any working place shall be supervised by an employee fitted for the job by ability, experience, and training.
5. All repairs, adjustments or other work on any type of electrical equipment shall be performed only by qualified employees.

6. Electrical equipment and wiring shall be inspected systematically and at regular intervals by the employer to insure a safe operating condition, and any defective equipment shall be repaired or replaced at once.

7. Efficient fire extinguishers and/or other equipment for fighting electrical fires first shall be kept at or near all electrical stations or substations.

8. Exposed live controller contacts, resistor grids, unprotected motor terminals and unprotected switches shall not be used unless they can be adequately guarded.

9. Enclosed safety switches must be used on all powerlines and must be maintained at all times in good working conditions.

10. Electrical power circuits and equipment supplied from such circuits shall be protected against lightning, voltage surges, overheating, and overloading.

11. Disconnecting switches shall be installed at all main power circuits, and separate circuits shall have separate switches. All switches shall be of a safety type.

12. Fuse or equivalent protective devices of the correct type and capacity shall be installed on all electrical equipment for protection against excessive overload.

13. Switches and circuit breakers shall be installed so that they are readily accessible and can be operated without danger of contact with moving or live parts.

14. Each piece of electrical equipment and the circuit supplying it shall be provided with switches or other controls of safe design and construction.

15. Electric drills or other electrically operated hand rotating tools shall have the electric switch constructed so as to break the circuit when the hand releases the switch, or shall be equipped with friction or safety devices, and shall be properly grounded.

16. Switchboards shall be well lighted for operation in front, and for maintenance and repair when necessary. The rear of the switchboards

shall be so guarded as to prevent anyone getting near them and, if possible, they should be enclosed and kept locked.

17. All rooms or buildings which contain switchboards shall be kept free of debris and refuse at all times.

18. All switches, circuit breakers, power controls and other such electrical equipment shall be mounted on suitable insulating material.

19. Before any repair work is started on any power circuit or electrical equipment, the power must be disconnected, and the switches shall be locked out while repairs are made on machinery or other equipment. The key to the lockout device must remain in the possession of the person doing the work.

20. Switches which are open to permit work on lines or equipment must be tagged with warning signs so that no employee or other person or persons will close the switch.

21. When repairs are finished, but before any employee closes the switch, he shall make certain that the closing will not start a fire or electrocute a fellow employee.

22. Wires, pieces of wire, or other conducting materials shall not be used as a substitute for properly designed fuses. Where circuit breakers are used, they shall be maintained in proper operating condition and adjusted so equipment cannot be overloaded.

23. No employee working in an elevated position on electrical equipment shall do so without using an approved safety belt and lifeline, unless there are proper guard rails around such elevated positions.

24. All electrical appliances, machines, conductors, and other equipment shall be large enough for the work required of them, and all electrical circuits shall be of ample size for the current carried.

25. All electrical equipment, both underground and surface, shall be effectively grounded and tested for resistance and continuity immediately after installation.

26. Work on hot lines and energized electrical equipment underground is absolutely forbidden except for the work required to de-energize the line.

27. Abandoned electrical circuits shall be de-energized and isolated so that they cannot become energized inadvertently.

28. Principal power switches shall be labeled to show which units they control, unless identification can be made readily by location.

29. Suitable danger signs shall be posted at all major electrical installations.

30. When a potentially dangerous condition is found it shall be corrected before equipment or wiring is energized.

31. Powerlines shall be well separated or insulated from waterlines, telephone lines, and air lines.

32. Circuits shall be de-energized before fuses are removed or replaced.

33. Fuse tongs or hotline tools shall be used when fuses are removed or replaced in high-potential circuits.

34. Deviation from these rules will require a special permit from the Commissioner of Mines.

35. Inspection and cover plates on electrical equipment shall be kept in place at all times except during testing or repairs.

51. <u>ELECTRICITY</u>

1. Voltage over five hundred (500) volts shall not be used on portable electrical equipment, hand tools, or any other such equipment. The voltage for such equipment should not exceed two hundred fifty (250) volts between conductors. Metal frames of such tools must be effectively grounded.

2. Open wiring or electrical conductors shall not be used in any location considered hazardous because of gassy or dusty atmosphere containing corrosive vapors or fumes.

3. Open conductors shall not be used in explosive magazines, change rooms, compressor rooms, or battery changing stations.

4. Power shall be cut off from idle sections of underground workings. It should be cut off from entire workings on the days that no work is being done or no power is being used.

5. Where metallic tools or equipment can come in contact with trolley wires or bare powerlines, the lines shall be guarded or de-energized.

6. The potential or bare signal wires accessible to personal contact shall not exceed forty (40) volts.

71. GASES

1. When the atmosphere in any mine, or part of the mine, is known to contain or is suspected of containing any explosive or toxic gas, it shall be tested by approved means before employees are allowed to work therein.

2. Tests shall be made by an employee designated by the employer as competent to make such tests.

3. Hazardous gas or vapor conditions shall be deemed to exist when the place of employment contains higher concentration limits than shown in the following table:

Gases and Vapors

Name	Parts of Million	
Ammonia	50	
Benzine	25	
Carbon Dioxide	5000	
Carbon Monoxide	50	- .005% by volume
Chlorine	1	
Gasoline	500	
Hydrogen Cyanide	10	
Hydrogen Sulphide	10	
Methane	500	- .5% by volume
Naphtha (petroleum)	100	
Nitrogen Dioxide	5	
Nitrogen Oxides	25	

4. The maximum allowable concentrations of gases and vapors are according to standards set forth in Rules and Regulations pertaining to Occupational Health, Colorado Department of Health, as follows:

OH 2.8 Permissable Atmospheric Concentrations (Threshold Limit Value).

1. The acceptability of the concentration of atmospheric

contaminants in the air breathed by workmen shall be governed by the latest revised document pertaining to Threshold Limit Values as prepared by the American Conference of Governmental Industrial Hygenists.

2. It is not implied that observance of the Threshold Limit Values will be a guarantee against possible ill health of workers exposed, or that medical control can be neglected.

Idaho (7)

13. ELECTRICITY

13.1 The National Electrical Code and National Electrical Safety Code are considered to contain basic minimum provisions necessary for safety.

(A) All electrical equipment, conductors, etc., shall be adequately guarded by location, enclosures or guards and be properly posted.

(B) 1. Adequate protection and disconnecting means shall be provided on the primary side of power and distribution transformers.

2. Transformers shall be of a type and design suitable for the location in which they are to be installed.

(C) 1. In all substations, ample working spaces shall be provided and maintained around all electrical equipment.

2. Control devices shall comply with National Electrical Manufacturers Association Standards.

3. When starters are required to control motors, the starter shall have a rating not less than that of the motor which it controls. Oil-filled transformers shall be installed in fire-resistant locations. All transformer stations shall be fenced or otherwise protected to remove likelihood of dangerous contact.

13.3 Distribution boxes shall be provided with disconnect switches.

POWER CIRCUITS

13.5 High-potential transmission cables shall be covered, insulated, or placed according to acceptable electrical codes to prevent contact with low-potential circuits.

13.8 Lightning arrester grounds shall be connected to earth at least 10 feet from the track or mine return circuit.

13.9 Overhead high-potential powerlines shall be installed as specified by the National Electrical Code, or Idaho Code 3.

13.20 Conductors shall be suitable for the locations, current requirements, and voltage of the circuit to which they are applied, as set forth in the National Electrical Code, and shall be protected from mechanical injury.

13.21 The potential on bare signal wires accessible to personal contact shall not exceed 40 volts.

13.22 Suitable control and overload protective devices shall be inserted in all feeders and utilization equipment and shall be readily accessible and as close as practicable to the point of utilization.

13.23 Control equipment shall comply with National Electrical Manufacturer's Association Standards.

13.24 (A) Supply circuit cables to portable equipment, unless armored, shall conform to the National Electrical Code standards and contain a grounding conductor.

(B) Portable cables transmitting power at a potential exceeding 650 volts shall have a grounded sheathing consisting of tinned copper wire mesh or equivalent around each power conductor.

(C) When it is necessary to handle an energized portable cable having a potential in excess of 650 volts, rubber gloves and insulated tongs, or hooks shall be provided and shall be used.

(D) Connectors on portable cables shall be so constructed that the grounding prod will be the first to be engaged and last to be broken when the connector is open or closed.

(E) Splices in trailing cables shall be substantially constructed.

(F) Trailing cable shall be protected from damage.

(G) Trailing cable and power-cable connections to junction boxes shall not be made or broken under load.

(H) Individual overload protection or short circuit protection shall be provided for the trailing cables of mobile equipment.

(I) All electrical equipment as covered in section 13.24 shall be maintained and repaired by qualified personnel.

13.25 All portable electric hand tools shall be adequately grounded, or equipped with ground fault interrupters.

13.27 Circuits shall be protected against excessive overload by fuses or circuit breakers of the correct type and capacity.

13.28 Power wires and cables shall be insulated adequately where they pass into or out of electrical compartments.

13.29 Splices in power cables, including ground conductors, where provided shall be:

(A) Mechanically strong with adequate electrical conductivity.

(B) Effectively insulated and sealed to exclude moisture.

(C) Provided with mechanical protection and grounded if applicable around splice.

(D) Not more than five splices shall be made in any trailing cable unless they are vulcanized.

(E) On machines not using cable reels, no splices shall be present in the first 25 feet of trailing cable adjacent to the equipment.

13.30 Continuity and resistance of grounding systems shall be tested immediately after installation.

13.31 When a potentially dangerous condition is found, it shall be corrected before equipment or wiring is energized.

13.32 Electric motors, switches and controls exposed to dust or water shall be of dusttight and watertight construction.

13.33 Electrical equipment shall be de-energized before work is done on such equipment. Switches shall be locked out and suitable warning signs posted by the individuals who are to do the work; locks shall be removed only by the person who installed them.

13.34 Inspection and cover plates on electrical equipment shall be kept in place at all times except during testing or repairs.

13.36 Portable extension lights and other lights that may present a shock or burn hazard shall be guarded.

13.37 Circuits shall be de-energized on the load side of fuses before removal or replacing.

13.38 Electrical equipment and circuits shall be provided with switches or other controls. Such switches or controls shall be of approved design and construction and shall be properly installed.

13.39 Fuse tongs or hot-line tools shall be used when fuses are removed or replaced in high-potential circuits.

13.49 Power circuits shall be de-energized before work is done on such circuits unless hot-line tools are used. Where power circuits have been de-energized, switches shall be locked out and suitable warning signs posted by the individuals who are to do work; locks shall be removed only by the persons who installed them.

13.50 Principal power switches shall be labeled to show which units they control.

13.51 Ample working space shall be provided around stationary electric equipment or switch gear where access or travel is necessary.

13.52 Dry wooden platforms, insulating mats, or other electrically non-conductive material shall be kept in place at all switchboards and power-control switches where shock hazards exist. However, metal plates on which a person normally would stand and kept at the same potential as the grounded metal noncurrent carrying parts of the power switches to be operated may be used.

13.53 Suitable danger signs shall be posted at all major electrical installations.

13.54 Areas containing major electrical installations shall be entered only by authorized personnel.

13.55 Electrical connections and resistor grids that are difficult or impractical to insulate shall be guarded unless protection is provided by location.

13.57 All metal enclosing or encasing electrical circuits shall be grounded. This requirement does not apply to battery operated equipment.

UNDERGROUND

13.60 Power cables in shafts and boreholes shall be fastened securely in such manner as to prevent undue strain on the sheath, insulation or conductors.

13.61 Disconnecting switches that can be opened safely under load shall be provided on underground primary power circuits at each distribution point.

Montana (8)

MT 57.12 ELECTRICITY. General - Surface and Underground.

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

MT 57.12-2 Mandatory. Electric equipment and circuits shall be provided with switches or other controls. Such switches or controls shall be of approved design and construction and shall be properly installed and maintained.

MT 57.12-3 Mandatory. Individual overload protection or short-circuit protection shall be provided for the trailing cables of mobile equipment.

MT 75.12-4 Power wires and cables should have adequate current-carrying capacity and should be protected from mechanical injury.

MT 75.12-8 Power wires and cables should be insulated adequately where they pass into or out of electrical compartments.

MT 75.12-11 Mandatory. High-potential transmission cables shall be covered, insulated, or placed according to acceptable electrical codes to prevent contact with low-potential circuits.

MT 57.12-12 The potential on bare signal wires accessible to personal contact should not exceed 40 volts.

MT 57.2-13 Splices in power cables, including ground conductors, where provided, should be:

(a) Mechanically strong with adequate electrical conductivity.

(b) Effectively insulated and sealed to exclude moisture.

(c) Provided with mechanical protection and electrical conductivity as near as possible to that of the original.

MT 57.12-16 Mandatory. Electrical equipment shall be de-energized before work is done on such equipment. Switches shall be locked out or other measures taken which shall prevent the equipment from being energized without the knowledge of the individuals working on it. Such locks, or preventative devices shall be removed only by the persons who installed them or by authorized personnel.

MT 57.12-17 Mandatory. Power circuits shall be de-energized before work is done on such circuits unless hot-line tools are used. Suitable warning signs shall be posted by the individuals who are to do the work. Switches shall be locked out or other measures taken which shall prevent the power circuits from being energized without the knowledge of the individuals working on them. Such locks, signs, or preventative devices shall be removed only by the personnel who installed them or by authorized personnel.

MT 57.12-18 Mandatory. Principle switches shall be labeled to show which units they control, unless identification can be made readily by location.

MT 57.12-19 At least 3 feet of clearance should be provided around all parts of stationary electric equipment or switchgear where access or travel is necessary.

MT 57.12-21 Mandatory. Suitable danger signs shall be posted at all major electrical installations.

MT 57.12-22 Mandatory. Areas containing major electrical installations shall be entered only by authorized persons.

MT 57.12-23 Mandatory. Electrical connections and resistor grids that are difficult or impractical to insulate shall be guarded, unless protection is provided by location.

MT 57.12-25 Mandatory. All metal enclosing or encasing electrical circuits shall be grounded or provided with equivalent protection. This requirement does not apply to battery-operated equipment.

MT 57.12-28 Mandatory. Continuity and resistance of grounding systems shall be tested immediately after installation.

MT 57.12-29 Electric equipment and wiring should be inspected by a competent person as soon as necessary to assure safe operating condition.

MT 57.12-30 Mandatory. When a potentially dangerous condition is found it shall be corrected before equipment or wiring is energized.

MT 57.12-31 Electric motors, switches, and controls exposed to damaging dust or water should be of dusttight or watertight construction.

MT 57.12-32 Inspection and cover plates on electrical equipment should be kept in place at all times except during testing or repairs

MT 57.12-34 Portable extension lights and other lights that may present a shock or burn hazard should be guarded.

MT 57.12-36 Mandatory. Fuses shall not be removed or replaced by hand in an energized circuit, and they shall not be otherwise be removed or replaced in an energized circuit unless equipment and techniques especially designed to prevent electrical shock are provided and used for such purposes.

MT 57.12-37 Mandatory. Fuse tongs or hot-line tools shall be used when fuses are removed or replaced in high-potential circuits.

MT 57.12-40 Mandatory. Operating controls shall be installed so that they can be operated without danger of contact with energized conditions.

MT 57.12-41 Mandatory. Switches and starting boxes shall be of safe design and capacity.

MT 57.12-54 Tools and supplies should be carried in the hands and not on the shoulders when men travel near bare power conductors.

New Mexico (9)

ARTICLE 27 - ELECTRICAL EQUIPMENT IN MINES OTHER THAN COAL

63-27-3 VOLTAGE OF ELECTRICAL APPARATUS. Motors of electric locomotives, loaders, cutting machines and other portable apparatus under three hundred (300) horsepower shall not be operated at a voltage exceeding six hundred fifty (650) volts. Portable apparatus, used in underground mines, which are rated three hundred (300) horsepower or above may be operated at higher voltage, not in excess of a nominal voltage of four thousand one hundred and sixty (4,160), only if the conductors in the trailing cable are surrounded by a grounded flexible metallic sheath and the ground circuit is continuously monitored in a method approved by the state inspector of mines, and the equipment is designed by manufacturer for the amount of voltage applied and as approved by the state mine inspector.

63-27-4 VOLTAGE FOR TRANSMISSION. For transmission purposes underground, a voltage in excess of five hundred fifty (550) volts may be used if the circuits are carried inside metallic sheaths or armors with the sheaths or armors permanently grounded. This higher voltage may only be applied to transformers or stationary motors, except as provided in section 63-27-3 New Mexico Statutes Annotated, 1953 Compilation.

63-27-5 CAUTION SIGNS AT ELECTRIC STATIONS. At electric stations where caution sign notices will tend to prevent electrical accidents, such notices shall be posted.

63-27-6 REPAIRS, RENEWALS OR EXTENSIONS - PRECAUTIONS WHEN MAKING. Repairs, renewals, or extensions of electrical apparatus and circuits shall not be made while such apparatus or circuits are alive unless conditions make it absolutely necessary, in which case the utmost precaution shall be taken when working on them.

63-27-8 GROUNDING OR ELECTRICAL APPLIANCES

(a) The frames, cases and bedplates of electrical apparatus, other than portable motors, such as stationary motors, generators, transformers and the non-current-carrying metallic parts of switchboards and other electrical applicances, shall be effectively grounded.

(b) Metallic frames, casings and other enclosures of portable electrical equipment, used in underground mines, requiring four hundred forty (440) volts or more, except equipment using an overhead trolley system, shall be effectively grounded or provided with equivalent protection. In addition, portable electric apparatus operated over six hundred fifty (650) volts shall be provided with ground circuit monitoring as provided in section 63-27-3 New Mexico Statutes Annotated, 1953 Compilation.

63-27-10 UNDERGROUND SWITCHES

(a) All switches for use underground shall be rugged in construction and adequately proportioned as to capacity. Switches replaced new, operative on circuits over one hundred twenty-five (125) volts, except trolley lines, that are opened while under load, shall be provided with quick-break attachments to prevent excessive arcing. Where, because of moisture, there is likelihood of switch handles becoming electrically charged, special switches operated with short wood handles shall be provided. In so far as feasible, switches shall be located in a thoroughly dry place. In case the switches cannot be so located, an insulated platform shall be provided for mine workers to stand on when operating the switch.

(b) Where there is danger of accident due to the closing of an open switch, proper warning signs shall be placed at such switch by the person opening the switch. Where practicable, switches shall be so wired that the blades will not be alive when the switch is open. Switches shall not be installed in such a manner as to close by gravity. Switches shall be convenient and accessible, yet safeguarded so that the liability to accidental contact with live parts thereof shall be reduced to a minimum.

(c) Oil or air switches shall be used for operating or controlling all alternating current circuits above six hundred (600) volts.

63-27-11 FUSES-AUTOMATIC CIRCUIT BREAKERS. Fuses and automatic circuit breakers shall be constructed so as to effectually interrupt the current when a short circuit occurs or when the current through them exceeds a predetermined value. Iron or copper wires shall not be used for fuses. All fuses shall be stamped or marked, or shall have a label attached indicating their rating. Fuses shall be adjusted or replaced only by an authorized person.

SECTION 73 - ELECTRICAL POWER: CIRCUIT BREAKERS, SWITCHES AND SWITCH BOARDS

(.12-1) Circuits shall be protected against excessive overloads by fuses or circuit breakers of the correct type and capacity.

A. Wire or other conducting material shall not be used as a substitute for fuses. Circuit breakers shall be maintained in good operating condition.

(.12-2) Electric equipment and circuits shall be provided with switches or other controls. Such switches or controls shall be of approved design and construction and shall be properly installed.

B. On the stationary equipment, provision shall be made for locking starting equipment in the "off" position to prevent accidental application of power.

(.12-20) Dry wooden platforms, insulating mats, or other electrically nonconductive material shall be kept in place at all switchboards and power-control switches where shock hazards exist. However, metal plates on which a person normally would stand and which are kept at the same potential as the grounded, metal, non-current-carrying parts of the power switches to be operated may be used.

C. When not needed, underground power circuits shall be de-energized on idle days and shifts.

D. Electrical parts, such as switches, circuit breakers, rheostats, relays and fuses, shall be mounted on nonconductive, noncombustible bases.

(.12-32) Inspection and cover plates on electrical equipment and junction boxes shall be kept in place at all times except during testing or repairs.

(.12-36) Fuses shall not be removed or replaced by hand in an energized circuit, and they shall not otherwise be removed or replaced in an energized circuit unless equipment and techniques especially designed to prevent electrical shock are provided and used for such purpose.

(.12-41) Switches and starting boxes shall be of safe design and capacity.

SECTION 74 - ELECTRIC POWER: SAFETY LOCKOUT AND TAGGING

(.12-16) Electrical equipment shall be de-energized before work is done on such equipment. Switches shall be locked out or other measures taken which shall prevent the equipment from being energized without the knowledge of the individuals working on it. Such locks, or preventative devices shall be removed only by the persons who installed them or by authorized personnel.

(.12-17) Power circuits shall be de-energized before work is done on such circuits unless hot-line tools are used. Suitable warning signs shall be posted by the individuals who are to do the work. Switches shall be locked out or other measures taken which shall prevent the power circuits from being energized without the knowledge of the individuals working on them. Such locks, signs, or preventative devices shall be removed only by the person who installed them or by authorized personnel.

SECTION 75 - ELECTRIC POWER: POWER CIRCUITS

A. All power wires and cables shall have adequate current-carrying capacity, shall be protected from mechanical injury, and with the exception of trailing cables and power cables connected to junction boxes, should be installed in a permanent manner.

B. Wires and cables not encased in armor shall be supported by properly installed insulators and shall not touch combustible materials; provided, however, that this does not apply to ground wires, grounded power conductors, and trailing cables.

(.12-3) Individual overload protection or short-circuit protection shall be provided for the trailing cables of mobile equipment.

(.12-7) Trailing cable and power-cable connections to junction boxes shall not be made or broken under load.

(.12-8) Power wires and cables shall be insulated adequately where they pass into or out of electrical compartments. Cables shall enter metal frames of motors, splice boxes, and electrical compartments only through proper fittings. When insulated wires, other than cables, pass through metal frames, the holes shall be substantially bushed with insulated bushings.

(.12-11) High-potential electrical conductors shall be covered, insulated, or placed to prevent contact with low potential conductors.

(.12-13) Permanent splices and repairs made in power cables, including the ground conductor where provided, shall be: (a) Mechanically strong with electrical conductivity as near as possible to that of the original; (b) Insulated to a degree at least equal to that of the original, and sealed to exclude moisture; and, (c) Provided with damage protection as near as possible to that of the original, including good bonding to the other jacket.

C. Insulated cable tongs or hooks shall be used in handling energized portable cables or ropes attached thereto.

F. All power circuits and electrical equipment shall be de-energized before work is done on them; provided, however, that employees may, where necessary, repair energized trolley wires if they wear insulated shoes or work off an insulated platform, and wear lineman's gloves.

J. Splices in power cables shall be made in accordance with the following:

1. Mechanically strong, with adequate electrical conductivity.
2. Effectively insulated and sealed so as to exclude moisture.
3. If the cable has metallic armor, mechanical protection and electrical conductivity equivalent to that of the original armor shall be provided.

K. All power wires and cables shall be insulated adequately where they pass into or out of electrical compartments, where they pass through doors, and where they cross other power wires and cables.

SECTION 76 - ELECTRIC POWER: GROUNDING

A. All metallic sheaths, armours, and conduits enclosing power conductors shall be electrically continuous throughout and grounded effectively.

(.12-25) All metal enclosing or encasing electrical circuits shall be grounded or provided with equivalent protection. This requirement does not apply to battery-operated equipment.

(.12-26) Metal fencing and metal buildings enclosing transformers and switchgear shall be grounded.

(.12-27) Frame grounding or equivalent protection shall be provided for mobile equipment powered through trailing cables.

(.12-28) Continuity and resistance of grounding systems shall be tested immediately after installation.

SECTION 77 - ELECTRIC POWER: GENERAL

(.12-23) Electrical connections and resistor grids that are difficult or impractical to insulate shall be guarded, unless protection is provided by location.

(.12-30) When a potentially dangerous condition is found it shall be corrected before equipment or wiring is energized.

(.12-34) Portable extension lights, and other lights that by their location present a shock or burn hazard, shall be guarded.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Green, Charles E

Develop safety practices for electrokinetic treatment of mine waste / by Charles E. Green. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. ; available from National Technical Information Service, 1979.

72 p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; GL-79-14)

Prepared for Office of the Assistant Director - Mining, Bureau of Mines, U. S. Department of the Interior, Washington, D. C., under Contract No. H0272005.

References: p. 46-47.

1. Electrokinetics. 2. Mine wastes. 3. Safety. I. United States. Bureau of Mines. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; GL-79-14.

TA7.W34m no.GL-79-14