

# SEALING OF COAL MINES

## + Will Reduce the Acidity

## Of Their Effluent Waters

By R. D. LEITCH

Associate Chemical Engineer  
Pittsburgh Experiment Station  
U. S. Bureau of Mines  
Pittsburgh, Pa.

SINCE 1928 the United States Bureau of Mines has directed attention to the benefits to be derived from sealing abandoned mines and worked-out sections of active mines. Sealing lessens stream pollution and also reduces losses and expense from corrosion of equipment handling acid mine drainage.<sup>1</sup> The effect of sealing is to exclude air from contact with the ferrous sulphide, ordinarily called pyrite, occurring in coal, and particularly in the strata immediately above and below the coal beds, and so prevent oxidation of the pyrite to sulphate. In later years others<sup>2</sup> have supplied considerable data and information. Probably the most important recent contribution to previous information, certainly that of most recent general interest, is the sealing of abandoned coal mines under the program of the Civil Works Administration for unemployment relief.

<sup>1</sup>Leitch, R. D., and Yant, W. P.: "A Comparison of the Acidity of Waters From Some Active and Abandoned Mines," U. S. Bureau of Mines Report of Investigations 2895, 1928, 8 pp. Leitch, R. D.; Yant, W. P., and Sayers, R. R.: "Effect of Sealing on Acidity of Mine Drainage," U. S. Bureau of Mines Report of Investigations 2994, 1930, 11 pp. Leitch, R. D.: "A General Review of the United States Bureau of Mines Stream Pollution Investigation," U. S. Bureau of Mines Report of Investigations 3098, 1931, 7 pp. "Sealing Abandoned Mines as a National Industrial Recovery Act Project," U. S. Bureau of Mines mimeographed report, August, 1933, 8 pp.

<sup>2</sup>Stevenson, W. L.: "Coal-Mine Drainage Disposal," Proc. Third International Conference on Bituminous Coal, Carnegie Institute of Technology, 1931, II, pp. 913-920. Harris, Wesley S.: "Controlling the Acidity of Mine Water by Sealing," Indiana Coal Mining Institute, February, 1932. Carpenter, Lewis V., and Herndon, L. K.: "Acid Mine Drainage From Bituminous-Coal Mines," Research Bulletin No. 10, Engineering Experiment Station, West Virginia University, September, 1933, p. 13. Van Zandt, H. M.: "Impounding Mine Water to Reduce Acidity in the Coal Mines of Western Pennsylvania," Proc. Coal Mining Institute of America, 1933 (in press).

Published by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)

Coal-mine drainage usually is acid. This condition is caused by moist air coming in contact with pyrite in exposed coal-bearing strata and oxidizing the insoluble iron pyrites to water-soluble iron sulphates. These iron sulphates appear as white or greenish-white crystals on the coal ribs, mine floor or other places where iron pyrite is exposed to contact with air. Entering surface or subsurface waters dissolves the ferrous and ferric sulphate crystals so formed; further oxidation and chemical action known as hydrolysis liberate free sulphuric acid and iron oxide. The latter usually is a precipitate of yellow to red hydrated oxides of iron, which when it settles out, commonly is known as "sulphur mud." Precipitation and settling are accelerated by dilution of the mine drainage and quiescent conditions, and therefore usually occur to a large extent in stream beds outside the mine, where the characteristic red color has become familiar to many.

The free sulphuric acid liberated simultaneously with the iron oxides is colorless. It is the most active corrosive agent of coal-mine drainage. Moreover, the oxidation of pyrite to form iron sulphates, with subsequent hydrolysis to form iron oxide and free sulphuric acid, is continuous and the various steps usually are coexisting.

The idea of sealing abandoned mines or parts of active mines to exclude air and prevent acid formation, yet at the same time permit drainage to flow, occurred to the writer early in 1927. At that time he observed that drainage from a number of naturally caved mines was

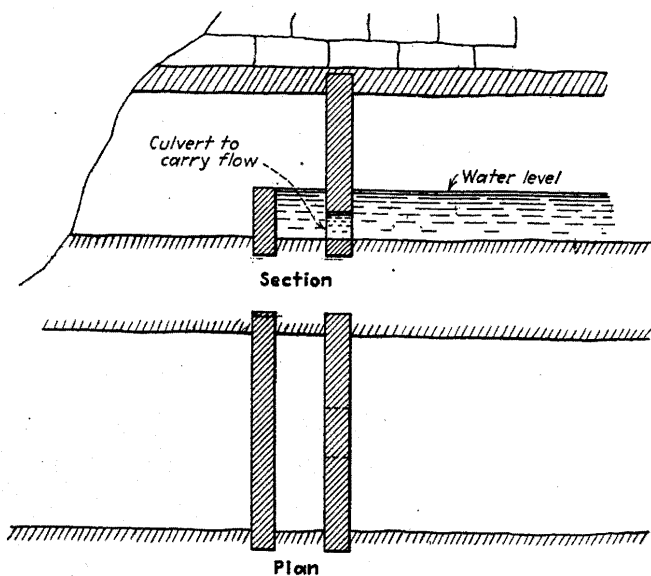


Earth Dam and Weir Box Seal  
by Raising Water Level.

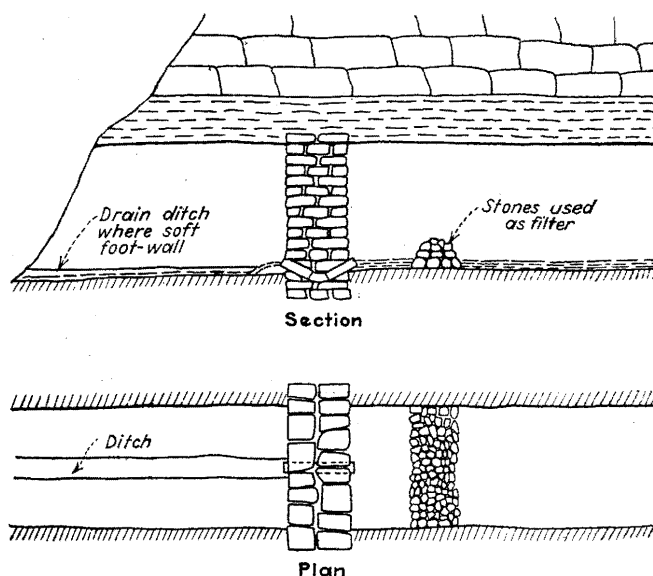
either not acid or was much less acid than that from open mines in the same district. The obvious reason for this condition appeared to be the absence of air in the caved mines. Laboratory experiments conducted soon afterward demonstrated that if oxygen could be kept from contact with iron pyrites, acid would not be formed. Since that time repeated practical illustrations of the theory have been observed and reported in the various references listed.

Early in the summer of 1933 it seemed likely that the public benefits to be realized from extensive sealing of abandoned mines would justify the necessary expenditure of public money made available for unemployment relief. Consequently, the Bureau of Mines advocated such use of relief funds. Damages done by acid drainage were cited, benefits to be expected from the sealing program were listed, and the general suitability of the project as a relief measure was described, with probable cost of the work. Sportsmen's organizations early realized the benefit of the work from a recreational standpoint, but failed to emphasize the economic value of reduced corrosion and the savings in treatment of public and industrial water supply.

In October, 1933, officials of the Penn-



Concrete Air Seal for Drift Mine.



Rock Seal With Cement-Mortar Tile Drain.

sylvania Department of Health interested the U. S. Bureau of Public Health Service in the project, and that bureau obtained CWA funds because of the public-health aspects of the program. The work was begun early in December, 1933, as a federal CWA project, under the general direction of the U. S. Bureau of Public Health Service. The fund was divided among the several major coal-producing States upon estimates of the probable amount of work necessary in each. The actual direction of sealing abandoned mines in each State was assigned to the respective departments of health. Upon request the U. S. Bureau of Mines loaned the services of the writer to the U. S. Bureau of Public Health Service for approximately 2½ months to prepare directions for clos-

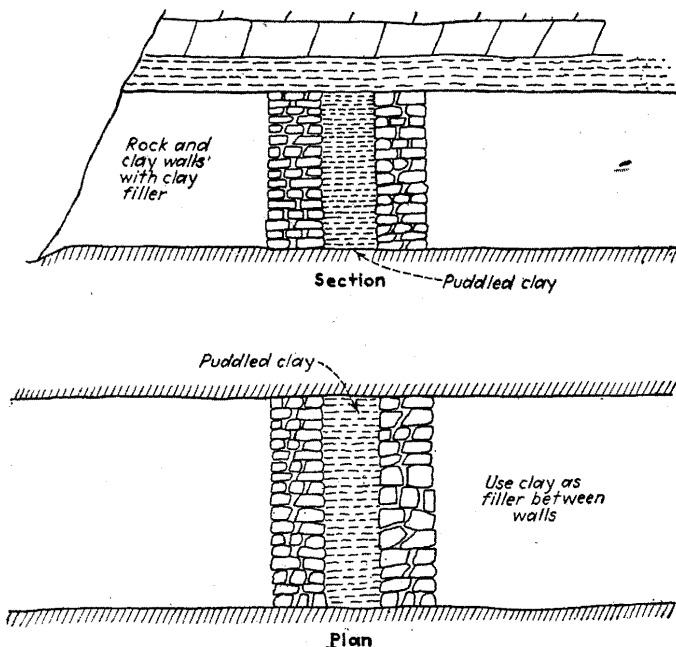
ing abandoned mines, advise in the selection of personnel, plan methods for the collection and analysis of samples, and assist in other related technical problems of less importance. A sum of \$1,500,000 originally was allocated by the CWA for this program, but actually less than one-fifth of this amount was spent as a federal CWA project.

The States selected for allocation of money for mine-sealing work were: Pennsylvania, West Virginia, Alabama, Ohio, Kentucky, Maryland, Tennessee, Virginia, Illinois and Indiana. The allocation of money to the States was made by public health officials on the basis of probable work necessary in each State; these amounts ranged between approximately \$20,000 and \$600,000. The number of persons allowed for the work in

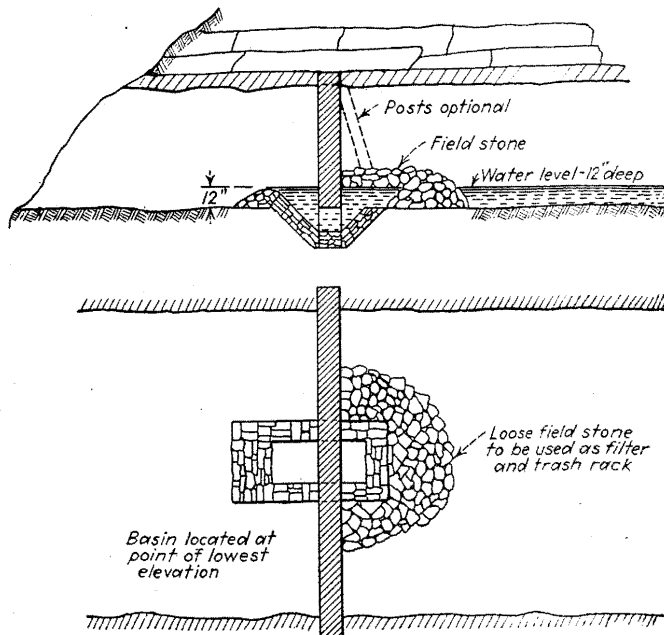
each State ranged from about 300 to 2,600. Actually these quotas were never realized; the highest percentage is believed to have been employed in West Virginia, where for a short time nearly 75 per cent of its entire quota was at work.

Under federal CWA regulations the work was to last 2½ months, ending on Feb. 15, 1934. A few of the States began work soon after official notification of allocation of the money, while others were not able to start for several weeks. At best, the magnitude of the work and the time required for organizing it precluded any possibility of completion in 2½ months, and the general federal CWA "stop order" of Jan. 19, 1934, placed an additional handicap on continued progress. The necessity for

Rock Wall With Clay Mortar for Dry Openings



Air-Trap Seal With Field-Stone Dam to Exclude Dirt.



procuring releases on all properties—often from different owners of land and mineral rights—before sealing could be begun, the lack of tools and supplies, and finally the unusually severe winter weather of 1933-34 were all serious handicaps. Despite adverse conditions, sufficient work was done and interest aroused so that when the project passed out of federal control, West Virginia, Pennsylvania and Ohio carried on the work as State and finally as county projects in a limited manner for several months, at first as State CWA projects and later under provisions of the Federal Emergency Relief Administration.

In a paper<sup>3</sup> delivered before the con-

"has been continuously carried on, though only about 150 men are at work in ten counties now (September, 1934), compared to nearly 1,000 in seventeen counties during the winter (1933-34) months." He states that it is estimated that one and one-third million pounds of acid are flowing from abandoned mines into West Virginia streams per day and that this weight slightly exceeds 36 per cent of the total from all mine drainage in the State. Idle mines add another 27 per cent of the total acid in all streams. Some or even most of these mines may never be operated again, so that the improvement possible in West Virginia is at once obvious. He states

that cattle are now drinking water issuing from sealed sections of these abandoned mines closed under our program . . .

"Contrary to expectations, the results of sealing have shown up much sooner than anticipated . . . even with many of the seals shrinking and admitting air, measurable and visible results are already apparent, showing acid reductions of 25 per cent and better.

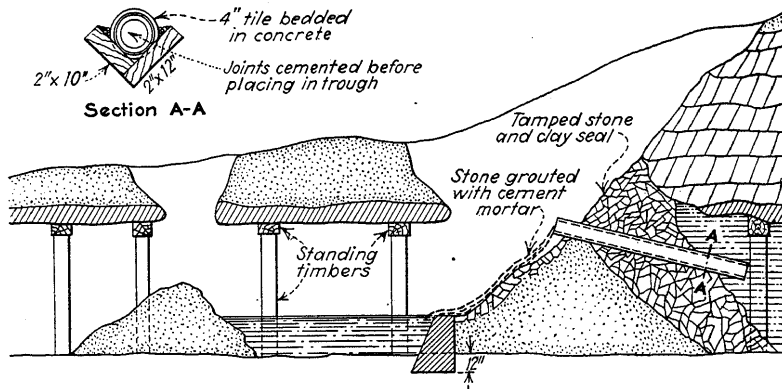
"Exceptional cooperation and support have been received from both coal operators and surface owners. A substantial percentage of the material consisted of salvaged stone, lumber, brick, etc., donated by the coal companies and surface owners. . . . The program should be carried to completion in West Virginia. Economically, it is known that the *annual expense* caused by acid waters is many times the total cost of the preventive program."

On Oct. 4, 1934, B. F. Hatch, Sanitary Engineer, Department of Health, Columbus, Ohio, delivered a paper, entitled "Sealing Abandoned Coal Mines," before the Eighth Annual Ohio Conference on Sewage Treatment. This paper furnished additional information, some of which is quoted:

"There are no statutes in Ohio requiring mine owners to close openings when mines are abandoned. Owners of surface rights usually have insufficient funds to carry on the necessary construction. The land is often not worth the cost. Therefore, at the present time, the financial burden of any program of sealing abandoned mines must be borne either by the State or Federal Government." No survey for locating and listing abandoned mines in Ohio had been made previous to the sealing program. "Therefore, it may be fairly stated that in Ohio the mine-sealing program was started under the severe handicap of lack of basic information necessary to commence full-scale operations immediately.

"In closing drift openings it has been our practice to follow the methods of nature and resort to earth fills wherever possible. Naturally, this type of closure cannot be used on wet openings or along vertical outcrops. The earth fill, however, may be used in about nine openings in ten, and is the cheapest method of sealing. A complete closure of this type will cost on the average about \$15. . . . In closing wet openings—that is, openings from which drainage is flowing—it is usually necessary to use masonry construction. Two general types are used . . . and local materials are used as far as possible. In many localities in the mining district stone from the roof or from adjacent outcrops may be obtained . . . Where such material is not available, the walls are constructed of brick or concrete. Stopplings of this type will cost from \$30 to \$250, depending upon the work required to clean out the openings, to ditch away accumulated drainage from behind cave-ins, and to retimber to provide safe working conditions.

"In slope and shaft mines our work centers largely in filling or capping shafts. . . . It is interesting to note that, although our present mining laws require that open shafts be protected by a fence, no provision is made for the maintenance of the fence. When the fence posts eventually rot off and the fence falls down, a yawning hole varying in depth from 15 to 250 ft. remains as a hazard to the safety of man and beast . . . On tillable farmland the owners prefer that the shafts be filled . . . in order to avoid having an obstruction in the field. In many such



Air-Trap Seal Set Back in Mine Where Roof Is Bad.

vention of the American Water Works Association in September, 1934, E. S. Tisdale, director, Division of Sanitary Engineering, West Virginia Department of Health, enumerated the results of mine-sealing work in that State. He refers to a summary report formulated by the Ohio River Board of Engineers in which the following reasons for unified action in sealing abandoned mines are set forth:

"The report further enumerates in addition to the menace to public health . . . that acid mine drainage is damaging on account of:

"(a) Requiring increased cost of construction and operation of water works.

"(b) Corrosion of the metal and concrete of federally built and operated navigation dams, amounting to several million dollars annually, according to the reports of army engineers.

"(c) Corrosion of metal boats using such streams for transportation of goods in interstate commerce.

"(d) Making difficult the use of water of such streams for industrial and steam-raising purposes.

"(e) Disintegration of metal and concrete culverts and bridge abutments on State and federal highways as shown by studies in certain States.

"(f) Preventing stock watering in the smaller tributary streams and injury to agricultural lands.

"(g) Preventing recreational use of streams."

"The program," says Mr. Tisdale,

<sup>3</sup>Tisdale, E. S., and Lyon, E. W.: "Scope and Accomplishments—Mine Sealing Program—Ohio River Watershed."

that "53 streams in northern West Virginia can be reclaimed, as the mines are 100 per cent abandoned and available for sealing." Up to Sept. 1, 1934, 205 mines have been sealed at a total cost of \$155,000. The number of openings so closed was 4,025, and the average cost per opening has been about \$38. Over 1,100 water tests have been made in order to measure accurately the rate of lessening acid content in the mine water. Approximately 3,500 openings still remain to be sealed, according to Mr. Tisdale's report.

Two papers<sup>3,4</sup> report very decided improvements. Some of these follow:

"Public benefits derived from this project are threefold—that is, prevention of stream pollution, elimination of fire hazards and promotion of public safety. By stopping acid mine drainage, already from 100 to 200 miles of beautiful streams suffering from the ill effects of acid mine drainage have been benefited and are showing recovery to normal streams again. The Coal River . . . is the outstanding example to date. Major H. W. Shawhan, Director of Conservation, is authority for the statement concerning the improvement noted this year in Coal River. Watering stock, fishing and improved recreation facilities have been observed in several streams in Harrison, Marion and Barbour Counties. Carl Hornor, outstanding mining engineer in central West Virginia, in commenting upon the sealed mines on territory adjoining his properties, has stated

<sup>4</sup>Tisdale, E. S.; Lyon, E. W., and McNutt, J. P.: "The 'Why,' 'How' and 'Where' of Abandoned Mine Sealing," State Health Department, Charleston, W. Va.

cases mine refuse from gob piles is used as filling material with a layer of earth on top." This is a sensible method of obtaining necessary filling, and it removes from the land surface, at least some unsightly refuse which, if not already burned, is a continual hazard to both air and stream pollution when left on the surface.

"On Oct. 1, 1934, we had closed 2,089 openings . . . About 75 per cent of these openings have been closed under FERA work projects set up since the close of CWA on April 1, 1934. . . . Under the FERA our maximum employment in all counties has never reached 200 men and has averaged about 130 men. . . . At the present time, between 400 and 500 openings are being closed per month. . . .

"During August and September, samples of the drainage from a number of mines which have been more or less completely sealed for several months were collected and analyzed. Comparison of these analyses with those of samples collected prior to sealing showed marked reduction in acidity in several instances. Taking into consideration the fact that the volume of drainage was found to be less than the previous measurements, the results prove the soundness of the basic theory on which the program is based.

" . . . While the mine-sealing program was inaugurated primarily to rehabilitate surface streams already polluted by mine drainage as a protection to public water supplies, several other advantages have been self-evident as the work has progressed. Enumerated in the order of their relative importance, these are as follows:

"1. Recovery of smaller streams for stock watering.

"2. Protection to property from mine fires started in abandoned openings by trespassers or by adjacent brush fires.

"3. Reclamation of bottom lands formerly rendered unfit for grazing or agricultural purposes by acid drainage.

"4. Protecting public safety by removal of hazards such as unprotected shafts, drift, and slope openings.

"5. Recovery of streams for recreational purposes.

" . . . The program has progressed sufficiently far to warrant the conclusion that the sealing of abandoned mine openings to exclude air from contact with acid-forming materials in the mine workings will materially reduce and perhaps ultimately correct the acid mine-drainage problem from abandoned mines. It is recommended that legislation be immediately enacted in Ohio requiring that mine openings be closed when abandoned by the mining companies involved. . . ."

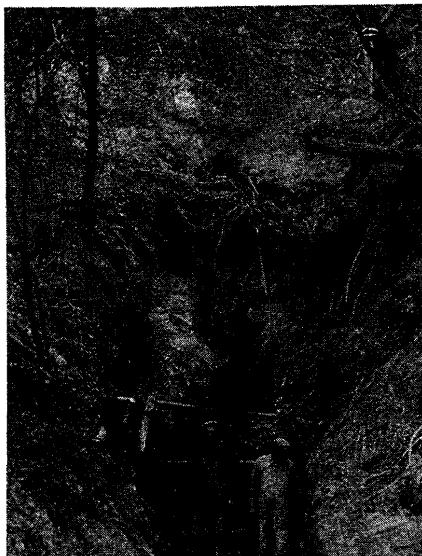
No authoritative information is available from Pennsylvania later than April 28, 1934. In a report<sup>5</sup> covering work done up to that time, J. W. Paul states that 32 mines had been completely sealed. Work has been continued as county relief projects more or less steadily for more than a year under the general direction of the Sanitary Water Board, Pennsylvania Department of Health. According to a paper<sup>6</sup> prepared for the Coal Division of the A.I.M.E. in October,

<sup>5</sup>Paul, J. W., Assistant Director: "Sealing Abandoned Coal Mines in Pennsylvania," May, 1934.

<sup>6</sup>Paul, J. W.: Trans. A.I.M.E., 1934.

1934, a few sealed mines in Pennsylvania have discharged greatly reduced quantities of acid drainage since sealing. At the same time, acidity values were reduced markedly. Forty-two selected openings in West Virginia, Ohio and Pennsylvania were said to be discharging about 21 tons less acid per day at that time than before the mines were sealed. Newspaper reports from time to time cite improved stream conditions in several localities credited to sealing abandoned mines.

In Butler County, Pennsylvania, a group of sixteen workmen under the direction of L. G. Hines and Francis Patterson, working independently of the



Preparations as Laborious as Sealing.

State program, closed sixteen mines on Slippery Rock Creek watershed early in 1934 in accordance with the advice of the writer and following Bureau of Mines procedure. Greatly decreased acidities in the water from several of these openings already have been noted, and four swimming beaches previously unfit for use are stated to have been improved so that they can now be used. Labor was furnished through CWA and RWD authorities of Butler County, and the necessary tools and supplies were furnished by the workmen or bought from funds of sportsmen's organizations of New Castle, Elwood City and Slippery Rock. The average cost to close the 32 openings in these mines, in 21 of which water traps were constructed, was \$56. The average cost for traps was \$86. The cost of the traps was kept low by using materials available at or near the sites. A total of 3,100 man-hours was required and the work was very well done. The residents of that section are highly elated at the definite improvement already noted.

The procedure of excluding air to reduce formation of acid can be applied in active mines where the room-and-pillar system of mining is used. It has been

shown (U. S. Bureau of Mines Report of Investigations 2994) that acid water "made" in sealed sections of active mines becomes alkaline in a relatively short time after sealing. This finding is supported further by Mr. Harris' in practical experience in southern Indiana coal fields. In 1928 Mr. Harris said<sup>7</sup> that sealing worked-out sections of active mines "will be the means of saving the coal industry many hundreds of thousands of dollars annually." Corrosion of pipes and pumps incidental to handling acid mine drainage is often a very expensive item in operation of mines. As work proceeds, sections finished could be sealed if water originates there. The alkaline effluent resulting in a short time not only will remove the previous acid burden from those sections but will have a definite neutralizing value when mixed with acid waters from active sections that cannot be so treated. The acidity of the main discharge will be reduced to that extent. It is not unreasonable to predict that this sealing procedure would result in an alkaline effluent for the whole mine long before completion of mining operations. The probable reduction in corrosion that might be noted by mine operators is obvious.

It seems quite conclusive that sealing abandoned mines will remove a considerable pollution burden from natural streams. Many streams in coal-producing States are polluted only by wastes from abandoned mines. The advantages of transforming these damaging wastes to beneficial alkaline waters seem evident from reports already available from a few of the States where sealing has been applied. Most responsible officials in direct contact with the work report wholehearted cooperation, particularly from mine operators. Those who have studied the question from an economic standpoint have uniformly admitted that chemical neutralization is generally impracticable and that sealing abandoned mines to exclude air and yet permit drainage to continue to flow is the first practicable method yet suggested for decreased stream pollution by acid mine waters.

So far as the mining industry is concerned, general application of the idea to worked-out sections of operating mines can effect a great saving in operating costs, and the improvements that can result from sealing abandoned mines will remove a great deal of the general criticism directed at the industry as an outstanding contributor to stream pollution. The nature and magnitude of this work suggest the necessity for federal or State funds. However, the enormous cost of present water treatment and the direct or indirect troubles experienced by so many persons indicate that if it is impossible to obtain public money for this work it could be supported profitably by other organizations.

<sup>7</sup>Private communication to the U. S. Bureau of Mines.