Principles and Guide to Practices in the

Control of Acid Mine-Drainage

supplemented by Case Histories

Compiled by

COAL INDUSTRY ADVISORY COMMITTEE

OHIO RIVER VALLEY

WATER SANITATION COMMISSION

OHIO RIVER VALLEY WATER SANITATION COMMISSION

An interstate agency representing Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Virginia and West Virginia

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PRINCIPLES, PRACTICES AND CASE HISTORIES IN THE CONTROL OF ACID MINE-DRAINAGE

Compiled by the
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of the
OHIO RIVER VALLEY WATER SANITATION COMMISSION

March, 1964

FOREWORD

The Coal Industry Advisory Committee was established in 1951 to advise and assist the Ohio River Valley Water Sanitation Commission in its regional crusade for the abatement and prevention of pollution from coal mining operations. The Committee consists of representatives from commercial and captive coal producers and coal-industry associations.

Pollution-control measures for acid mine-drainage were established by the Commission on January 14, 1960, by adoption of Resolution No. 5-60. The resolution was subsequently amended in January 1963 to include a provision regarding the handling of acid-producing materials encountered in the overburden in stripping operations.

This manual was prepared by the Coal Industry Advisory Committee for the use of coal operators and officials of pollution-control agencies. It provides a review of the fundamental principles involved in the formation of acid mine-drainage together with a guide to control practices that will aid in ameliorating the effects of mine drainage on the streams and rivers of the Ohio Valley.

At a meeting on September 12, 1963, the Commission accepted the manual for publication, and expressed appreciation to the Coal Industry Advisory Committee for its work in compiling the manual and for its aggressive efforts in implementing the provisions of Resolution No. 5-60.

CONTENTS

PRINCIPLES IN THE CONTROL OF ACID MINE-DRAINAGE

Research and study into the causes of acid mine-drainage, of preventing it, and of ameliorating its pollutional effects, have been going on for a number of years. Many individuals, agencies and institutions, in addition to the mining industry, have given much time to this problem. As yet there is no positive or complete solution known, but means have been found for helping the situation in many instances, and research and study are continuing.

In the meantime, certain fundamental principles which can be applied in the control of acid mine-drainage from coal mining and related operations have been recognized. These principles form the basis for the control measures contained in *ORSANCO* Resolution 5-60.

A copy of *ORSANCO* Resolution 5-60 is included with these Principles. It was adopted after years of study and extensive deliberations by the *ORSANCO* Engineering Committee and the Coal Industry Advisory Committee. It has been approved by both the Commission and the industry. The coal industry in the Ohio River watershed is now required to carry out the provisions of Resolution 5-60.

A study of the principles upon which the control measures contained in *ORSANCO* Resolution 5-60 are based will not only help to understand those measures, but will also help in carrying them out.

THE PROBLEM

Coal mining is one of the great industries of this country, but even before a single ton of coal was mined, water pollution from "coal drainage" was noted by early explorers. They documented it in their records, predicting the presence of ample quantities of coal by streams that were " . . . . . so impregnated with bituminous and sulphurous materials as to be frequently nauseous to the taste . . . . ." (The First Century and a Quarter of the American Coal Industry, Howard N. Evansen, Waverly Press, Baltimore (1942), Pg. 169).

Acid drainage is a natural occurrence which has been greatly increased by the mining process. Just as certain materials associated with the outcrop coal measures came in contact with other natural elements to cause pollution before mining, so do they come in contact with these elements in the mining process, and in far greater quantity. The elements which cause water pollution when associated with certain materials in the coal measures are two of the most common and essential in nature -- air and water.

If we could completely eliminate either air or water from coal mining operations there would be no acid mine-drainage. This has so far proven to be impractical of accomplishment by either physical or chemical means. Some control can be exercised over these elements, however, and another factor involved in the development of acid mine-drainage provides an opportunity for this control. That factor is time.

The production of acid is not an instantaneous process. The rapidity of its formation varies with different acid-producing materials, but the *amount of acid contributed by a given material is related to the length of time that material is exposed to air and water; however, complete submergence under water will prevent exposure to air, thereby eliminating acid production.*

THE FUNCTIONS OF AIR, WATER AND TIME IN PRODUCING ACID MINE-DRAINAGE

Oxidation of the acid-producing materials associated with coal mining is necessary for the formation of mine acids. Oxygen is a part of the chemical composition of these acids which is lacking until the material is exposed. There can be no acid, therefore, until exposure of the acid-producing materials to air.

Oxidation begins on the exposed surface of the materials, and proceeds according to the rapidity with which it can break down the other elements. Water, in the form of moisture in the atmosphere, hastens the process. As oxidation continues, acid is formed, and the parent materials are disintegrated to expose new surfaces to oxidation and further acid formation. Thus time becomes an important factor in the amount of acid formed. The longer the acid-producing materials are exposed to the atmosphere, the greater the amount of acid which will be formed.

Water invades almost every mine in the form of rain or snow, surface run-off or underground percolation. Sooner or later it passes through the mine or over or through mined material, becomes mine-drainage, and eventually mingles with other outside waters. Its quality at any time is the net result of the materials dissolved in it and the reaction of each upon the others. When the water comes in contact with acid material in the mine, it leaches the acid from them. If the acid thus picked up is greater than the ability of the water to neutralize it, the water will be acid in character. In this manner, water becomes acid mine-drainage. Thus, *as water passes through the mine, or over or through mined materials, and comes in contact with acids, it dissolves them and becomes their transport agent.*

Generally speaking, the longer water remains in contact with acid materials, the more acid it will pick up and transport.

"ACID-PRODUCING" IN RELATION TO "ACID-NEUTRALIZING" MATERIALS

Not all materials exposed during the mining process are acid-producing. Some have acid-neutralizing properties. *Both acid-producing and acid-neutralizing materials occur in all coal measures,* although the amount and character of each may vary considerably from mine to mine.

All coal measures contain sulfur. It may be organic, sulfate or sulfide sulfur. Only the sulfide sulfur, occurring as the mineral "pyrite," forms acid if exposed to oxidation. Thus, *all coal mines have acid-producing potentials, even though all coal mines do not produce acid mine-drainage.*

Acid-neutralizing materials, or alkalis, occur in almost all earth strata, even those containing acid-producing materials. These alkalis are also present in all coal measures in varying amounts and are exposed by the mining process. So it can be concluded that all coal mines have acid-neutralizing potentials.

Acid and alkali waters react with and neutralize each other. In the case of mine-drainage, the result of this action depends upon the amount of each present. The character of the drainage from any given mine, therefore, depends upon the amounts of acid and alkali that dissolve in the water as it passes through the mine. Even in so-called acid mines, *the exercise of control to decrease the production of acid and increase neutralization by alkali, will have a beneficial effect upon the character of the mine-drainage.*

In no case should the principle of neutralization of acid water be substituted for acid prevention principles.

MEASUREMENTS AND NEUTRALIZATION OF MINE ACIDS

When we see the word "acid," we generally think of a concentrate which will destroy cells and tissue, and we think of an extremely caustic substance when we see the word "alkali." We often forget that fruits, vinegar and carbonated beverages are acids, and that baking soda, limestone and household ammonia are alkalis.

Most matter is either acid or alkaline. Some acid or some alkali does not necessarily mean an unnatural or undesirable condition. Therefore, *control of acid mine-drainage need not require the attainment of completely neutral conditions in all cases.*

Acids and alkalis are opposites which are defined in terms of their ability to act with and neutralize each other. When they are dissolved in water, the water is either acid, alkaline, or neutral. This character, or condition, of water can be indicated by a measurement known as "pH," a term devised by the chemist to indicate the concentration of hydrogen ions in solution in water. When the concentrations of hydrogen and hydroxyl ions are equal, the water is neutral, or pH 7. The greater the hydrogen ion concentration, or the more indication of acid, the lower the pH below 7. The greater the hydroxyl ion concentration, or the more indication of alkaline character, the higher the pH above 7. *The pH measurement is used to indicate the acid or alkaline character of water, and warn of possible extremes.*

In efforts to control the acidity of acid mine-drainage, the amount of neutralization needed to change the acid character cannot be measured by pH, since it is only an indication of the degree of acid or alkaline condition. The terms "acidity" or "alkalinity" are used to define quantity, and, in general, an equal quantity of the opposite character would be necessary to attain a neutral condition. *The determination of the amount of neutralization necessary to control the acid character of a given mine-drainage is a laboratory procedure.*

Dilution may offer a means of ameliorating the pollutional effects of acid mine-drainage. If the added water is alkaline, some degree of neutralization can be expected. Dilution alone will not change the total amount of acid, but it will reduce the concentration, which can result in ameliorating its pollutional effects. The principle of utilizing the assimilative capacity of the stream is involved in the recommendation that acid mine-water be released to streams during periods of high flow. *Dilution to ameliorate the pollutional effects of acid mine-drainage should be practiced whenever feasible.*

THE COMPLEXITY OF ACID MINE-DRAINAGE

Acid mine-drainage is not a simple dilute solution of pure acid. As has been pointed out, all of the soluble materials with which it has come in contact have affected its quality. Even the acids it has picked up are not simple solutions. They have been formed by the oxidation of pyrite into any one of a series of iron sulphate salts, or from aluminum sulphate salts, which the water has dissolved and diluted and which may be acted upon further by other material which the water may contact. *Acid mine-drainage is variable and extremely complex. Whenever possible, prevention is preferable to treatment.*

While acid mine-drainage is not necessarily harmful when consumed by man or animals, it it often harmful to fish and other aquatic life. It usually degrades water quality for many uses and must be regarded as a serious source of water pollution. It is pollutional if it causes a condition in the receiving stream which adversely affects the treatment procedure of a municipal water supply, causes excessive expense by other industries, is harmful to fish and other aquatic life, or has deleterious effects upon other users of water. We can conclude, therefore, that EVERY PRACTICAL EFFORT MUST BE MADE TO PREVENT THE PRODUCTION OF ACID MINE-DRAINAGE AND TO AMELIORATE ITS POLLUTIONAL EFFECTS.

SUMMARY

(1) Acid drainage is a natural occurrence which is generally increased by the mining process. (Ref. 1, 3, 4. See Appendix III).

(2) If we could completely eliminate either air or water from coal mining operations there would be no acid mine-drainage. (Ref. 7).

(3) The amount of acid contributed by a given material is related to the length of time that material is exposed to air and water; however, complete submergence under water will prevent exposure to air, thereby eliminating acid production. (Ref. 2).

(4) Oxidation of the acid-producing materials associated with coal mining is necessary for the formation of mine acids. (Ref 3, 4, 6, 7, 9).

(5) As water passes through the mine, or over or through mined materials, and comes in contact with acids, it dissolves them and becomes their transport agent. Generally speaking, the longer water remains in contact with acid materials, the more acid it will pick up and transport. (Ref. 1).

(6) Both acid-producing and acid-neutralizing materials occur in all coal measures, although the amount and character of each may vary considerably from mine to mine. All coal mines have acid-producing potentials, even though all coal mines do not produce acid mine-drainage. (Ref. 2, 4, 5).

(7) The exercise of control to decrease the production of acid and increase neutralization by alkali, will have a beneficial effect upon the character of the mine-drainage. In no case should the principle of neutralization of acid water be substituted for acid prevention principles. (Ref. 8, 13).

(8) Control of acid mine-drainage need not require the attainment of completely neutral conditions in all cases.

(9) The pH measurement is used to indicate the acid or alkaline character of water, and warn of possible extremes. (Ref. 10, 11).

(10) The determination of the amount of neutralization necessary to control the acid character of a given mine-drainage is a laboratory procedure. (Ref. 10).

(11) Dilution to ameliorate the pollutional effects of acid mine-drainage should be practiced whenever feasible. (Ref. 4, 14).

(12) Acid mine-drainage is variable and extremely complex. Whenever possible, prevention is preferable to treatment. (Ref. 1, 3, 4, 10, 11).

GUIDE TO PRACTICES IN ACID MINE-DRAINAGE CONTROL

(Some Operating, Planning and Administrative Techniques Relating to the Practical Application of ORSANCO Resolution No. 5-60)

The following material is intended to be explanatory of the five measures contained in Resolution 5-60. This material is presented as a guide to operators and an aid to administrative agencies in applying the provisions of Resolution 5-60. This material is not necessarily complete, nor is it intended to limit the application of Resolution 5-60. It is believed, however, that it covers most of the known practical techniques in acid mine-drainage control. As progress is made in the application of such control techniques, revision and expansion of this material may be required. The application of these techniques has to be fitted to the wide variations in local conditions which characterize coal mining.

It is to be noted that attention should be given to over-all planning of mining operations to facilitate application of good drainage practices.

CONTROL MEASURE I (a)

"Surface waters and ground waters shall be diverted where practicable to prevent the entry or reduce the flow of water into and through workings."

The application of this measure obviously requires that in every mine an effort must be made to determine the source of all mine drainage. In underground mines such water may come from water-bearing strata overlying or underlying the coal, from cracks to the surface, from adjoining mines or mine workings, or from shaft, drift or slope openings.

Where the source of mine drainage can be determined, every practicable effort should be made to shut off the water source. In some cases cracks to the surface can be plugged by filling the cracks with earth. In some cases it may be practical to seal such cracks by grouting methods. Where surface water is being admitted by shaft, slope, drift, or other mine openings, water should be diverted around such openings, or other measures taken to prevent the flow into the mine.

In strip mining the same principles should be applied. Control Measure " I (a)" would require that wherever practicable, diversion ditches be maintained above the highwall to minimize run-off water from entering the pit.

In an area where mining operations encounter other mine workings, or mine pits, precautions should be taken to prevent entry of water from such encountered mine workings or mine pits into or through such mining operations. Measures should also be taken to control the discharge of such water into the drainage system affected in accordance with Control Measure III of Resolution 5-60.

CONTROL MEASURE I (b)

"Water that does gain entry to the workings shall be handled in a manner which will minimize the formation and discharge of acid mine-drainage to streams."

This provision requires that mine drainage be controlled within the mine to minimize the distribution or flow through or over acid-producing materials. To accomplish this, mine drainage should be removed as quickly as possible from acid-forming materials, or accumulated in sumps or other storage facilities for removal, as near as practicable to the point of entry into the mine. Local depressions in the floor which permit the accumulated water to spread out over a relatively large area are not suitable sumps. Wherever practicable mine water should be conducted in pipes rather than ditches, unless such ditches can be kept free from acid-producing materials. Where such water cannot be handled in pipes, or suitable ditches, by gravity flow, local pumping stations or suction pick-up stations should be employed. These techniques can be applied to both underground and strip mines. In both underground and strip mines, good housekeeping practices should be followed with respect to accumulations of crushed coal or other acid-producing materials. Acid is formed on exposed surfaces and acid-producing debris is capable of producing large quantities of acid. Where flowing or standing mine water is permitted to contact such debris, it may become contaminated with a relatively large quantity of acid. It should be remembered that such good housekeeping practices are also important from the standpoint of mine safety.

CONTROL MEASURE II

"Refuse from the mining and processing of coal shall be handled and disposed of in a manner which will minimize discharge of acid mine-drainage therefrom to streams. Where acid-producing materials are encountered in the over-burden in stripping operations, these materials shall be handled so as to prevent or minimize the production of acid mine-drainage, taking into consideration the need for stream pollution prevention and all economic factors involved."

A refuse pile shall mean any deposit of any waste coal, rock, shale, culm, boney, slate, clay and related materials, associated with or near a coal seam, which are either brought above ground or otherwise removed from the mine in the process of mining coal, or which are separated from coal during the cleaning or preparation operations, provided, however, that a refuse pile shall not mean overburden from strip mining operations or rock from mine shafts and mine tunnels.

In order to reduce acid formation in refuse piles and to reduce infiltration of water into the pile, refuse should be compacted. Where the "size consist" of the refuse is such as to prevent effective compaction, a suitable size consist should be obtained by crushing or other suitable means as necessary.

The run-off from the area surrounding the refuse piles should not be permitted to infiltrate the piles. If such run-off must pass through the piles it should be contained in a suitable conduit. Run-off water from the area surrounding refuse piles should be diverted around the piles by suitable ditches or conduits.

Probably the most effective protection against the formation of acid by refuse piles is permanent submergence under water.

Refuse piles may be made in strip pits or other depressions and covered by suitable non-acid producing material.

Refuse should not be used for road surfacing or other filling operations where it will produce acid drainage.

In the process of surface mining the practice of selective placement of materials is followed whenever practical, for the purpose of stabilizing the banks. The practice should also include the placement of acid-producing materials, when possible, where such materials will not be exposed even when the surface of the bank is graded. Pit cleanings and waste coal materials should be placed where they will not become exposed.

CONTROL MEASURE III

"Discharge of acid mine-drainage to streams shall be regulated insofar as practicable to equalize the flow of daily accumulations throughout a 24-hour period."

Equalization of the flow of mine drainage may be accomplished in various ways, such as:

A. The pumping equipment can be designed or adjusted to suit the flow at any given location.

B. The discharge from the mine may be accumulated in a lagoon or other suitable reservoir, and released at a controlled rate into the stream.

C. In case of accidental or unusual discharge from the mine which may cause pollution, notification should be given to the proper control authorities as provided in *ORSANCO* Resolution No. 14-59, adopted September 30, 1959, amended January 12, 1961.

CONTROL MEASURE IV

"Upon discontinuance of operations of any mine all practicable mine-closing measures consistent with safety requirements, shall be employed to minimize the formation and discharge of acid mine-drainage."

Effective application of this provision will require that careful planning of underground mine openings to the surface be carried out so as to avoid, wherever practicable, locations that would render sealing ineffective. The plan of the mine workings, including the openings to the surface, should be recorded on appropriate mine projection maps, and such maps should be made available to pollution control administrative agencies.

It should be recognized that mine sealing by the use of bulkheads is not effective in preventing acid mine-drainage unless the coal seam and other acid-producing strata and materials are submerged. This presents a serious problem in mines, the workings of which lie above the natural drainage elevation.

Where practicable, such bulkheads should be designed to be water-tight seals and so constructed as to withstand the water and earth pressure which may be imposed upon them.

Upon the permanent abandonment of strip pits, or the completion of auger mining, all acid-producing refuse should be removed, buried, or submerged, the face of the coal seam in the bottom of the pit should be covered or submerged and proper provisions for handling water should be established.

CONTROL MEASURE V

> *"Under appropriate circumstances, consideration shall be given to the treatment of acid mine-drainage by chemical or other means in order to mitigate its pollutional properties."*

Under certain conditions, circumstances may develop which are appropriate for the application of chemical or other treatment of acid mine-drainage, as a temporary measure.

As scientific and practical progress is made on the chemical or other treatment of acid mine water, such developments should be considered for application.

CASE HISTORIES IN THE CONTROL OF ACID MINE-DRAINAGE

Mining is not an ordinary industry. Its basic difference is that it is continually moving into new conditions. Even the most carefully engineered mine is subject to day by day adjustment to meet these changing situations.

Many of the water and water quality problems acquired by the mining industry are also unusual. Since they are largely the result of the conditions encountered, they vary from mine to mine and may also vary from day to day. They are a part of the problems of mining. As such, the operating personnel of any particular mine, if they are competent to do so, are in the best position to determine and apply the most practical procedures for the solution of the problems.

The control measures embodied in *ORSANCO* Resolution 5-60 recognize these factors. The degree to which they are given consideration by those charged with the administration and enforcement of the measures will undoubtedly depend upon the initiative taken by each individual mine or mining company in conscientiously applying them in their day to day operations.

The Principles and Guide to Practices contained in this publication are general in their application. Specific procedures cannot be recommended for any and all conditions. However, certain procedures which have proven successful in one mine under certain conditions may be applicable to another mine under similar conditions, be adaptable to other conditions or serve to create an idea which would lead to an applicable procedure. For this reason a section on Case Histories has been included.

It is intended that additional Case Histories will be prepared from time to time and added to the manual in accordance with the following outline:

Control Measure I (a)

Determination of the source of mine water from:

1a-1 Water-bearing strata overlying the coal
2 Water-bearing strata underlying the coal
3 Cracks to the surface
4 Adjoining mines and mine workings
5 Shaft, drift or slope openings

Efforts made to control water inflow by:

6 Filling surface cracks with earth
7 Grouting methods
8 Diverting surface water around openings
9 Sealing openings
10 Maintaining diversion ditches above high wall
11 Diverting stream water flows from surface mining operations

Control Measure I (b) -- (Accumulation and removal of mine drainage)

1b-1 Acceptable underground water drainage
2 Unacceptable underground water drainage
3 Other underground water storage facilities
4 Piping of mine drainage underground
5 Piping of mine drainage in surface mines
6 Underground water drainage ditches free from acid-producing materials
7 Surface water drainage ditches free from acid-producing materials
8 Unsuitable drainage ditches
9 Local pick-up or suction stations for feeding central water disposal system
10 Good housekeeping techniques with respect to acid-producing materials, both surface and underground

Control Measure II -- (Coal refuse disposal)

2-1 Compaction of coal refuse in a refuse pile
2-2 Crushing or other control of coal refuse size consist
2-3 Channeling of run-off water away from coal refuse pile
2-4 Piping of water under or through coal refuse pile
2-5 Inundation of coal refuse
2-6 Burial of coal refuse in strip pits and/or other depressions
2-7 Covering and seeding coal refuse pile
2-8 Conditions resulting from improper use of coal refuse for road surfacing

Control Measure III -- (Mine drainage discharge equalization)

3-1 Adjustment of pump size to fit discharge requirements
3-2 Adjustment of pump discharge to fit discharge requirements
3-3 Controlled release from lagoon or reservoir

Control Measure IV – (Mine closing measures)

4-1 Mine working plans

4-2 Mine sealing which inundates the coal seam and other acid-producing strata

4-3 Watertight seals

4-4 Removal, burial or submergence of acid-producing refuse in strip or auger operations

4-5 Covering of coal faces in surface mining

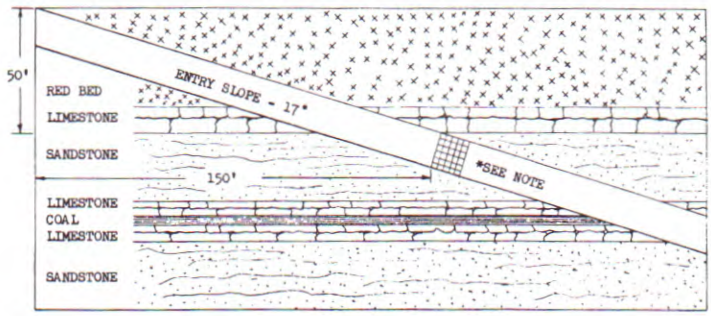
4-6 Submergence of coal faces in surface mining

Control Measure V – (Chemical treatment of acid mine-drainage)

5-1 Emergency circumstances requiring chemical treatment for protection of downstream water quality

5-2 Emergency circumstances requiring chemical treatment within mining operation

USE OF DYES TO LOCATE SOURCE OF MINE WATER



**NOTE: HATCHED AREA SHOWS WHERE EXCESSIVE WATER SEEPAGE OCCURRED. SEE FRONT VIEW DIAGRAM FOR DETAILS ON CHEMICAL GROUTING.*

Figure 1. Side View-Entry Slope

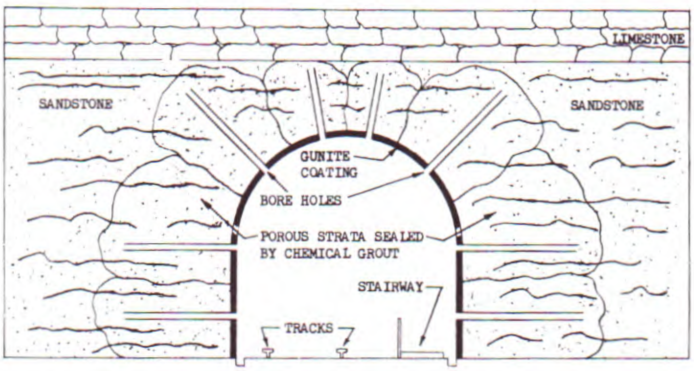


Figure 2. Front View-150 Feet Down Entry Slope
(Vertical Depth - 50 Feet)

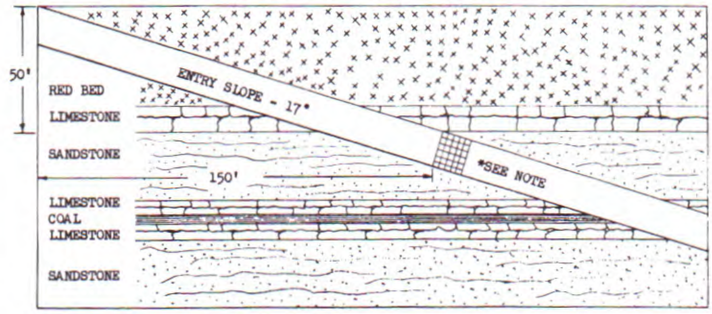
MINING METHOD: Underground mining.

LOCATION: Western Pennsylvania, Upper Freeport Seam.

RESULTS ACHIEVED: Location of underground aquifer severed by slope into mine established so that leakage into mine could be prevented and eliminated subsequently by chemical grouting. (See case history describing "Chemical Grouting to Prevent Inflow of Water" - Case History No. 1a-7).

DESCRIPTION: Water leakage occurred along the plane of intersection of the mine entry with water-bearing strata. Water containing a fluorescent yellow-green dye (Calcocid Uranine) was pumped into bore holes at selected locations near the suspected source of water leakage. Time lapse between injection of dye into bore hole and appearance of dye in water entering mine was measured and later used to (a) establish exact location of water-bearing strata, and (b) establish gel-times required for subsequent sealing off the water leakage by chemical grouting.

CHEMICAL GROUTING TO PREVENT INFLOW OF WATER



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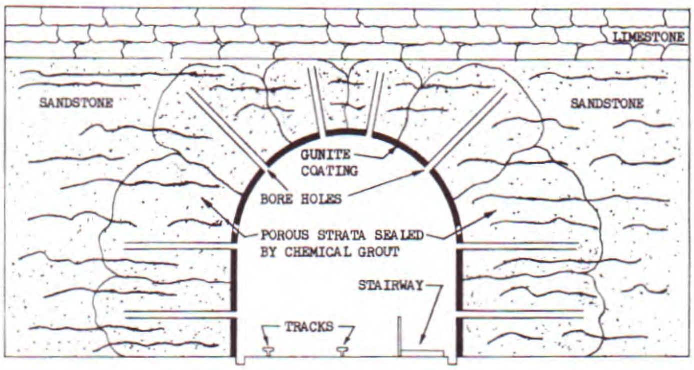


Figure 2. Front View-150 Feet Down Entry Slope
(Vertical Depth - 50 Feet)

MINING METHOD: Underground mining.

LOCATION: Western Pennsylvania, Upper Freeport Seam.

RESULTS ACHIEVED: Inflow of water into mine stopped. This in turn eliminated severe icing conditions on the walls and ceiling of the mine slope near the entry. This resulted in improved safety conditions and in substantial savings in time and material. The method would be useful to control mine drainage.

DESCRIPTION: Water leakage occurred along the plane of intersection of the mine entry with water-bearing strata. Holes were drilled in the roof and ribs of the entry. First, water containing Calcocid Uranine dye, a fluorescent yellow-green color, was pumped into these holes to locate the leakage; then chemical grout was pumped into the holes to seal off the water.

(over)

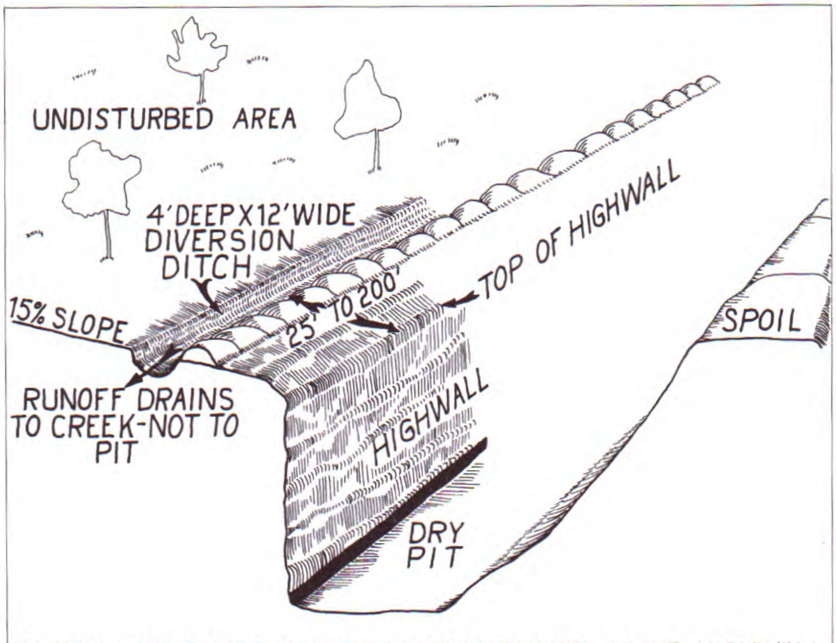
No coal seams were encountered in the drilling. The rock types present were typical of strata overlying coal measures and included claystone, fossil shales and fine-grained sandstones.

American Cyanamid Company's AM-9 is a dry-powder mixture of two acrylic monomers that is applied as an aqueous solution. When catalyzed a cross-linked polymer is formed that renders soil and rock formations impermeable to water.

Because solutions of AM-9 retain the same density and biscosity as water until the point of its instantaneous gelation, they could be pumped into the areas located by the dye in the same time intervals. The gel-time of the grout was set so that the leaky channels would be completely sealed.

The use of 220 gallons of 10 percent AM-9 pumped into 15 bore holes was sufficient to eliminate the entry of water into the roof and ribs of the mine.

DIVERSION DITCH MAINTAINED ABOVE THE HIGHWALL



SKETCH OF DIVERSION DITCH MAINTAINED ABOVE HIGHWALL

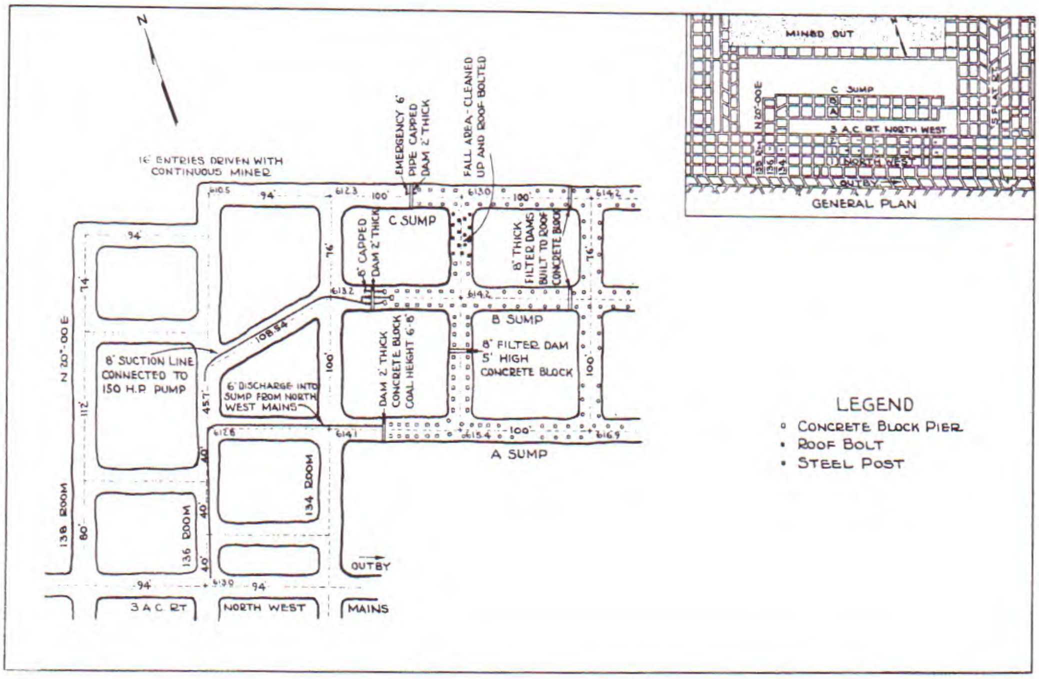
MINING METHOD: Surface.

LOCATION: Western Kentucky Coal Field, Ohio County, Kentucky. Carbondale Formation. Seam No. 9.

RESULT ACHIEVED: Surface water prevented from entering active pit to prevent flooding and formation of acid water.

DESCRIPTION: Contour diversion ditch dug above highwall around pit. Water diverted to stream. Cost of constructing a 4 ft. deep diversion ditch at this mine was approximately $3,200 per mile. Work done with a tractor-bulldozer. The terrain was lightly wooded and gently rolling topography.

ACCEPTABLE UNDERGROUND WATER DRAINAGE



PLAN VIEW SHOWING TYPICAL SUMP ENTRY FOR WATER STORAGE

MINING METHOD: Mechanized underground mining.

LOCATION: Western Pennsylvania, Pittsburgh Seam Coal.

RESULT ACHIEVED: Water is not allowed to accumulate in working areas, thereby keeping the water from prolonged contact with acid-forming material in the mine. Storage sumps and regulated pumping equalize the mine water discharge over a 24-hour period.

DESCRIPTION: Gathering or main sumps are provided in the mine by driving separate sump entries or by digging up the bottom. This practice does not permit water to accumulate in low gob areas where acid-producing surface areas would be exposed to the water. Pipes instead of ditches are provided to conduct the water by gravity to these sumps wherever possible. These large sumps provide detention and prevent surges of mine water from entering a stream. By regulated pumping the discharges are equalized over a 24-hour period.

COMPACTION OF COAL REFUSE TO MINIMIZE ACID DRAINAGE

Coal refuse disposal showing coal refuse deposited behind a clay face wall and on top of a previously deposited layer of coal refuse which has been leveled and thoroughly compacted by the directed travel of refuse trucks.

MINING METHOD: Underground mining - wet coal preparation.

LOCATION: Western Pennsylvania, Freeport Seam Coal.

RESULT ACHIEVED: Coal refuse deposited in this location does not produce appreciable acid drainage. Much of the rainfall on the pile flows off over the surface rather than through refuse material.

DESCRIPTION: The coal refuse deposited on this pile contains a relatively large amount of acid-producing material, and when deposited in a haphazard fashion can produce appreciable quantities of acid drainage. The refuse is produced in a coal preparation operation and has a top size of about 4 inches with sufficient fine material for good compaction. Additionally, the refuse shows excellent weathering characteristics so that exposure to atmospheric conditions for a few months will soften the refuse and aid compaction.

In the construction of this refuse pile a face wall of earth is deposited about 4 feet high at the outer edge of the pile. The back of the pile is sealed against

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a hillside from which vegetation is cleared before refuse is deposited on it. Refuse is hauled by truck from the preparation plant and deposited in 10-ton piles adjacent to each other so that a layer thickness of 36 inches will be realized when the pile is leveled and compacted. These piles are permitted to weather for a period of 3 to 6 months before they are leveled and initially compacted with a bulldozer. Further compaction of refuse is achieved by directing the travel of loaded trucks carrying clay or refuse over the entire surface. Successive layers are similarly constructed.

The upper surface of each layer of the refuse pile is sloped into the hill so that rainfall on the refuse will flow off quickly with a minimum of penetration into the refuse pile and without disturbing the clay seal. Water draining off the refuse pile has been found occasionally to be slightly acid; this, however, is dissipated when it is mixed with a flow of surface water from the hill above the pile so that the flow of water from the property is not acid.

CHANNELING RUNOFF WATER AWAY FROM COAL REFUSE PILE

Coal refuse disposal showing drainway to carry surface water around refuse pile.

MINING METHOD: Underground mining - wet coal preparation.

LOCATION: Northern West Virginia, Pittsburgh Seam Coal.

RESULT ACHIEVED: Surface water is diverted around the coal refuse pile rather than flowing over and through it.

DESCRIPTION: Coal refuse is deposited in a layer and compacted. A drainage channel is maintained alongside the coal refuse pile so that surface water from the drainage area above the pile is conducted around the pile and into the stream below the refuse pile. By this technique water which would otherwise flow over and through the refuse pile is prevented from contact with the refuse and the acid-producing materials contained therein.

COVERING AND SEEDING COAL REFUSE PILE

Vegetative cover established on covered refuse pile to minimize erosion.

MINING METHOD: Surface

LOCATION: Western Kentucky Coal Field, Hopkins County, Kentucky. Carbondale Formation, Seams 9, 11 and 12.

RESULT ACHIEVED: Acid water runoff from refuse pile to stream minimized.

DESCRIPTION: Old refuse pile in valley, compacted and graded on 23.2 acres. Cost of covering 23.2 acres of coal refuse with average of 3 ft. of overburden materials and soil:

Cost Breakdown	Per Acre	Total
Dirt Moving	$343.06	$7,959.06
Establishment of Vegetative Cover	95.73	2.220.97
	$438.79	$10,180.03

The spoil and soil used for covering the refuse pile were available immediately adjacent to the refuse dump which reduced the costs of earth moving. The covering material was moved with a self-propelled scraper pan and leveled off with a road maintainer. The covering material was native acid soil of sandstone origin and spoil. It was heavily limed with a lime-spreader truck, fertilized and drill-seeded to Balboa rye and Kentucky 31 fescue. Later on in the late winter it was also seeded to Korean lespedeza.

ADJUSTMENT OF PUMP DISCHARGE TO FIT DISCHARGE REQUIREMENTS

Deep Well Pump Installation Drawing Water from Mine Sump 370 Feet Below

MINING METHOD: Mechanized underground mining.

LOCATION: Western Pennsylvania, Pittsburgh Seam Coal.

RESULT ACHIEVED: Water seeping into the pool contacts less gob and picks up less acid and iron. The pH of the discharge has changed from 6.0 to 6.7 and the iron content from about 200 mg/l to the neighborhood of 50 mg/l.

DESCRIPTION: Abandonment of the existing borehole discharges on retreat sections allowed a large pool of water to form and threatened to inundate the main haulage area. Two deep well pumps were installed in a borehole 370 feet deep. At the outset of the operation of these pumps the level of water was at elevation 760 and the area covered was quite large. The iron content of the water was prohibitive and discolored the receiving stream for a distance of ten miles. Several methods of pumping were tried, varying the time and interval of pumping periods. Finally, the pumps were operated continuously and the water level was lowered to elevation 710. This diminished the area covered by water and improved the water quality. The seepage water is of an alkaline nature and since this area is abandoned and has no circulating air currents, the exposed gob area apparently does not oxidize rapidly. Today the stream is discolored for a short distance below the discharge point and from there on the stream is clear and contains an abundance of aquatic life.

APPENDIX I

ORSANCO RESOLUTION NO. 5-60, ACID MINE-DRAINAGE CONTROL MEASURE

(Adopted January 14, 1960, and amended January 10, 1963)

WHEREAS: By resolution adopted on the 6th day of April, 1955, the Ohio River Valley Water Sanitation Commission promulgated a statement of policy and procedures for the control of industrial-waste discharges into waters included within its jurisdiction by the terms and provisions of the Ohio River Valley Water Sanitation Compact; and

WHEREAS: Waters of the Ohio River Valley Water Sanitation District are being polluted by acid discharges from coal mining and related operations, hereinafter referred to as "acid mine-drainage," contrary to the language and intent of the Ohio River Valley Water Sanitation Compact; and

WHEREAS: It has been demonstrated that the conscientious application of certain principles and practices will, under certain conditions, alleviate the pollution from acid mine-drainage;

NOW, THEREFORE: In furtherance of the policy and procedures as above set forth and for the general purpose of contributing to the achievement of the objectives specified in Article I of the Ohio River Valley Water Sanitation Compact;

BE IT RESOLVED: That the following measures are hereby adopted by the Commission for the control of acid mine-drainage pollution in the Ohio River Valley Water Sanitation District and pursuant to the statement of policy and procedures are to be followed by the signatory states:

I. (a) Surface waters and ground waters shall be diverted where practicable to prevent the entry or reduce the flow of waters into and through workings.

(b) Water that does gain entry to the workings shall be handled in a manner which will minimize the formation and discharge of acid mine-drainage to streams.

II. Refuse from the mining and processing of coal shall be handled and disposed of in a manner which will minimize discharge of acid mine-drainage therefrom to streams.

Where acid-producing materials are encountered in the overburden in stripping operations, these materials shall be handled so as to prevent or minimize the production of acid mine-drainage, taking into consideration the need for stream pollution prevention and all economic factors involved.

III. Discharge of acid mine-drainage to streams shall be regulated insofar as practicable to equalize the flow of daily accumulations throughout a 24-hour period.

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IV. Upon discontinuance of operations of any mine all practicable mine-closing measures, consistent with safety requirements, shall be employed to minimize the formation and discharge of acid mine-drainage.

V. Under appropriate circumstances, consideration shall be given to the treatment of acid mine-drainage by chemical or other means in order to mitigate its pollutional properties.

Nothing stated in this control measure shall be construed to relieve any municipality, corporation, person or other entity from responsibility for compliance with existing federal, state and local laws and regulations.

APPENDIX II

ORSANCO RESOLUTION NO. 14-59, NOTIFICATION OF SPILLS AND ACCIDENTAL DISCHARGES

(Adopted September 30, 1959, and amended January 12, 1961)

WHEREAS: Spills and other accidental discharges of sewage, industrial wastes and other substances which are contrary to the language and intent of the Ohio River Valley Water Sanitation Compact and are in violation of the treatment standards and other regulations duly promulgated by the Ohio River Valley Water Sanitation Commission are likely to occur from time to time, notwithstanding efforts to prevent them; and

WHEREAS: Such spills and discharges are likely to have such a deleterious effect upon the quality of the waters of the Ohio River Valley Water Sanitation District as to cause serious damage to or to impose unwarranted burdens upon the users thereof;

BE IT RESOLVED: That, in order to minimize the adverse effect which the above-described occurrences may have upon users of waters within its jurisdiction, the Ohio River Valley Water Sanitation Commission does hereby establish the following procedure for the dissemination of information with regard to such occurrences among agencies, municipalities, corporations, persons or other entities which or who may be affected thereby:

1. Each and every municipality, corporation, person or other entity which or who may cause or be responsible for any spill or accidental discharge into any of the waters of the Ohio River Valley Water Sanitation District of sewage, industrial waste or other substance of such character and in such quantity as to be unsightly or deleterious to the quality of such waters shall give immediate notification thereof by telephone to the water pollution control agency of the state in which such spill or discharge may occur;

2. Such notification shall set forth the time and place of such spill or discharge, the type or types and quantity or quantities of the material or materials included therein, action or actions taken to stop such spill or discharge and to minimize the polluting effect thereof, the measure or measures taken or to be taken in order to prevent a recurrence of any such spill or discharge and such additional information as may be requested by the state agency;

3. It shall be the responsibility of each industrial establishment or other entity discharging directly to a stream to have available insofar as practicable and reasonable the following information pertaining to those

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substances that are employed or handled in its operations in sufficiently large amounts as to constitute a hazard in case of an accidental spill and discharge into a public stream:

(a) Potential toxicity in water to man, animals and aquatic life,

(b) Details on analytical procedures for the quantitative estimation of such substances in water,

(c) Suggestions on safeguards or other precautionary measures to nullify the toxic effects of a substance once it has gotten into a stream;

4. A written verification of such report shall be submitted upon request of the state agency;

5. Whenever any such spill or discharge may affect interstate waters which are within the jurisdiction of the Ohio River Valley Water Sanitation Commission, the state agency receiving the notification to be given as above provided shall promptly relay the information contained therein to the Ohio River Valley Water Sanitation Commission by telephone in order to permit it to alert downstream state agencies and water users which are or who may be adversely affected by such spill or discharge;

6. Nothing herein shall relieve any municipality, corporation, person or other entity from responsibility for complying with the terms, provisions and conditions of the Ohio River Valley Water Sanitation Compact or with treatment standards and other regulations promulgated under authority thereof or from responsibility for complying with any federal, regional, state or local statutes, ordinances or regulations which may be applicable.

APPENDIX III

REFERENCES

(From the Coal Industry Advisory Committee Library on Mine-Drainage, Bituminous Coal Research, Monroeville, Pennsylvania)

1. Braley, S. A., *Summary Report of Commonwealth of Pennsylvania* (Department of Health) Industrial Fellowship Nos. 1-7, Aug. 1946 - Dec. 1953. Mellon Institute Fellowship No. 326 B, Feb. 1954. (Pages 11, 17, 30, 69).

2. Braley, S. A., *The Oxidation of Pyritic Conglomerates.* Mellon Institute Research Project No. 370-6, Nov. 1960.

3. Moulton, E. I., et al., *Acid Mine-Drainage Problem in Ohio.* Eng. Exp. Sta., Ohio State Univ. Bull. 166. (Pages 5, 13, 37).

4. Brant, R. A., and Moulton, E. I., *Acid Mine-Drainage Manual,* Eng. Exp. Sta., Ohio State Univ. Bull. 179. (Pages 1, 8, 11, 34).

5. Tracy, L. D., *Mine Water Neutralizing Plant at Calumet Mine,* Mining and Metallurgy I, 29-30, 1920.

6. Temple, K. L., and Koehler, W. A., *Drainage from Bituminous Coal Mines,* W. Va. Univ. Exp. Sta. Research Bull. No. 25 (1954). (Page 9).

7. Braley, S. A., *Mine Drainage from Coal Mines,* Mining Engineering Vol. III, No. 8, August (1951), AIME Trans. Vol. 190.

8. Braley, S. A., *Neutralization of Acid from Bituminous Coal Mines,* Commonwealth of Pennsylvania, Department of Health, Harrisburg, Pa., Apr., 1951.

9. Burke, S. P., and Downs, R. *Oxidation of Pyritic Sulfur in Coal Mines,* AIMME, Tech. Pub. No. 769 (1947) Trans. AIMME, 130, (1938).

10. Braley, S. A., *Evaluation of Mine Drainage Water,* Mining Eng., Jan. 1957.

11. Selvig, W. A., and Ratcliff, W. C., *The Nature of Acid Water from Coal Mines and the Determination of Acidity,* J. Ind. Eng. Chem. 14 (1922).

12. Braley, S. A., *Mine Acid Control, A New Approach,* Coal Age, March 1957.

13. Braley, S. A., *Strip Mines Show No Stream Pollution,* Mining Congress Journal, Sept. 1952.

14. Braley, S. A., *An Evaluation of Mine Sealing,* Special Report, Mellon Institute, Feb. 1962.

APPENDIX IV

REGULATORY AGENCIES OF THE SIGNATORY STATES

ILLINOIS	Technical Secretary State Sanitary Water Board Springfield, Illinois 62706
INDIANA	Technical Secretary Indiana Stream Pollution Control Board 1330 West Michigan Street Indianapolis, Indiana 46207
KENTUCKY	Executive Director and Chief Engineer Kentucky Water Pollution Control Commission 275 East Main Street Frankfort, Kentucky 40601
NEW YORK	Director Bureau of Water Resources Services Division of Environmental Health Services New York State Department of Health 84 Holland Avenue Albany, New York 12208
OHIO	Chief Sanitary Engineer Division of Sanitary Engineering Ohio Department of Health Columbus, Ohio 43215
PENNSYLVANIA	Sanitary Water Board P. O. Box 90 Harrisburg, Pennsylvania 17120
VIRGINIA	Executive Secretary State Water Control Board 415 West Franklin Street Richmond, Virginia 23220
WEST VIRGINIA	Executive Secretary State Water Resources Board 1709 Washington Street, East Charleston, West Virginia 25301