RI 8730

Bureau of Mines Report of Investigations/1982

NATIONAL MINE HEALTH & SAFETY ACADEMY
REFERENCE COPY
Do Not Remove From Learning Resource Center

Sealing Openings in Abandoned Mines by Pneumatic Stowing

By Slavoljub D. Maksimovic and Jennings R. Lipscomb

UNITED STATES DEPARTMENT OF THE INTERIOR

Report of Investigations 8730

Sealing Openings in Abandoned Mines by Pneumatic Stowing

By Slavoljub D. Maksimovic and Jennings R. Lipscomb

NATIONAL MINE HEALTH & SAFETY ACADEMY
REFERENCE COPY
Do Not Remove From Learning Resource Center

UNITED STATES DEPARTMENT OF THE INTERIOR
James G. Watt, Secretary

BUREAU OF MINES
Robert C. Horton, Director

This publication has been cataloged as follows:

Maksimovic, S. D

Sealing openings in abandoned mines by pneumatic stowing.

(Report of investigations ; 8730)

Includes bibliographical references.

Supt. of Docs. no.: I 28.23:8730.

1. Mine filling. 2. Stone, Crushed. 3. Gravel. 4. Sand. 5. Compressed air. I. Lipscomb, Jennings R. II. Title. III. Series: Report of investigations (United States. Bureau of Mines) ; 8730.

TN23.U43 [TN292] 622s [622'.8] 82-600239

CONTENTS

ILLUSTRATIONS

TABLES

TABLES--Continued

SEALING OPENINGS IN ABANDONED MINES BY PNEUMATIC STOWING

Slavoljub D. Maksimovic [1] and Jennings R. Lipscomb [2]

ABSTRACT

The Bureau of Mines, through a memorandum of agreement with the State of Ohio, tested a method of constructing seals in abandoned mine openings in Ohio by means of pneumatic stowing of crushed limestone and gravel with sand. A total of five openings and one shaft were backfilled. Pneumatic stowing uses compressed air to convey material through a pipeline and into the mine opening. The stowing equipment consists of a power supply, a blower, a feeder to inject the material into the pipeline through an airlock, and a nozzle for directing the placement. Material is ejected from the nozzle at high velocity, creating a high-compaction fill upon impact. Well-graded aggregate up to 2 inches in diameter and having sufficient fines is used as fill. The stowing method is safer and faster than conventional methods, is cost competitive, prevents trespass into abandoned mine openings, and eliminates or reduces the exposure of workers to possible hazards since the discharge nozzle can be kept at the mouth of the opening. The equipment is mobile, and, with some modification, the technique could be widely used for sealing abandoned and active mine openings, even in remote locations and during severe weather conditions.

[1] Mining engineer, Pittsburgh Research Center, Bureau of Mines, Pittsburgh, Pa.
[2] Hydrologic technician, Pittsburgh Research Center (Morgantown Office), Bureau of Mines, Morgantown, W. Va.

INTRODUCTION

Pneumatic conveying is the transport of solids in a gas, generally air.[3] Pneumatic conveying has been used in various industries, including the chemical, construction, and food industries; more recently, it has been used in the mining industry for conveying sand, cement, clay, fly ash, and coal.

Pneumatic stowing was developed in European coal mines and has been used there since the early 1930's. This type of backfilling has usually been associated with longwall mining, although it has been used on a limited scale in room-and-pillar mining, where additional support is required. It it also used to reduce subsidence and to increase the percentage of coal extraction. The method has also been applied to convey coal and mine waste pneumatically to the surface, supplementing the primary hoisting system. For this purpose, vertical and horizontal pipelines were used.[4]

Pneumatic stowing using low-pressure compressed air is a relatively new method in North American mines. It has been used to move mine waste independently of the coal or ore, and to bring cutting material from the bottom of raise drill shafts to the surface through large holes and pipelines, thus eliminating long underground transportation. It has also been used to remove mine waste from the working area and to place it underground into mined-out areas.[5]

Pneumatic stowing is also a relatively novel method for backfilling abandoned mine openings. During the backfilling, the material is ejected from a nozzle at varying velocities; upon impact, the material creates a high-density fill that will support the mine roof and ribs. Ejection rates greater than 100 tons per hour have been achieved for quick seal construction. The composition of the fill material can be modified by adding cement or bentonite.

This study of pneumatic stowing was initiated in response to the Office of Surface Mining requirements for mine closure and to supplement the Mine Safety and Health Administration (MSHA) requirements of Title 30, section 75.1711.[6] During the summer of 1979 and the winter of 1980-81, the Bureau of Mines demonstrated pneumatic stowing as a new technique of constructing mine seals at selected sites in Pennsylvania and Ohio. The purpose of these demonstrations was to backfill abandoned mine openings to prevent trespass, as well as to evaluate the effectiveness of the technique. The results of the first demonstration, at a Pennsylvania mine that was being closed, are published in a separate report.[7] The results of the demonstration in Ohio are presented in this report.

---

[3]Weber, M., and N. Schauki. Pneumatic and Hydraulic Conveying. National Coal Board, Great Britain, Trans. 3750, A.2691/JG; Aufbereit.-Tech., No. 10, October 1967, pp. 549-556.

[4]Ball, D. G., and D. H. Tweedy. Pneumatic Hoisting From Underground. CIM Bull., v. 68, January 1975, pp. 59-63.

National Coal Board, Great Britain. Pneumatic Stowing From the Surface at Crookhall Colliery. Inf. Bull. 56/158, 1958, 8 pp.

[5]Mason, R. H. New Methods Speed Shaft-Making. Coal Min. and Process., v. 18, No. 2, February 1981, pp. 54-56.

[6]U.S. Code of Federal Regulations. Title 30--Mineral Resources. Chapter VII--Office of Surface Mining Reclamation and Enforcement, Department of the Interior; Subchapter K--Permanent Program Performance Standards; Parts 816-817--Surface and Underground Mining Activities. Chapter I--Mine Safety and Health Administration, Department of Labor; Subchapter O--Coal Mine Safety and Health; Part 75--Mandatory Safety Standards--Underground Coal Mines; Sec. 75.1711--Sealing of Mines. July 1, 1981.

[7]Maksimovic, S. D., and J. C. Draper. Building Seals by Pneumatic Stowing in Mine Closure Operations. BuMines RI 8729, in press; for information, contact S. D. Maksimovic, Bureau of Mines, Pittsburgh, Pa.

ACKNOWLEDGMENTS

The Bureau of Mines acknowledges the cooperation of the Ohio Department of Natural Resources and especially Charles E. Call, Chief, Division of Reclamation, and Terry Van Offeren, of Mined Land Reclamation, for their efforts and supervision during the field operations and for providing the baseline data relevant to the project.

PNEUMATIC STOWING DEMONSTRATION

The Bureau of Mines, through a memorandum of agreement with the Ohio Department of Natural Resources, Columbus, Ohio, tested a method of constructing seals by pneumatic stowing at six abandoned mine openings at three mines in Ohio. This method was in compliance with the requirements of the U.S. Code of Federal Regulations (30 CFR 75.1711), which includes sealing of shaft openings, slope or drift openings, and openings of active mines. Section 75.1711 requires that the fill consist of incombustible material, which should be used for the first 50 feet from the bottom of the shaft when the shaft is sealed, and for a distance of at least 25 feet into slope or drift openings. No other approvals were necessary for the project.

Equipment

A pneumatic stower is used for backfilling abandoned mine openings. This is a transport system that moves material in a pipeline by applying low-pressure compressed air. A schematic diagram of a pneumatic stower is shown in figure 1. For the Ohio project, the equipment was furnished by Eby Enterprises, Inc., of Kent, Wash., the Bureau contractor. The system includes the following:

1. Power supply unit with 425-hp diesel engine, model Cummins K7A1150P.

2. A compressed-air blower unit to provide air to the feeder. The air compressor, model Gardner Denver 11CDL23B, was rated 4,250 cfm at 12 psi.

3. A feeder to put material into the pipeline through an airlock.

4. Eight-inch-ID pipeline in 10-foot sections.

5. Nozzle for directing and placing the material.

This equipment, installed on a 42-foot-long trailer, weighed approximately 40 tons and was pulled by a tractor. Fill material was loaded by a front-end loader with a 1.5-yd^3 bucket into an 8-yd^3 main hopper, which was located

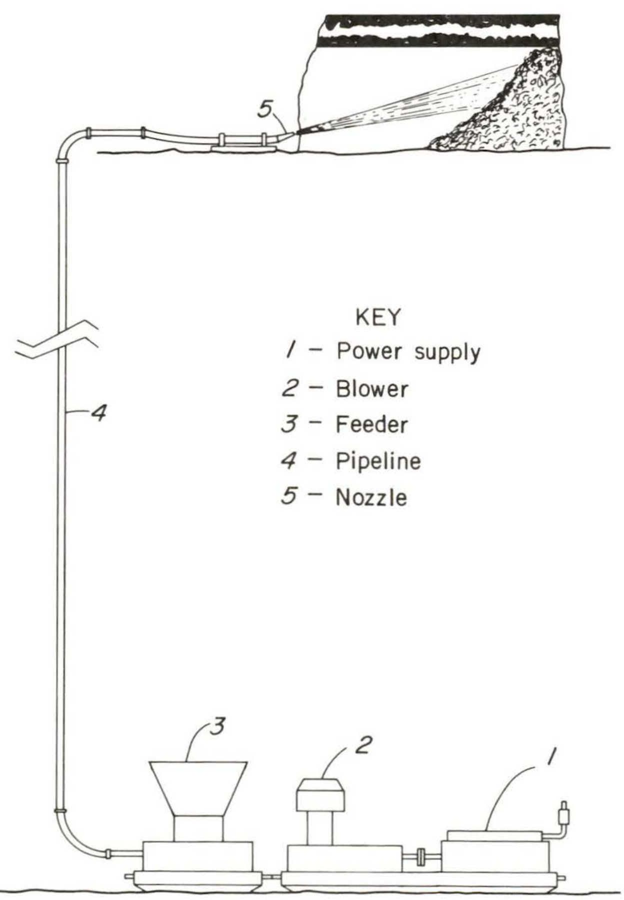

FIGURE 1. - Schematic diagram of pneumatic stower.

over a conveyor system. Another hopper, next to the main hopper, allowed feeding of additives such as cement.

The fill material was conveyed to an infeed hopper located over the airlock feeder, which metered the material into an airstream provided by a blower powered by a diesel engine. This equipment is designed to deliver 100 tons per hour of fill material through an 8-inch-ID pipeline at a distance of 500 feet, less over longer distances. Any type of material up to 3 inches in diameter may be conveyed, even if excessive moisture is present. For the Ohio project, the fill material ranged up to 2 inches in diameter.

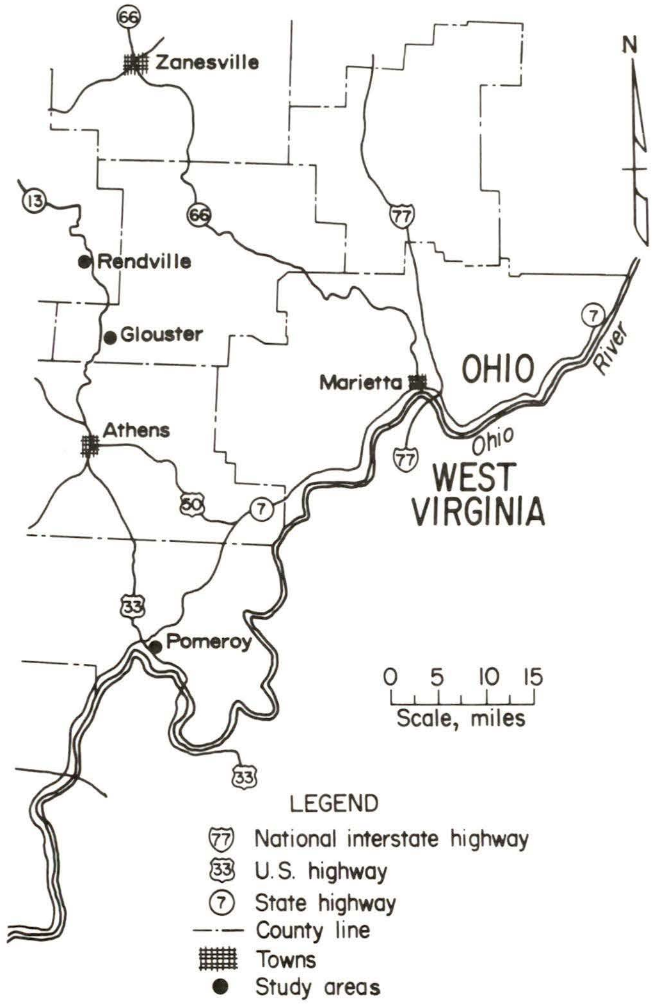

FIGURE 2. - Locations of sites in Ohio.

Description of Test Sites

For the pneumatic stowing demonstrations in the State of Ohio, six openings were selected at three abandoned mines. Three openings are in the Peacock Mine at Pomeroy, Meigs County; one opening in the Hisylvania No. 22 Mine at Glouster, Athens County; and two openings--a shaft and a slope--in the Ohio Collieries No. 268 Mine at Rendville, Perry County (fig. 2). The mines were abandoned between 1909 and 1925. Presently, there is no active underground mining in these areas.

The Peacock Mine at Pomeroy is located near a residential area. Several petitions have been received by the Ohio Department of Natural Resources for closure of the mine openings in this area since they present a safety hazard to residents.

Peacock Mine opening 1 is approximately 1,600 feet north of opening 2. Opening 2, which is less accessible, is about 1,400 feet northwest of opening 3. Opening 3 is on the Ohio River side and opposite the hill from opening 2 (fig. 3). All three Peacock Mine openings are located in the Redstone Coalbed (8-A), which ranges in thickness from 42 inches to 54 inches. A typical stratigraphic section in this area from the uppermost strata down includes Pomeroy Sandstone, Redstone Coal, Redstone Limestone, Marly Shale, and Upper Pittsburgh Sandstone. Redstone Coal is high-quality bituminous coal with low moisture and mineral matter content, 2.2 pct sulfur, and a heat value of 13,550 Btu/lb.[8]

The Hisylvania No. 22 Mine is located off State Route 13, south of the village of Glouster (fig. 2). A railroad track runs parallel to the hillside, which is covered with mine waste extending nearly to the cemetery, south of Glouster. Two

[8]Offeren, T. V. Private communication, 1981. Available upon request from T. V. Offeren, Division of Reclamation, Ohio Department of Natural Resources, Columbus, Ohio.

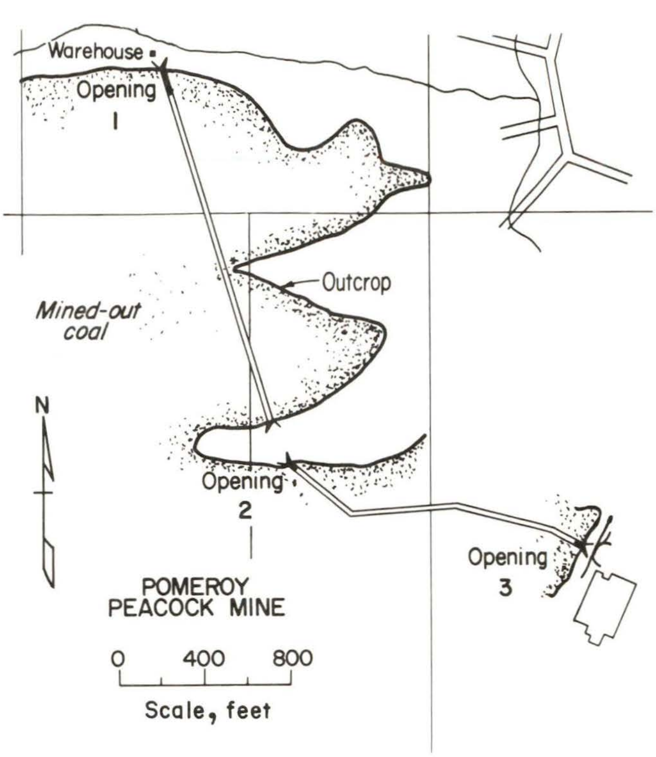

FIGURE 3. - Locations of sealed openings in Peacock Mine.

slope openings are located in the Middle Kittanning No. 6 Coalbed, which ranges in thickness from 28 to 66 inches. A typical stratigraphic section includes the Lower Freeport Shale and Sandstone, Upper and Middle Kittanning Coal, Snow Fork Ironstone, and Strasburg Coal. The Middle Kittanning No. 6 Coal in the Glouster area is of low moisture and mineral matter content, about 1.0 pct sulfur, and has a heat value of 13,650 Btu/lb.[9]

Ohio Collieries No. 268 Mine is located off State Route 13, at Rendville, about 10 miles north of Glouster (fig. 2). The ventilation shaft is about 260 feet north of the slope opening. The shaft and slope are in the Middle Kittanning No. 6 Coalbed, which in this area is 5 to 6 feet thick. A typical stratigraphic section includes Lower Freeport Shale and Sandstone, Middle Kittanning No. 6 Coal, Middle Kittanning Clay, Strasburg Coal, Oak HIll Clay, and Hamden Limestone.

Stowing Materials

The materials used for the stowing demonstration were a crushed limestone (minus 2 inches in diameter) and gravel with sand (minus 1 1/2 inches in diameter). Limestone was used to fill four openings, and gravel with sand to fill two openings. Crushed limestone and gravel blended with sand were obtained from quarries within the vicinity of the sites to be backfilled. The percentage of fines passing the No. 40 sieve (below 0.420 mm) ranged from 9 to 18 pct in the limestone and from 5 to 15 pct in the gravel. Materials for filling were sampled at all locations and tested. The test results indicated that the limestone used for the filling operations was within the limits of the Ohio Highway Specification for No. 304 limestone, except as noted in the appendix. The screened river gravel with 25 to 35 pct sand was comparable to the Ohio Highway Specification No. 67 (appendix). The final 5 feet of each opening were sealed with a concrete mixture consisting of 10 pct cement, 30 pct sand, and 60 pct aggregate. An exception to this was the shaft at the Ohio Collieries No. 268 Mine, where the concrete cap was 3.5 feet thick.

SEAL CONSTRUCTION

The pneumatic stowing technique for mine sealing was applied at the six abandoned openings in December 1980 and January 1981. Four openings had at least a 25-foot-long seal, one had a 65-foot seal, and one (the shaft) was filled to a depth of 60 feet, in compliance with MSHA requirements.

Peacock Mine Site, Pomeroy, Ohio

At the Peacock Mine, three openings were pneumatically sealed. The opening locations are shown in figure 3. This mine was abandoned in 1909.

[9]Communication cited in footnote 8.

Opening 1

This was an arched tunnel opening lined with cut sandstone blocks, in the area of Osborne Street, Pomeroy, adjacent to a residence and apartment complex. The tunnel was partially collapsed at a distance of 41 feet from the entrance, and there was evidence of subsidence up the slope from the entrance in a wooded area. The opening discharged 1.2 to 3.0 gpm of acid water during the sealing operation. The pH ranged from 3.0 to 4.6 and the acidity from 70 to 130 ppm. Before sealing, a 4-inch-diameter PVC pipe, 70 feet long, was laid in the aggregate along one rib for water discharge (fig. 4). The staging area for the pneumatic stower was on a narrow one-way street adjacent to the opening.

It was found that the mine opening was enlarged at a depth of 64.8 feet, where caving had formed a large room about 16 feet high, 22 feet wide, and 30 feet long. The original intent was to seal the entire length of the opening. It was later decided that it was too dangerous to work in the caved area, so a backstop was built at 65 feet and the entire length from there to the entrance was filled with crushed limestone. No underground cleanup was done. The final 5 feet were sealed with concrete to the surface with a 1:3:6 mixture of cement, sand, and aggregate. It took approximately 4 days to complete the seal and to clean up the area.

Opening 2

This opening was located about 210 feet from the end of Peacock Avenue, Pomeroy, on the opposite side of the hill from opening 3. The opening was badly deteriorated since there was no support other than weathered ribs (fig. 5). Several sections of roof strata were separated and in imminent danger of falling. The access road to the opening was improved with 265 tons of gravel before the equipment was moved onsite. The seal was started at 25.5 feet from the entrance after a plywood backstop was erected (fig. 4). Screened river gravel with about 30 pct of sand was used to fill the first 20.5 feet of the opening. The final 5 feet were filled with concrete to the surface. No dust problem was encountered during the filling operation. It took approximately 5 days to complete this seal and to clean up the area.

Opening 3

This haulage entry was located about 50 feet from West Main Street, at the rear of Simmons Motor Co., in Pomeroy. The total length of the opening was lined with sandstone blocks. At approximately 57 feet from the entrance, an old seal had been placed, presumably during the Work Progress Administration mine-sealing project in the early 1930's.[10] This was a dry seal of sandstone blocks with a 2-foot by 2-foot opening in the lower right side (fig. 4). The filling operation started at about 25 feet inside the opening, using gravel with sand as the fill. The nozzle and the crew were located at the mouth of the opening during the filling operation (fig. 6).

The final 5 feet of the opening were filled with concrete to the surface. To obtain a damp concrete that would be suitable for tamping, the amount of water had to be increased threefold. It took approximately 4 days to complete the seal, clean up the area, and move the equipment.

Hisylvania No. 22 Mine Site, Glouster, Ohio, Opening 1

The Hisylvania No. 22 Mine was opened in 1913 and abandoned in 1925. This was a slope mine, which included brick-lined passageway and haulage slopes. The roof in the passageway slope, located south of the haulage slope, had collapsed about 12 feet from the entrance and hence could not be filled in accordance with the requirements of 30 CFR 75.1711-3.

[10]Communication cited in footnote 8.

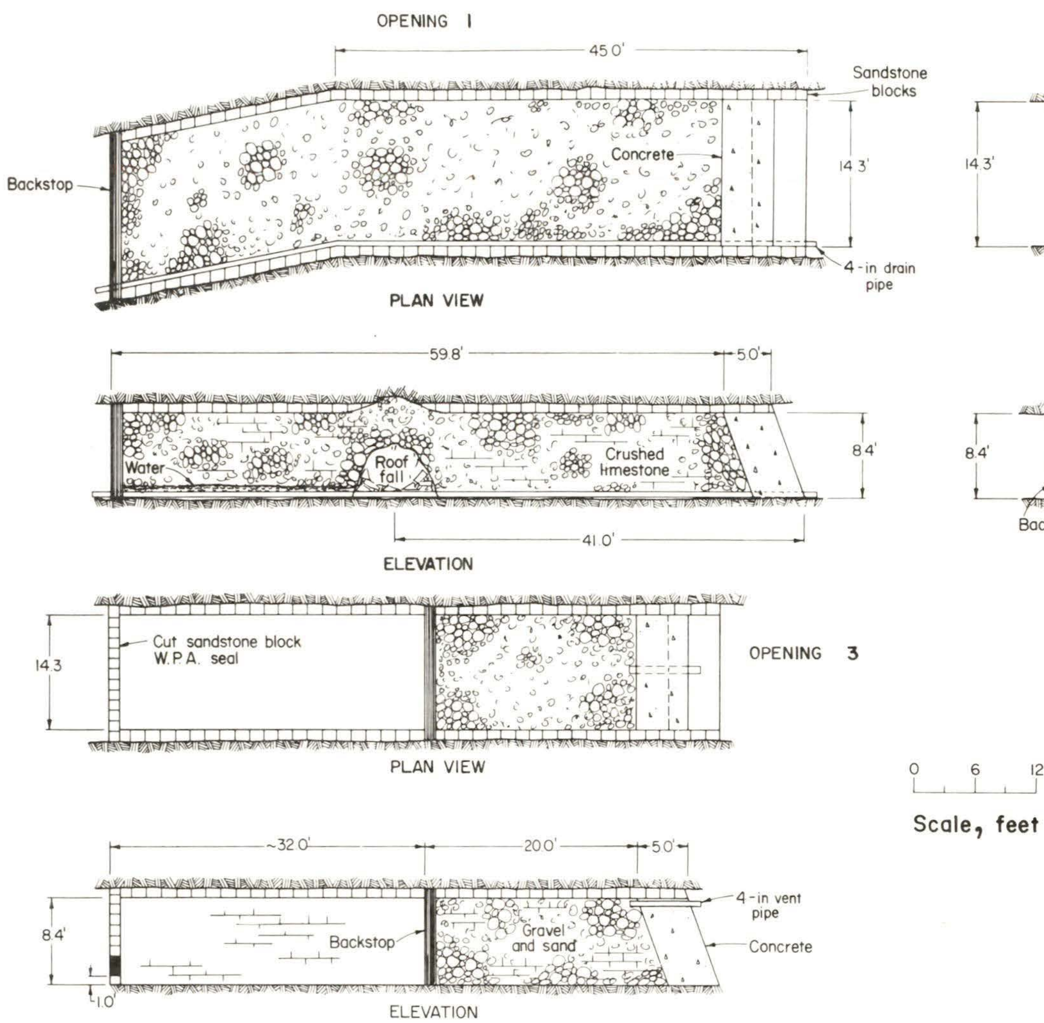

FIGURE 4. - Plan views and elevations of sealed openings at Peacock Mine, openings 1, 2, and 3.

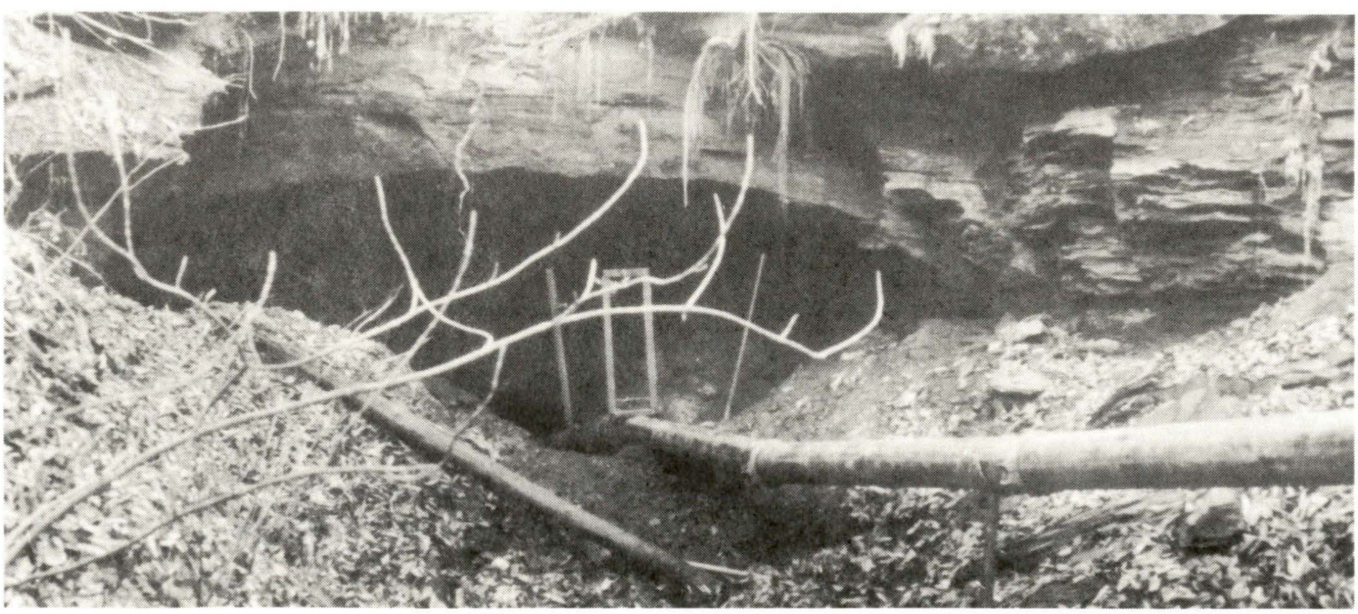

FIGURE 5. - Deteriorated entry at Peacock Mine, opening 2.

FIGURE 6. - Typical stowing operation at Peacock Mine, opening 3.

FIGURE 7. - Pneumatic stower with pipeline crossing railroad tracks at Hisylvania No. 22 Mine.

The haulage slope was an open entry about 80 feet long containing a pool of water, brick retaining walls, and various foundation remnants. The Ohio Historical Society, Columbus, Ohio, implementing the National Historical Preservation Act of 1966, requested that the entry of this slope be preserved by stopping the stowing operations at least 10 feet from the entrance. The stowing equipment was set up about 250 feet from the opening. Part of the stowing pipeline, which crossed a set of railroad tracks, had to be removed each time a train was scheduled to pass (fig. 7).

A backstop of railroad ties and particle board was erected at a distance of 35 feet inby the entrance (fig. 8). Crushed limestone was used to fill the first 20 feet outby the backstop. The next 8 feet were filled with concrete, and the remaining 7 feet were left open. Because of poor communication between the crew at the nozzle and the crew at the stower, an extra 3 feet of concrete fill was pumped into the opening. However, the historical significance of the opening was not diminished by the additional concrete. The entire seal was constructed in 4 days, including cleanup and moving the equipment.

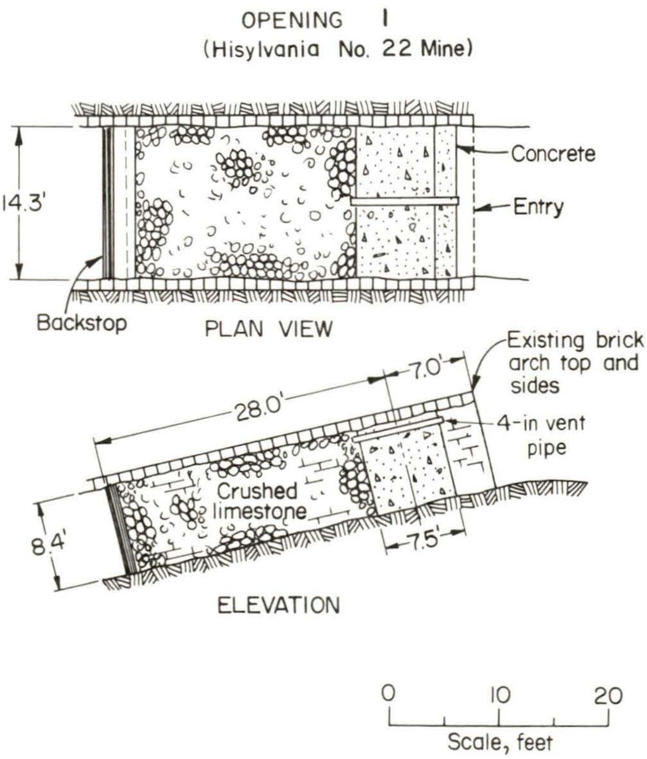

FIGURE 8. - Plan view and elevation of sealed opening at Hisylvania No. 22 Mine, opening 1.

Ohio Collieries No. 268 Mine Site, Rendville, Ohio

At Ohio Collieries No. 268 Mine, a shaft and a slope opening were pneumatically stowed. The mine was abandoned in 1923.

Shaft 1

This opening was used as a ventilation shaft and was about 60 feet deep and 12 feet in diameter (fig. 9). It had

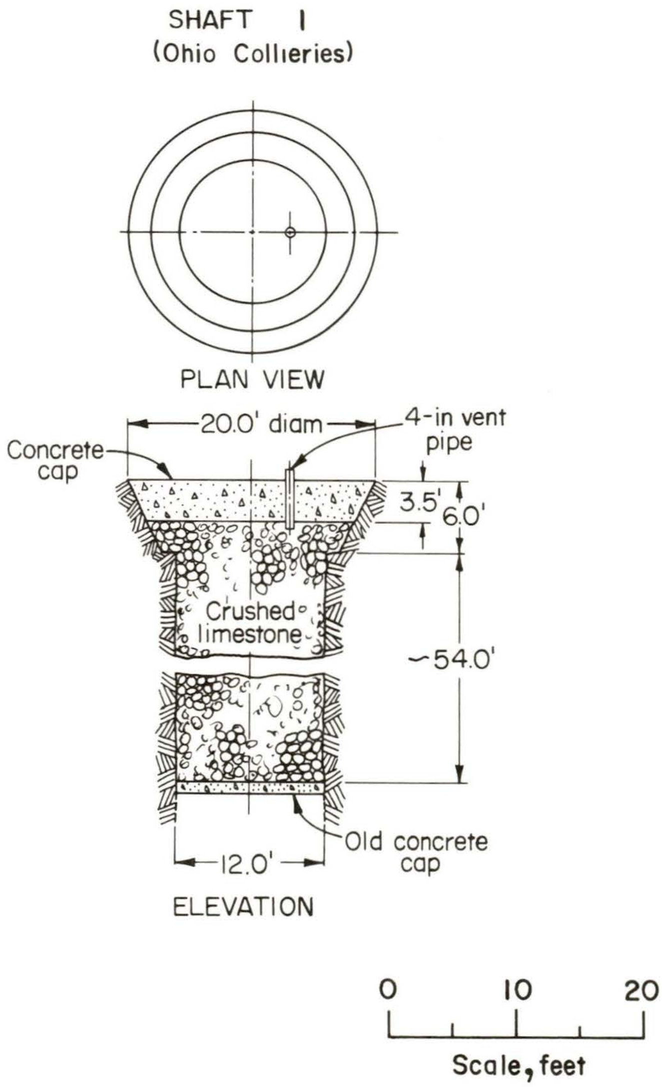

FIGURE 9. - Plan view and elevation of sealed opening at Ohio Collieries No. 268 Mine, shaft 1.

been capped with concrete. However, owing to wall failure, the cap had dropped and was wedged at an angle just below the opening. There was sufficient open space on two sides of the cap to constitute a safety hazard. Before filling started, the cap was broken and allowed to drop to the shaft bottom. To improve the 660-foot-long road from the nearest creek to the slope opening, over 235 tons of aggregate was used. The distance between the staging area for equipment and the shaft was about 260 feet. The shaft was filled with crushed limestone, and the final 3.5 feet were filled with concrete to the surface. The concrete was a mixture of 1:3:6-ratio of cement, sand, and gravel, with a sufficient amount of water to make a damp concrete. Because this was a shaft opening, the regular straight nozzle could not be used at the end of the pipeline. Instead, a rigid bent pipe was installed (fig. 10). The stowing material was moved at a

FIGURE 10. - Bent pipe at Ohio Collieries No. 268 Mine, shaft 1.

reduced velocity through the bent pipe, and a compaction of 71 to 77 pct at a depth of 5 feet was obtained, which is considered low.

Opening 1

This opening was a steep slope driven at an angle of about 25° and had been used for ventilation (fig. 11). Roof conditions in the accessible part of the slope were poor. A backstop was installed at a distance of 26 feet from the entrance to prevent material from sliding downslope. The backfilling started against the backstop and extended to the surface. Crushed limestone was used to fill the opening, and the final 5 feet were filled with a concrete mixture of a 1:3:6-ratio of cement, sand, and aggregate. A flexible pipe section was used, resulting in reduced material velocity and impact (fig. 12). It took approximately 10 days to fill the shaft and the slope opening and to clean up the area.

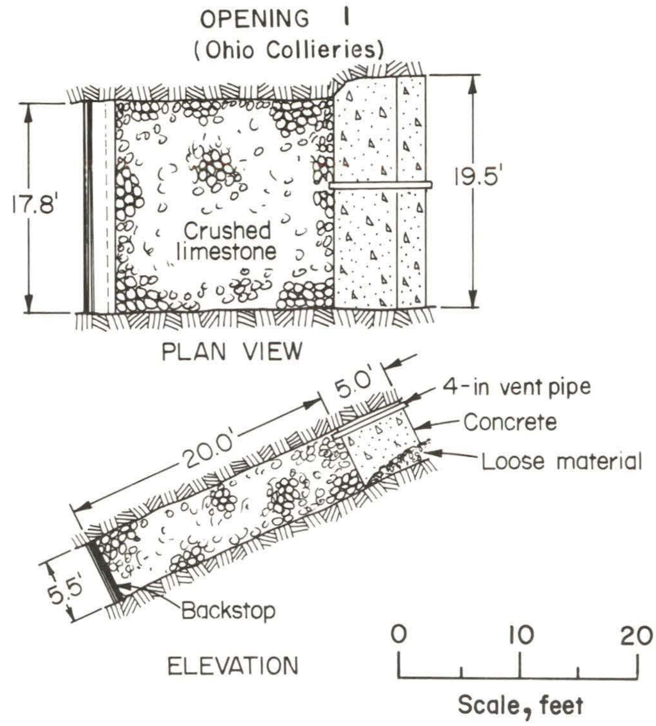

FIGURE 11. - Plan view and elevation of sealed opening at Ohio Collieries No. 268 Mine, opening 1.

FIGURE 12. - Flexible pipe section at Ohio Collieries No. 268 Mine, opening 1.

FIELD TESTING

Samples of the fill material were collected for testing at various locations and intervals during the filling operations. A total of 22 samples were collected at six openings. The field tests included gradation analysis, compaction, moisture content, dry density, and maximum dry density.

The average compaction of the crushed limestone ranged from 71.0 pct (Ohio Collieries No. 268 Mine, opening 1) to 88.2 pct (Peacock Mine, opening 1), with natural moisture contents of 6.9 and 8.7 pct, respectively. The average compaction for the gravel with sand was 81.9 pct (Peacock Mine, opening 2) and 83.8 pct (Peacock Mine, opening 3), with natural moisture contents of 5.0 and 4.2 pct, respectively. (See appendix for detailed analyses).

DISCUSSION AND EVALUATION

The rate of stowing during the operations ranged from 20 to 25 tons per hour at a maximum distance of 260 feet. These backfilling operations required 968 tons of material and 1,040 work-hours or, on the average, 161 tons and 173 hours per opening. Stowing operations required 129 work-hours or about 7.5 tons per hour. This is well below the rated capacity of 100 tons per hour for an 8-inch-ID pipe.

Table 1 presents a breakdown of labor requirements by site and category, in work-hours. A four- or five-member operating crew was required at each site during the stowing operation. A total of 376 work-hours (36.2 pct of the total time) was used to move and set up the equipment. Stowing and site preparation required 129 hours (12.4 pct). Another 141 hours (13.6 pct) were used for pipe installation. For tearing down and moving out the equipment and cleaning up the site, a total of 230 hours (22.1 pct) were used.

Table 2 shows the amount of stowing material used for stowing and road repair. Of the total 1,776 tons of material used for the stowing, 968 tons (55 pct) were used for backfilling and 808 tons (45 pct) for road improvement.

During the backfilling operations, occasional sparks were generated at the nozzle. This did not present a hazard, as there was no methane present in these shallow abandoned mine openings. Furthermore, the introduction of three to four thousand cubic feet of air per minute in the mine opening during the operations would have diluted any mine gases to a safe level. A 4-inch-ID vent pipe was installed at four openings to prevent gas accumulation behind the seal.

At Hisylvania No. 22 Mine, the pipeline for pneumatic stowing crossed a set of railroad tracks to reach opening 1 (fig. 7). Since the existing road was in poor condition, the pipeline was the simplest way to reach the opening to be filled, demonstrating the flexibility of the stowing method for sealing remote mine openings.

Field test data indicate that the greatest compaction was achieved with a straight, horizontal pipeline, at opening 1, Peacock Mine, and opening 1, Hisylvania No. 22 Mine. The pipeline length ranged from 30 to 260 feet; the minimum distance between the nozzle and the seal face was 20 feet. The lowest compaction was achieved at the Ohio Collieries No. 268 Mine. At the shaft opening, the pipeline had a rigid 60° bend, resulting in reduced rate of discharge of material (fig. 10); and at the slope opening, a flexible pipe section reduced material velocity and impact (fig. 12).

A comparison of the results and seal characteristics of the pneumatic stowing demonstrations in the States of Ohio and Pennsylvania is given in table 3.

TABLE 1. - Labor breakdown by site and category, hours

Site	Move in and set up	Prepara-tion and stowing	Backstop construction	Equipment maintenance	Pipe in-stallation
Peacock Mine:					
Opening 1............	130.0	23.0	4.0	2.5	19.0
Opening 2............	81.5	12.5	4.0	2.0	12.0
Opening 3............	31.5	15.5	5.0	1.0	21.0
Hisylvania No. 22 Mine: opening 1.............	50.0	11.0	10.5	8.0	21.0
Ohio Collieries No. 268 Mine:.................					
Shaft 1..............	83.0	39.0	0	6.0	56.0
Opening 1............	0	28.0	22.5	2.0	12.0
Total.............	376.0	129.0	46.0	21.5	141.0
Percent[1]..........	36.2	12.4	4.4	2.1	13.5

Site	Supervision	Public relations	Tear down and move out	Clean up
Peacock Mine:				
Opening 1............	9.0	0	28.5	17.0
Opening 2............	13.5	0	28.5	10.5
Opening 3............	16.0	3.0	9.0	18.5
Hisylvania No. 22 Mine: opening 1.............	12.0	0	9.5	13.0
Ohio Collieries No. 268 Mine:.................				
Shaft 1..............	24.0	8.0	35.0	30.0
Opening 1............	8.0	3.0	12.0	18.5
Total.............	82.5	14.0	122.5	107.5
Percent[1]..........	8.0	1.3	11.8	10.3

[1]Percent of grand total of all hours

TABLE 2. - Total material used for stowing and access roads

Site	Limestone and gravel, tons		Cement, bags
	Stowing	Road repair	
Peacock Mine:			
Opening 1.......................	144.00	124.00	98
Opening 2.......................	160.00	265.00	89
Opening 3.......................	120.00	184.00	89
Hisylvania No. 22 Mine: opening 1	126.00	0	51
Ohio Collieries No. 268 Mine:			
Shaft 1.........................	301.00	0	90
Opening 1.......................	117.00	235.00	45
Total.......................	968.00	808.00	462

TABLE 3. - Comparison of Ohio and Pennsylvania[1] demonstrations of pneumatic stowing

(The purpose of the stowing demonstrations in both States was to backfill abandoned mine openings to prevent trespassing, as well as to evaluate the effectiveness of the technique.)

Item	State of Ohio	State of Pennsylvania
Relationship between pneumatic stowing demonstration sites and mines.	Pneumatic stowing was demonstrated at abandoned mine openings with no active underground mining in the area.	Pneumatic stowing was demonstrated at abandoned mine openings that were part of an active mine closed shortly before the sealing started.
Relationship between openings.	Only 2 openings were interconnected underground.	All sealed openings were interconnected underground.
Site location and type of opening.	3 sites with 6 openings are within a 45-mile distance.	11 sites with 13 openings are within a 3-mile distance.
	Some of the openings are within or overlooking a residential area; some are remote.	Some of the openings are close to a residential area; some are remote.
	Most of the sites are accessible and easy to reach by vehicle.	Most of the sites are on the slopes of steep hills and difficult to reach by vehicle.
	Of 6 openings, 3 are drifts, 2 slopes, and 1 shaft.	Of 13 openings, 9 are drifts, 2 slopes, and 2 sinkholes.
Pneumatic stowing unit.	Included--	Included--
	Blower with air compressor rated 4,250 cfm at 12 psi;	Blower with air compressor rated 4,400 cfm at 13 psi;
	Power supply, 425-hp diesel engine;	Power supply, 315-hp diesel engine;
	Feeder to put material into pipeline;	Feeder to put material into pipeline;
	8-inch-ID pipeline in 10-foot sections;	8-inch-ID pipeline in 10-foot sections;
	Nozzle for directing the material.	Nozzle for directing the material.
	Approximate weight of stower: 40 tons.	Approximate weight of stower: 21 tons.
	Stower capacity: 100 tons per hour.	Stower capacity: 100 tons per hour.
	Pipeline length in the field ranged from 30 to 260 feet.	Pipeline length in the field ranged from 60 to 380 feet.

See footnote at end of table.

TABLE 3. - Comparison of Ohio and Pennsylvania[1] demonstrations of pneumatic stowing--Continued

Item	State of Ohio	State of Pennsylvania
Stowing material....	Crushed limestone was used to fill 4 openings, and screened gravel with sand was used to fill 2 openings.	Crushed limestone type 2A (with fines) and crushed limestone type 2B (washed of fines) were used to fill all openings.
	No additives were used.	Additives were used at 5 openings: Cement, expansive cement, and bentonite were mixed with limestone and used in the middle of the the seal.
	The final 5 feet of each seal opening were filled with concrete to the surface, except for the shaft, where only the final 3.5 feet were filled.	No concrete was used.
Cleaning of the openings.	No cleaning was required underground.	4 openings were partially or completely cleaned before additives were used with limestone.
Type of nozzle......	Manually operated nozzle was used at all openings except the shaft, where bent pipe was used.	Manually operated nozzle was used at 6 openings. Nozzle was not used at 6 openings where the hill was very steep. At 1 opening a skid type of nozzle was used.
Dust problem........	There was no dust problem since additives were not used.	During the sealing of 4 openings where cement and bentonite were mixed with limestone, the atmosphere was very dusty, and the crew had to stay upwind or use water spray.
Seal length.........	A total of 229 feet were pneumatically filled at 6 openings. The seal length ranged from 25 to 65 feet and averaged 38 feet.	A total of 491 feet were pneumatically filled at 13 openings. The seal length ranged from 12 to 90 feet and averaged 40 feet.
Field and laboratory testing:		
Field testing.....	All locations were sampled for field testing. A total of 22 samples were collected and tested.	Only 2 locations were sampled for field testing. A total of 29 samples were collected and tested.

See footnote at end of table.

TABLE 3. - Comparison of Ohio and Pennsylvania[1] demonstrations of pneumatic stowing--Continued

Item	State of Ohio	State of Pennsylvania
	Compaction averaged 80.5 pct and ranged from 70.6 to 94. 3 pct.	Compaction averaged 71.8 pct and ranged from 67.1 to 77.5 pct.
Laboratory testing	No laboratory testing was done. Gradation analyses were conducted in the field.	Included-- Gradation analysis; Moisture density relationship; Specific gravity; Direct shear; Permeability; Triaxial concrete mix.
Time required for construction.	It took approximately 27 days to complete the seals, to move the equipment, and to cleanup the area.	It took approximately 38 days to complete the seals, to move the equipment, and to clean up the area.
	No estimate was made of time required to construct conventional seal.	Estimated time for conventional seal construction was 149 days.
Total material required:		
For stowing.......	Aggregate: 968 tons. Cement: 462 bags.	Aggregate: 3,285 tons. Cement: 330 bags. Bentonite: 900 pounds.
For road repair and staging area.	Aggregate: 808 tons.	Aggregate: 2,721 tons.
Cost comparison.....	Actual cost of the stowing demonstration: $73,921.54.	Actual cost of the stowing demonstration: $245,146.
	An estimate of the cost of installing standard wall and clay-plug type seals was not made.	Estimated cost for installing standard wall and clay-plug type seals was $225,000.
	Depending on the weather and site conditions, the estimated costs for standard seals may vary.	Estimated costs were lower than actual costs.

[1]Details of the Pennsylvania stowing operation are given in Bureau of Mines RI 8729, now in press: Maksimovic, S. D., and J. C. Draper. Building Seals by Pneumatic Stowing in Mine Closure Operations. For information, contact S. D. Maksimovic, Bureau of Mines, Pittsburgh, Pa.

SUMMARY AND CONCLUSIONS

The pneumatic stowing technique proved to be simple and flexible in application but required proper preparation and control of fill material. This technique can be applied successfully to backfill abandoned mine openings. Fill material transported in a pipeline is protected against severe weather conditions; waste and pollution are prevented; and the material can be conveyed dry or wet.

The pneumatic stower system described is an enclosed system that is clean and requires little maintenance. The equipment is mobile, and the technique can be widely used for sealing abandoned mine openings, even in remote locations. Its use reduces or eliminates the exposure of workers to hazards, as the nozzle usually can be kept at the mouth of the opening. It is faster and cheaper than conventional methods when the fill material is properly prepared and regulated. However, this method is *not* recommended for building impermeable hydraulic seals to impound water, as it has not been proven safe for this purpose.

During the stowing operations, the ambient temperature ranged from 5° to 15° F. The only problem encountered was the freezing of the airlock, which was not cleaned regularly. Low temperature was actually an advantage in that the clay access roads were frozen, facilitating the movement of the heavy equipment. To ensure normal material feeding, the airlock must be cleaned, especially during periods of low temperature.

A nozzle control should be used to move material across the face and obtain a high compaction. A minimum distance of 20 to 30 feet should be maintained to ensure optimum compaction. At several locations this distance was not maintained, and low compaction rates resulted.

The fact that the rate of stowing was much lower than expected indicates that the pneumatic stower with an 8-inch-ID pipeline is oversized. A smaller, more flexible, and lighter stower using a 6-inch pipeline would be more suitable. Air requirements for transporting the material in the pipeline depend on the stower capacity.

The blower and the nozzle were excessively noisy; workers at the nozzle not only had to contend with nozzle noise, but also were out of sight of the stower crew, making communication between the nozzle workers and the blower-operating crew difficult.

Short rigid-bend pipe at the end of the pipeline should be avoided. Straight pipe sections should be added after bends or elbows to reaccelerate the fill material and increase compaction.

Based on the labor required for handling the stowing equipment, it is clear that a stower weighing over 40 tons is too bulky. A 10-foot section of 8-inch-ID pipe weighs about 180 pounds and requires two people to install, thereby increasing the toal work-hours needed for operations. Where feasible, smaller diameter and lighter pipe should be used to reduce installation time, lower cost, and increase the compaction rate at the face by increasing the velocity of the fill material.

APPENDIX.--FIELD TEST DATA

During December 1980 and January 1981, field tests were conducted by CTL Engineering Inc., Columbus, Ohio, at six locations in the State of Ohio. These tests were conducted to evaluate the pneumatic stowing technique for filling abandoned mine openings.

The materials used for the project included crushed limestone and screened river gravel with sand. Samples for field testing were collected at various intervals at the six locations during the filling operations. Field tests included gradation analysis, compaction, moisture content, dry density, and maximum dry density.

PEACOCK MINE SITE, POMEROY, OHIO

At Pomeroy, Ohio, three mine openings were pneumatically filled and field tested.

Opening 1

Gradation analysis was performed on the crushed limestone. The results fall within the limits of Ohio Highway Specifications for No. 304 limestone (fig. A-1, table A-1). Natural moisture of the aggregate was 8.7 pct.

TABLE A-1. - Gradation analysis, No. 304 limestone,[1] Peacock Mine, opening 1

Sieve size	Pct passing	Specification, pct
2 inch....	100.0	100
1 inch....	87.3	70- 90
3/4 inch..	79.1	50- 85
No. 4.....	46.7	25- 60
No. 40....	17.9	7- 30
No. 200...	1.6	0- 15

[1]Natural moisture: 8.7 pct.

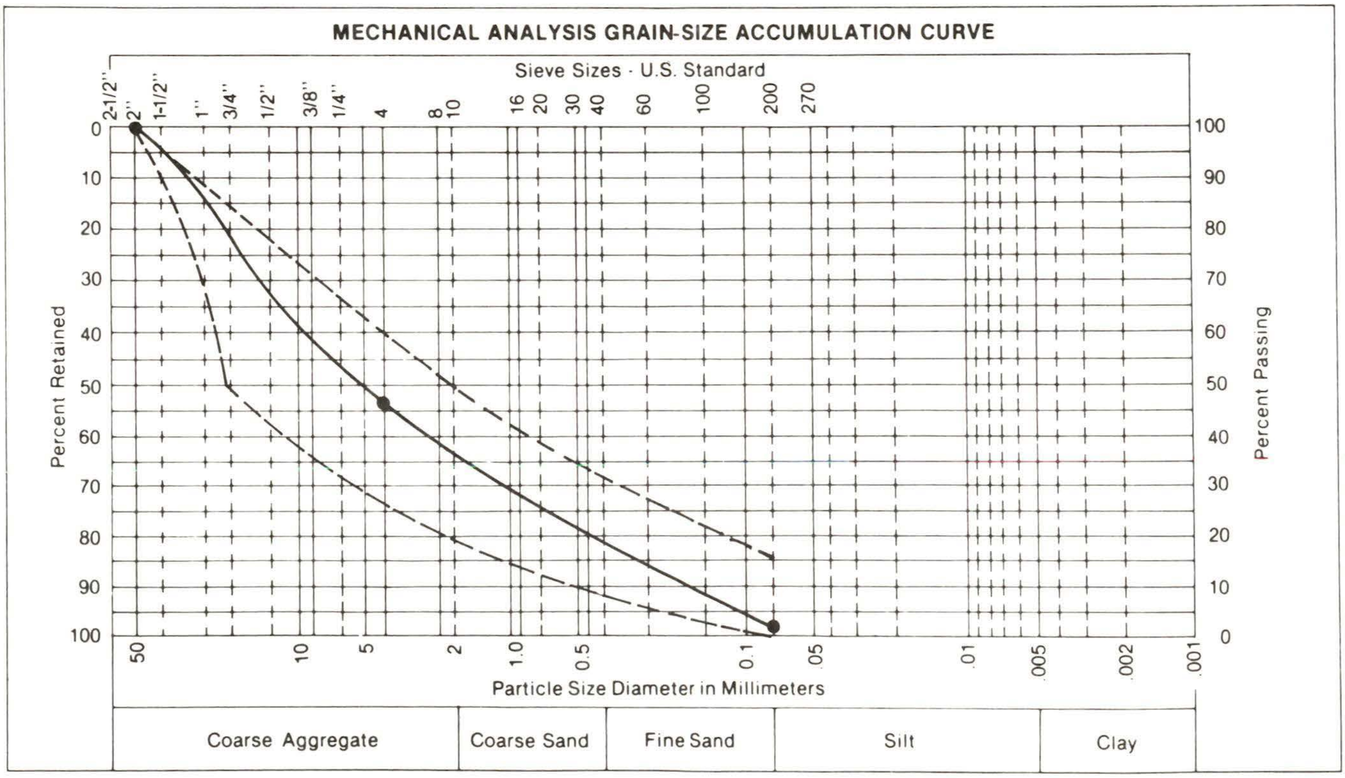

FIGURE A-1. - Grain-size distribution curve, Peacock Mine, opening 1. Dashed lines indicate Ohio Highway Specification limits for No. 304 limestone.

(Courtesy, CTL Engineering Inc.)

Four tests were conducted during the filling operations to determine compaction, moisture content, dry density, and maximum dry density. The results indicate that the compaction of the limestone averaged 88.2 pct and ranged from 81.8 to 94.3 pct. The average moisture content of the samples was 9.3 pct, as compared with an average optimum moisture content of 10.9 pct. The testing results are given in table A-2.

TABLE A-2. - Standard Proctor tests (ASTM D698 procedure), Peacock Mine, opening 1

Test[1]	Location of sample	Tested interval elevation, distance from roof, ft	Field test data[2]			Compaction, pct
			Wet unit weight, pcf	Moisture content, pct	Dry unit weight, pcf	
1....	4.15 feet from right, 52 feet from entrance.	2	134.1	12.1	119.6	94.3
2....	3.9 feet from right, 36.3 feet from entrance.	1.9	111.0	9.1	101.7	81.8
3....	4.9 feet to right of test 2, 36.3 feet from entrance.	1.8	112.2	7.8	104.0	83.7
4....	4.9 feet from right, 36 feet from entrance.	2.9	125.5	8.3	115.8	93.2

[1]Test date: Dec. 30, 1980.

[2]Control data: Test 1: curve T-15; maximum dry unit weight, 126.8 pcf; optimum moisture content, 9.8 pct. Tests 2-4: curve H; maximum dry unit weight, 124.2 pcf; optimum moisture content, 11.2 pct.

Opening 2

Gradation analysis was performed on the screened gravel with sand. The results could not be compared with the Ohio Highway Specifications since the contractor did not follow the submitted specifications (fig. A-2, table A-3). The natural moisture of the material was 5.0 pct.

TABLE A-3. - Gradation analysis, No. 67 gravel with sand,[1] Peacock Mine, opening 2

Sieve size	Pct passing	Sieve size	Pct passing
1-1/2 inch...........	100.0	No. 4................	45.7
1 inch...............	97.8	No. 8................	38.5
3/4 inch.............	90.2	No. 16...............	29.6
1/2 inch.............	76.2	No. 50...............	5.9
3/8 inch.............	54.6	No. 100..............	2.3

[1]Natural moisture: 5 pct; unrodded unit weight: 103.6 pcf; dry rodded unit weight: 123 pcf.

Six tests were conducted during the filling operations. The results show that the average compaction of the material was 81.9 pct and that compaction ranged from 78.3 to 83.5 pct. The average moisture content of the samples was 6.9 pct, as compared with the optimum moisture content of 8.5 pct. The results of the testing are given in table A-4.

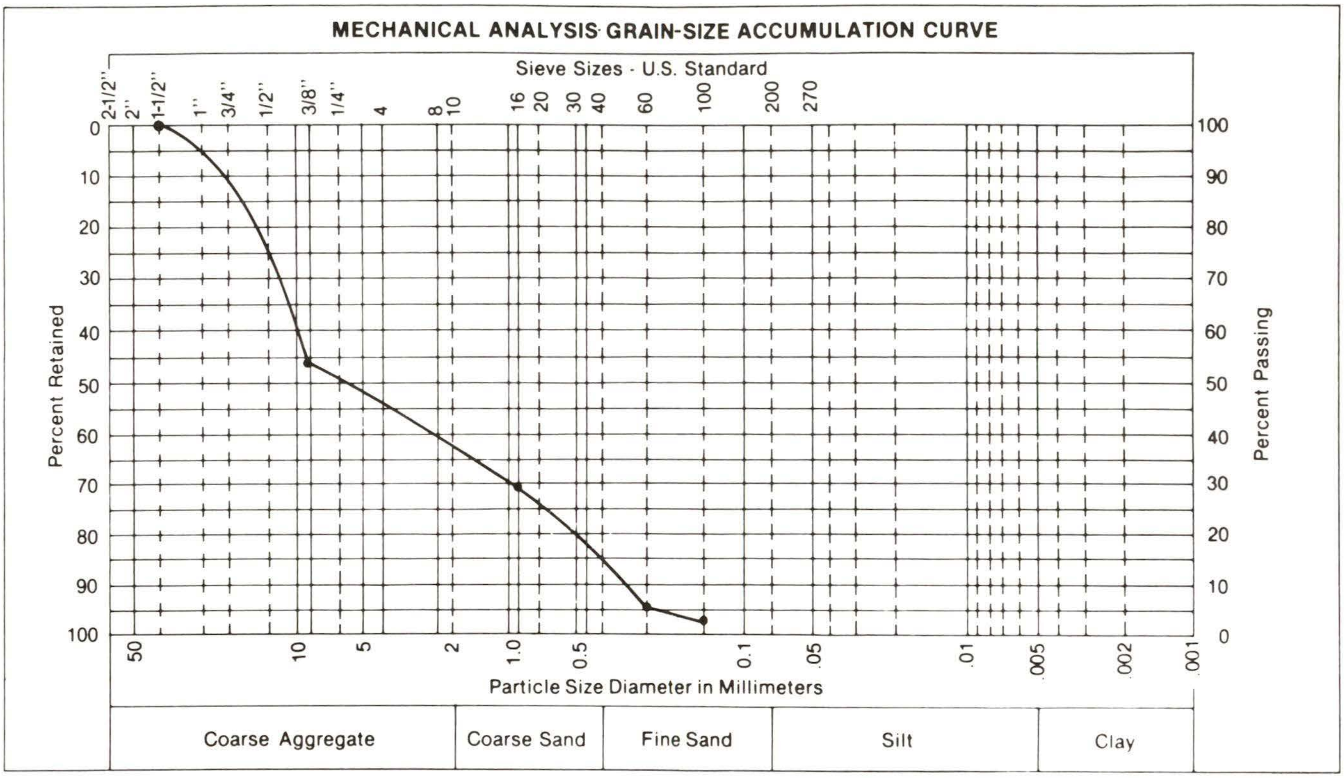

FIGURE A-2. - Grain-size distribution curve, Peacock Mine, opening 2.
(Courtesy, CTL Engineering Inc.)

TABLE A-4. - Standard Proctor tests (ASTM D698 procedure), Peacock Mine, opening 2

Test[1]	Location of sample	Tested interval elevation, distance below top, ft	Field test data[2]: Wet unit weight, pcf	Field test data[2]: Moisture content, pct	Field test data[2]: Dry unit weight, pcf	Compaction, pct
1.....	19 feet from face, 2.5 feet from left.	4	117.5	6.5	110.3	82.2
2.....	22 feet from face, 6 feet from left.	3.5	120.0	7.3	111.8	83.3
3.....	19 feet from face, 2.5 feet from right.	4	120.5	8.3	111.2	82.9
4.....	17 feet from face, 1.5 feet from left.	4.5	116.7	6.9	109.1	81.3
5.....	8.8 feet from face, 4 feet from right.	4.8	118.5	5.8	112.0	83.5
6.....	14.5 feet from face, 3.7 feet from right.	3	112.5	6.9	105.2	78.3

[1]Test date: Dec. 17, 1980.
[2]Control data: curve State-D; maximum dry unit weight: 134.1 pcf; optimum moisture content, 8.5 pct.

Opening 3

Gradation analysis was performed on the screened river gravel with sand. The results do not fall within the limits of the Ohio Highway Specification for No. 4 gravel, since No. 4 specification does not include fractions passing the No. 4 sieve opening (fig. A-3, table A-5). The natural moisture of the material was 4.2 pct.

Two field tests were conducted onsite. The results show that the average compaction of the material was 83.8 pct. The

TABLE A-5. - Gradation analysis, No. 4 gravel with sand,[1] Peacock Mine, opening 3

Sieve size	Pct passing	Specification, pct
1-1/2 inch..............	100.0	100
1 inch..................	100.0	20- 55
3/4 inch................	90.7	0- 15
1/2 inch................	60.3	NG
3/8 inch................	33.4	0- 5
No. 4...................	30.2	NG
No. 8...................	26.4	NG
No. 16..................	11.7	NG
No. 50..................	3.1	NG
No. 100.................	1.1	NG

NG Not given in specification.

[1]Natural moisture: 4.2 pct; unrodded unit weight: 105 pcf.

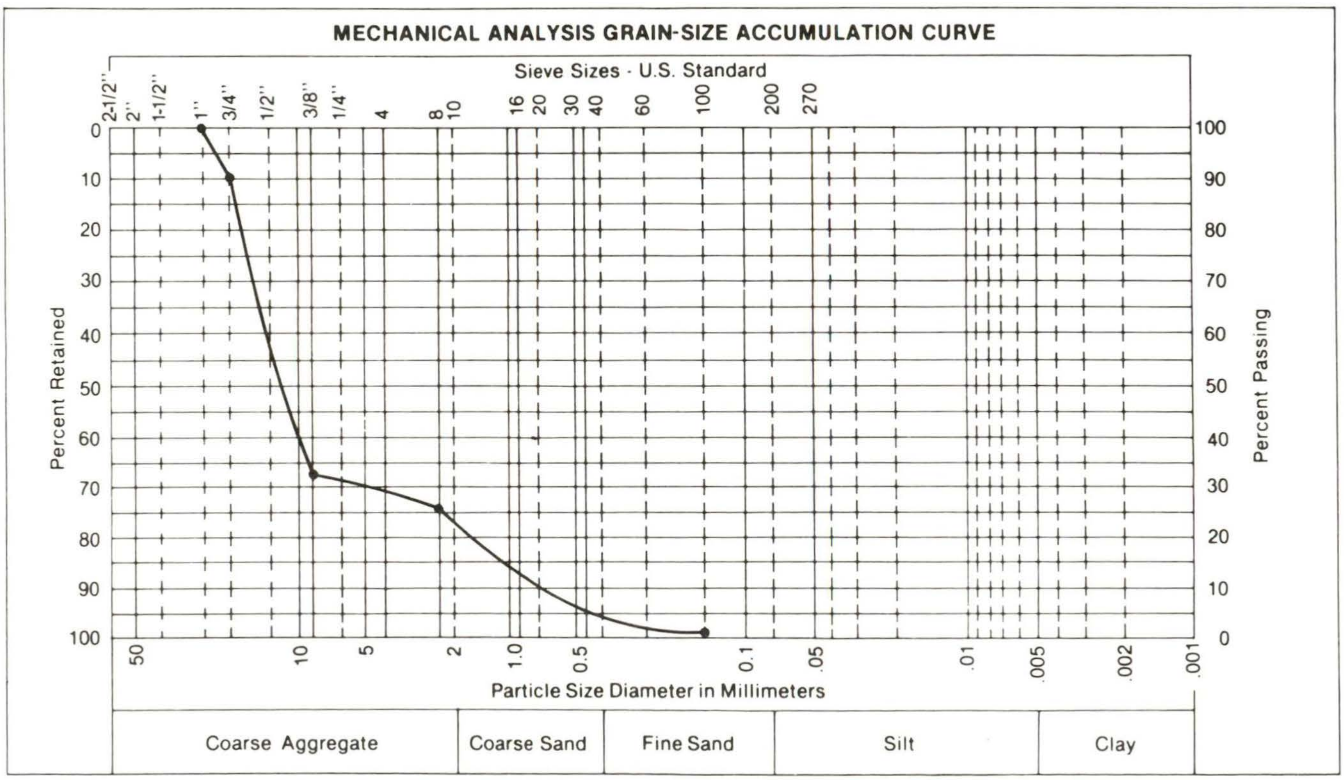

FIGURE A-3. - Grain-size distribution curve, Peacock Mine, opening 3.
(Courtesy, CTL Engineering Inc.)

average moisture content of the samples was 8.9 pct, as compared with the optimum moisture content of 10.8 pct. The testing results are given in table A-6.

TABLE A-6. - Standard Proctor tests (ASTM D698 procedure), Peacock Mine, opening 3

Test[1]	Location of sample	Tested interval elevation, distance from entrance, ft	Field test data[2]			Compaction, pct
			Wet unit weight, pcf	Moisture content, pct	Dry unit weight, pcf	
1.....	5.5 feet from right wall to left, 2 feet above floor.	22	117.0	7.5	108.8	87.2
2.....	7 feet from right, 6.5 feet from top.	23.6	111.0	10.4	100.5	80.5

[1]Test date: Dec. 12, 1980.
[2]Control data: curve T-14; maximum dry unit weight, 124.8 pcf; optimum moisture content, 10.8 pct.

HISYLVANIA NO. 22 MINE SITE, GLOUSTER, OHIO

At Glouster, Ohio, only one mine opening was pneumatically filled and tested.

Gradation analysis was performed on the crushed limestone. The results, except for the 1-inch size, fall within the limits of Ohio Highway Specification No. 304 (fig A-4, table A-7). Natural moisture content of the aggregate was 5.1 pct.

Two field tests were conducted on this location. The results indicate that the average compaction of the aggregate was 87.3 pct. The average moisture content of the samples was 5.2 pct, as compared with the optimum moisture content of 9.6 pct. The results of the testing are given in table A-8.

TABLE A-7. - Gradation analysis, No. 304 limestone,[1] Hisylvania No. 22 mine, opening 1

Sieve size	Pct passing	Specification, pct
2 inch..................	100.0	100
1 inch..................	92.6	70- 90
3/4 inch................	85.3	50- 85
No. 4...................	55.0	25- 60
No. 40..................	8.7	7- 30
No. 200.................	2.4	0- 15

[1]Natural moisture: 5.1 pct.

TABLE A-8. - Standard Proctor tests (ASTM D698 procedure), Hisylvania No. 22 Mine, opening 1

Test[1]	Location of sample	Tested interval elevation, distance from roof, ft	Field test data[2]			Compaction, pct
			Wet unit weight, pcf	Moisture content, pct	Dry unit weight, pcf	
1....	5 feet from left, 27.5 feet from entrance.	4.2	122.5	5.6	116.0	88.5
2....	2.75 feet from right, 27.5 feet from entrance.	3.2	118.0	4.7	112.7	86.0

[1]Test date: Jan. 6, 1981.
[2]Control data: curve T-18; maximum dry unit weight, 131.1 pcf; optimum moisture content, 9.6 pct.

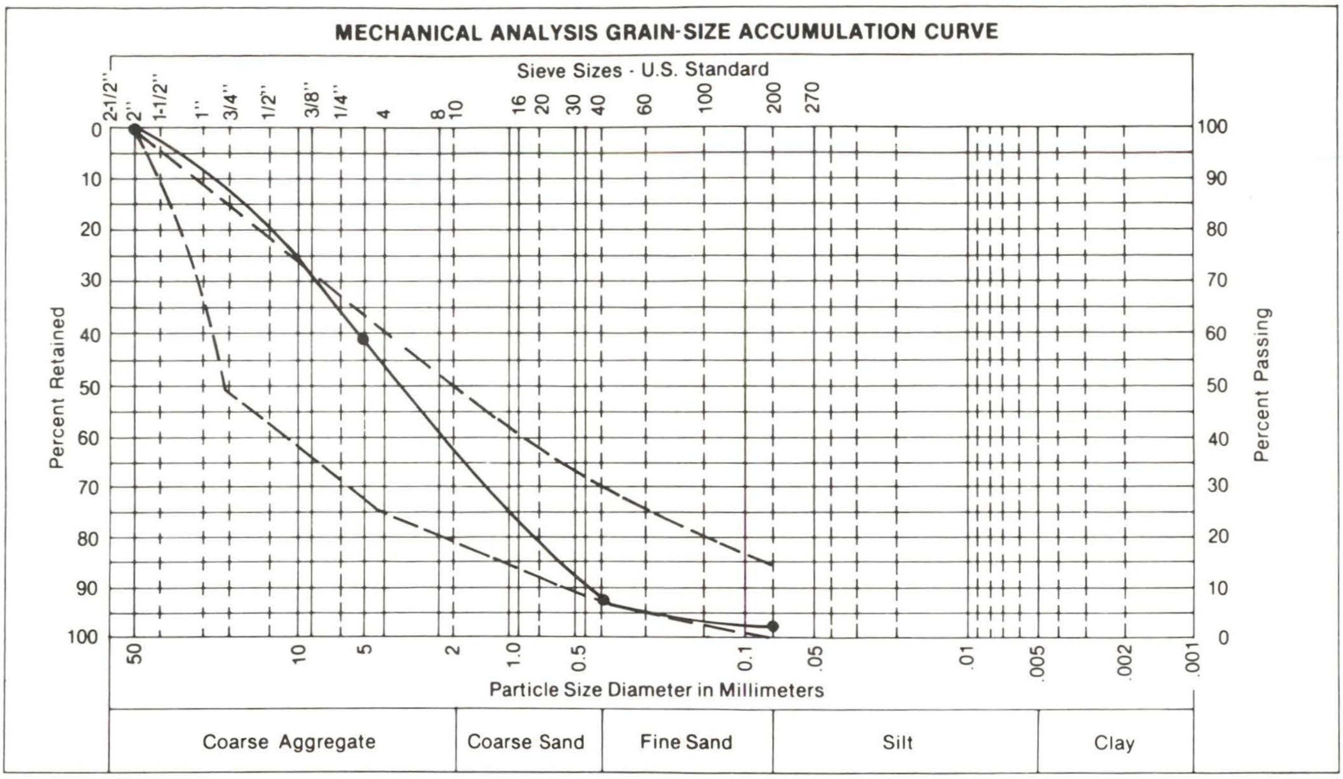

FIGURE A-4. - Grain-size distribution curve, Hisylvania Mine, opening 1. Dashed lines indicate Ohio Highway Specification limits for No. 304 limestone.

(Courtesy, CTL Engineering Inc.)

OHIO COLLIERIES MINE SITE, RENDVILLE, OHIO

At Rendville, Ohio, two mine openings were pneumatically filled and tested.

Shaft 1

Gradation analysis was performed on the crushed limestone aggregate. The results show that the larger fractions (1-inch and 3/4-inch sizes) are not within the limits of Ohio Highway Specification No. 304 (fig. A-5, table A-9). Natural moisture of the aggregate was 5.5 pct.

TABLE A-9. - Gradation analysis, No. 304 limestone,[1] Ohio Collieries Mine No. 268, shaft 1

Sieve size	Pct passing	Specification, pct
2 inch..................	100.0	100
1 inch..................	95.6	70- 90
3/4 inch................	90.7	50- 85
No. 4...................	59.3	25- 60
No. 40..................	11.4	7- 30
No. 200.................	4.2	0- 15

[1]Natural moisture: 5.5 pct; unrodded unit weight: 108 pcf.

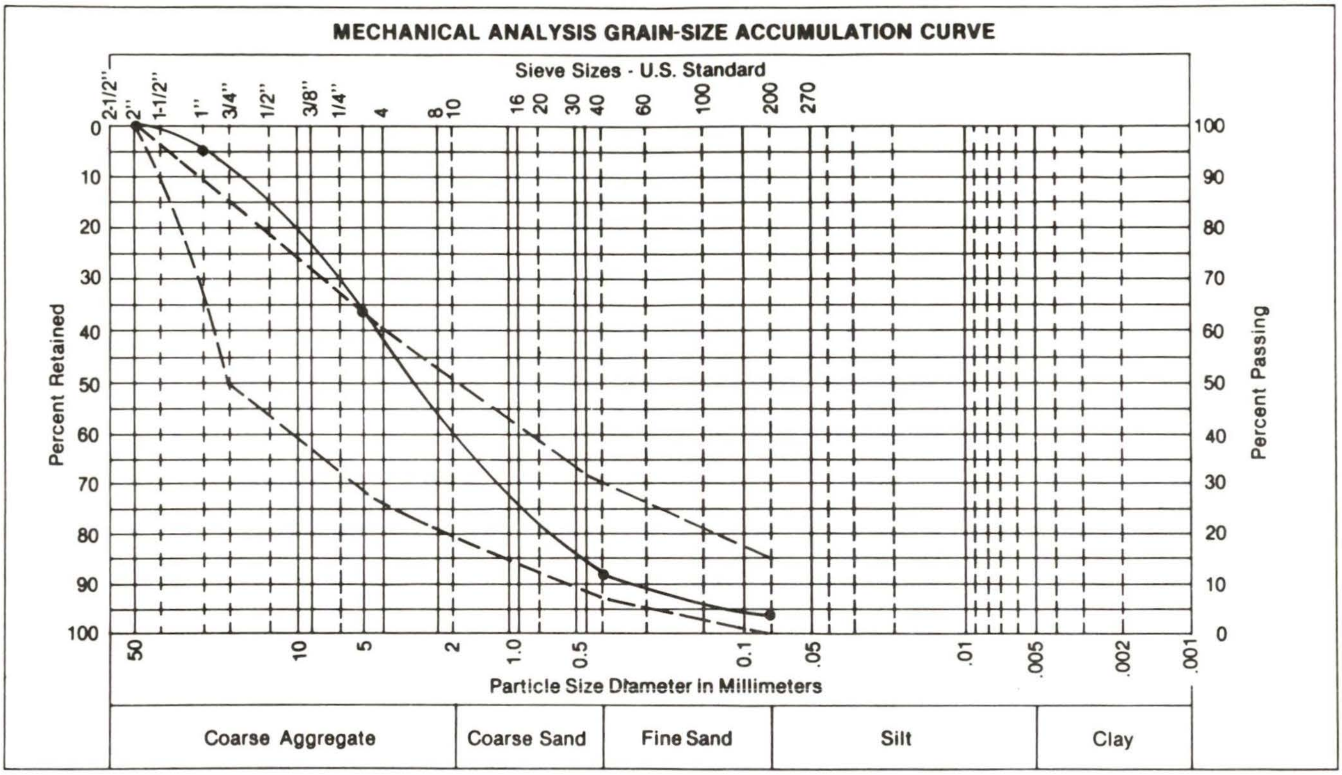

FIGURE A-5. - Grain-size distribution curve, Ohio Collieries No. 268 Mine, shaft 1. Dashed lines indicate Ohio Highway Specification limits for No. 304 limestone.

(Courtesy, CTL Engineering Inc.)

Five field tests were conducted during the filling operations. The results show that the compaction of the aggregate averaged 74.4 pct and ranged from 71.2 to 77.0 pct. The average moisture content of the samples was 6.7 pct, as compared with the optimum moisture content of 8.6 pct. The results of the testing are given in table A-10.

TABLE A-10. - Standard Proctor tests (ASTM D698 procedure), Ohio Collieries No. 268 Mine, shaft 1

Test[1]	Location of sample	Tested interval elevation, distance below subgrade, ft	Field test data[2]: Wet unit weight, pcf	Field test data[2]: Moisture content, pct	Field test data[2]: Dry unit weight, pcf	Compaction, pct
1....	Center of seal........	5	109.0	6.5	102.3	76.4
2....	3 feet NE. of center..	5	106.7	5.6	101.0	75.4
3....	4 feet NW. of center..	5	109.5	6.3	103.0	77.0
4....	3.5 feet SE. of center	5	102.5	7.6	95.3	71.2
5....	3 feet SW. of center..	5	103.5	7.5	96.3	72.0

[1]Test date: Jan. 16, 1981.
[2]Control data: curve T-19; maximum dry unit weight, 133.8 pcf; optimum moisture content, 8.6 pct.

Opening 1

Gradation analysis was performed on the crushed limestone aggregate. The results show that larger fractions (1-inch, 3/4-inch, and No. 4 sieve size) are not within the limits of Ohio Highway Specification No. 304 (fig. A-6, table A-11). Natural moisture of the aggregate was 6.9 pct.

TABLE A-11. - Gradation analysis, No. 304 limestone,[1] Ohio Collieries Mine No. 268, opening 1

Sieve size	Pct passing	Specification, pct
2 inch..................	100.0	100
1 inch..................	100.0	70- 90
3/4 inch................	87.5	50- 85
No. 4...................	67.8	25- 60
No. 40..................	9.5	7- 30
No. 200.................	1.5	0- 15

[1]Natural moisture: 6.9 pct.

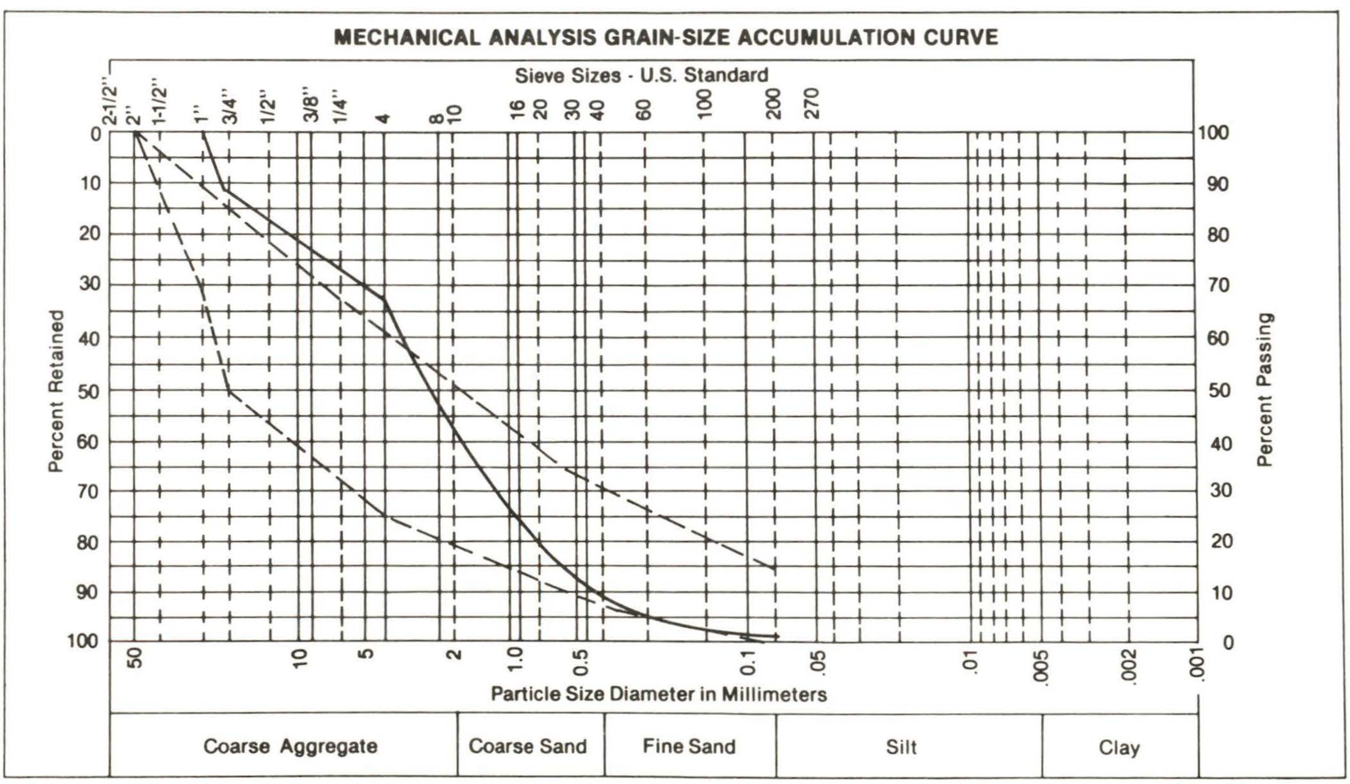

FIGURE A-6. - Grain-size distribution curve, Ohio Collieries No. 268 Mine, opening 1. Dashed lines indicate Ohio Highway Specification limits for No. 304 limestone.

(Courtesy, CTL Engineering Inc.)

Three tests were conducted during the stowing operations. The results show that the compaction of the aggregate averaged 71.0 and ranged from 70.6 to 71.3 pct. The average moisture content of the samples was 7.5 pct, as compared with the optimum moisture content of 8.6 pct. The results of testing are given in table 12.

TABLE A-12. - Standard Proctor tests (ASTM D698 procedure), Ohio Collieries No. 268 Mine, opening 1

Test[1]	Location of sample	Tested interval elevation, distance from roof, ft	Field test data[2]			Compaction, pct
			Wet unit weight, pcf	Moisture content, pct	Dry unit weight, pcf	
1....	15.6 feet from end of discharge, 8 feet from right.	2.4	100.5	6.3	94.5	70.6
2....	13.2 feet from end of discharge, 4 feet from right.	2.4	102.5	7.3	95.5	71.3
3....	13 feet from end of discharge, 2 feet from right.	2.4	103.7	8.9	95.2	71.1

[1]Test date: Jan. 16, 1981.
[2]Control data: curve T-19; maximum dry unit weight, 133.8 pcf; optimum moisture content, 8.6 pct.

NATIONAL MINE HEALTH & SAFETY ACADEMY
REFERENCE COPY
Do Not Remove From Learning Resource Center

NATIONAL MINE HEALTH & SAFETY ACADEMY
REFERENCE COPY
Do Not Remove From Learning Resource Center