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Lake Lynn Laboratory: Construction, Physical Description, and Capability

By Robert H. Mattes, Alex Bacho, and Lewis V. Wade

UNITED STATES DEPARTMENT OF THE INTERIOR

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LAKE LYNN LABORATORY: CONSTRUCTION, PHYSICAL DESCRIPTION, AND CAPABILITY

By Robert H. Mattes,[1] Alex Bacho,[2] and Lewis V. Wade[3]

ABSTRACT

The Lake Lynn Laboratory is a multipurpose mining research laboratory operated by the Bureau of Mines and located in Fairchance, Pa. It consists of both surface and underground facilities. The initial focus of the facility, scheduled for full operation in fall 1982, will be on the problems of fires and explosions in mines. The initial experimental explosion was fired on March 3, 1982. The intent of this document is to provide the reader with detailed information on the physical capabilities of the Lake Lynn Laboratory. Subsequent publications will focus on the capabilities of Lake Lynn as compared with those of other similar facilities worldwide, and a comparison of initial explosion test results realized at Lake Lynn and comparable results from the Bruceton Experimental Mines.

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INTRODUCTION

A HISTORY OF BUREAU OF MINES INVOLVEMENTS IN FIRES AND EXPLOSIONS RESEARCH

In 1910, the newly created Bureau of Mines (Act of Congress 36 Stat. 369, March 16, 1910) acquired a 36-acre tract of land at Bruceton, Pa., where an Experimental Mine was opened for use in large-scale research needed to support what was then the Bureau's main function--prevention and suppression of gas and coal dust explosions and the schedule testing and approval of coal mine explosives. The Bureau's schedule testing was initially carried out at the Government Arsenal in Pittsburgh, but when the Bureau's headquarters moved from the Arsenal to the Central Experiment Station at 4800 Forbes Avenue, for reasons of safety the explosives research and testing activities were transferred to the new Explosives Experimental Station at Bruceton. Later the Bruceton facility became the Explosives Testing Station; it is presently known as the Pittsburgh Research Center.

From 1880 to the present, about 500 major gas and dust explosions and several thousand minor explosions and ignitions have occurred in U.S. coal mines. The number of fatalities from these occurrences exceeds 15,000. Since 1910, the Bureau of Mines has been involved in research to combat coal mine gas and dust explosions. The Bureau has conducted over 3,900 large-scale coal dust and gas explosions in the Bruceton Experimental Mine of the Pittsburgh Research Center (PRC) complex. In 1961 the Bureau had to curtail large-scale coal dust explosion experiments because homes were being erected less than a mile from the Bruceton station. The Experimental Mine entries (6 ft high by 9 ft wide), while representative of mine geometries of the 1920's and 1930's, were no longer representative of the greater span mine geometries made possible by modern roof-support techniques. Furthermore, with the recurring application of longwall mining, a need existed to conduct explosion-related research in geometries similar to that of longwall panels; this could not be accomplished in the Experimental Mine.

In 1968 following the Farmington Mine explosion, the need to test barriers (devices to suppress coal dust explosion) under strong-explosion conditions became evident. The need for a test facility to conduct large-scale fire tests became even more imperative following the Sunshine Mine disaster in 1972.

Considering the continuing need for research to combat mine fires and coal mine gas and dust explosions, a companion facility to the Bruceton Experimental Mine was pursued. In the late 1970's, the Lake Lynn limestone mine was found to meet the experimental research needs for safeguarding miners against the risk of fires and gas and dust explosions. Planning and design of the Lake Lynn Laboratory was initiated, and construction work began on December 12, 1979. The underground development at Lake Lynn was designed to yield coal-mine-sized entries and configurations. A benefit of having such developments in limestone is the relative absence of shales that cause continuing roof control problems as they weather. A list of the major contractors and suppliers that participated in the design and construction of the Lake Lynn Laboratory and a chronology of activities are presented in the appendix, along with a description of the Bruceton Experimental Mine.

PURPOSE OF LAKE LYNN LABORATORY

The Lake Lynn Laboratory was chosen to alleviate the major constraints in carrying out explosion research at the Bruceton Experimental Mines. The Lake Lynn Laboratory provides the Bureau with a dedicated and remote location sufficiently removed from residences to allow for the testing of large-scale detonations with explosives and deflagrations of coal and gas explosions. In addition, Lake Lynn simulates modern mine widths based on advanced roof support technology. The availability of the Lake Lynn facility, in conjunction with continued work at the Bruceton Experimental Mine, will permit enhanced and accelerated research on fires and explosions.

The underground layout of Lake Lynn allows full-scale research of explosion propagation and suppression as encountered in modern U.S. coal mining. (More detail on the Lake Lynn layout is contained later in this report.)

Some specific areas of utilization of the Lake Lynn Laboratory include--

- evaluating fire and explosion extinguishing devices.
- testing passive and active explosion barriers for the range of weak to strong explosions (gas, coal dust, oil shale, and other dust and oil vapors).
- evaluating ventilation stopping and bulkheads.
- providing an underground test area for prototype mining equipment prior to testing in operating mines.
- providing a network of passages for ventilation studies, including large (50- by 30-ft) workings.
- conducting roof support studies.
- conducting large-scale blasting studies using 4- to 8-in-diam explosive charges (for oil shale acceptability needs).
- monitoring effects of ground vibrations.
- determining toxic hazards of explosives and diesel engines.
- determining explosion limits for coal and oil shale dust.
- performing explosive tests on the highwall bench (surface mining).
- investigating methane layering in large workings (salt, shale, gassy noncoal).
- investigating explosion hazards of mists and vapors (oil, shale, tar sands).
- evaluating remote methane detection hardware.
- evaluating effectiveness and incendivity of large-scale explosive charges.
- investigating novel blasting concepts (active stemming, face inerting).
- studying vibrations from explosives and blasts.
- providing a remote site for explosives destruction.
- conducting equipment maneuverability and functional tests.

OVERVIEW OF THE GEOMETRIES OF THE FACILITY

The facility occupies approximately 80 acres and is located 15 miles north of Morgantown, W. Va. (14 miles south of Uniontown, Pa.). Figure 1 shows the location of the facility. The site for the laboratory was provided by the Martin-Marietta Corp.

The underground facility consists of approximately 25,000 ft of 50-ft-wide by 30-ft-high entries that were developed in the mid-1960's as part of a commercial limestone mining operation and 7,500 ft of 18-ft-wide by 6.5-ft-high entries developed in 1980-81. The new entries' actual dimensions range from 6.2 to 7.5 ft high by 17.5 to 22 ft wide. Figure 2 shows a plan view of underground entries with the "new" and "old" developments identified. Figure 3 shows the approximate dimensions of the facility, and figure 4 shows the control-support building. Figure 5 is an artist's rendition of the underground workings.

FIGURE 1. - Location of the Lake Lynn Laboratory.

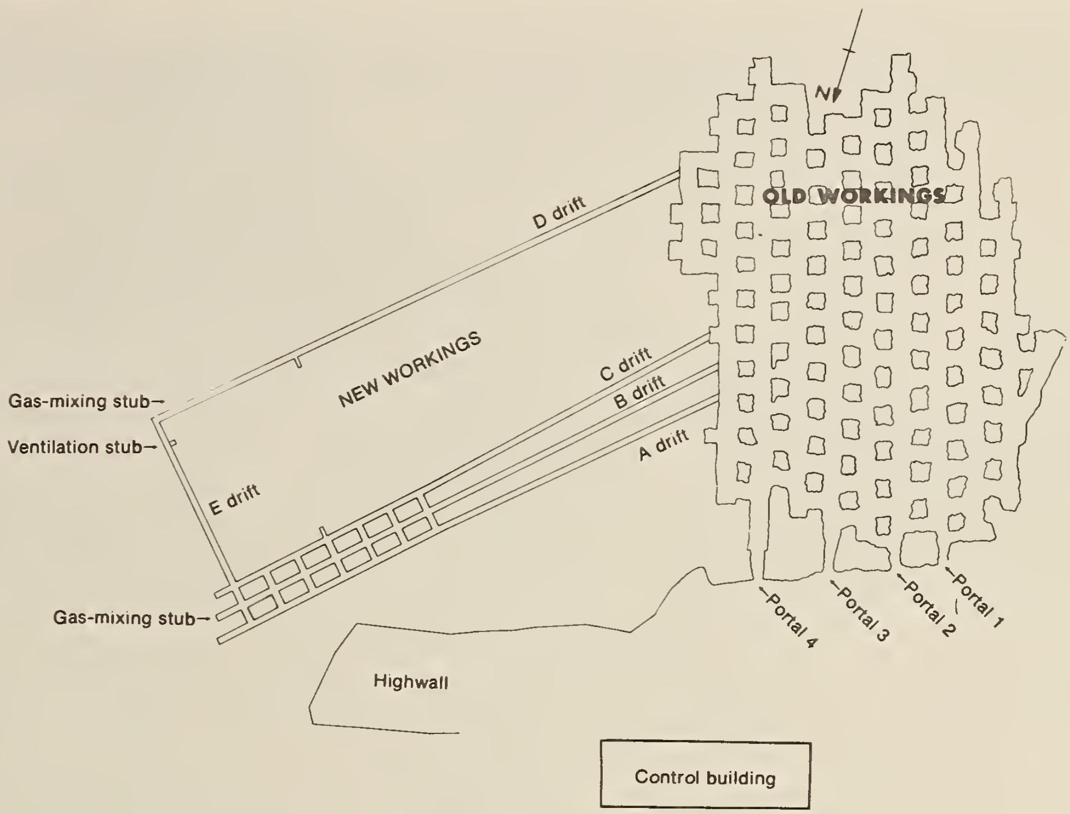

FIGURE 2. - Plan view of underground workings.

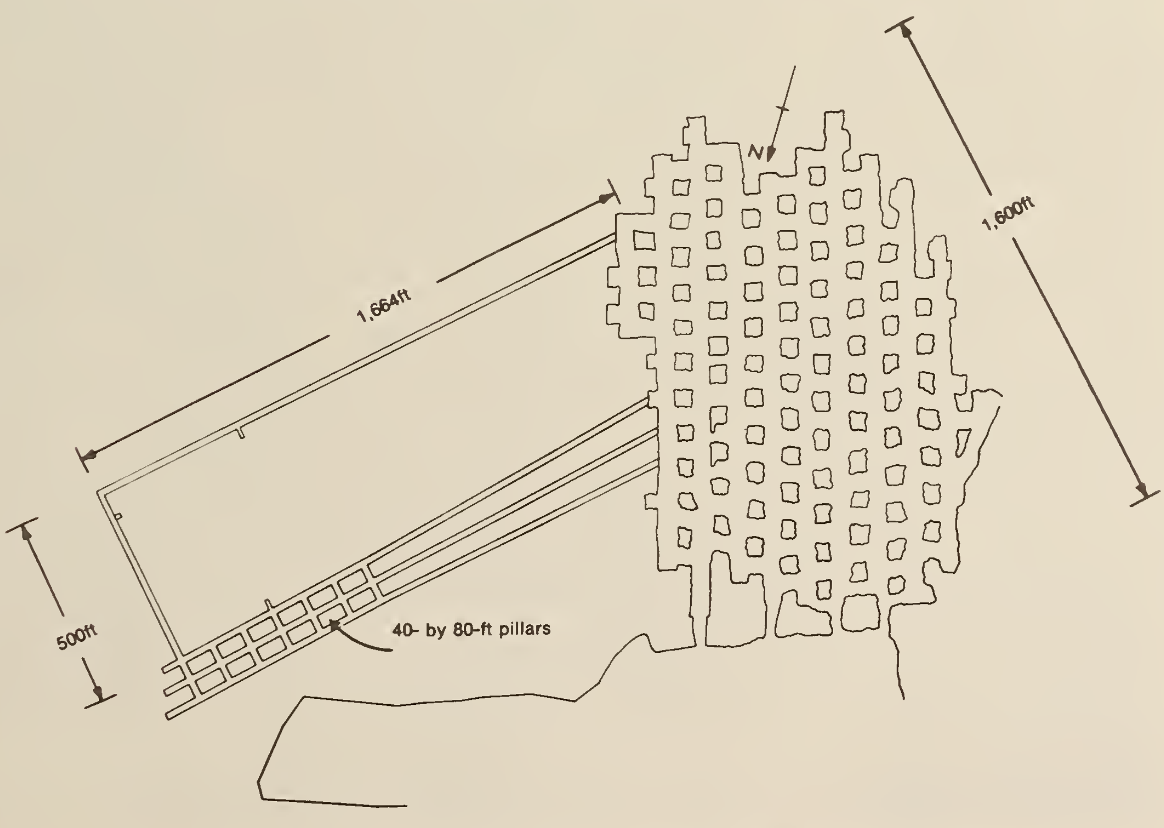

FIGURE 3. - Approximate dimensions of the underground workings.

FIGURE 4. - Control building.

The underground workings are accessed by four portals located in the highwall approximately 200 ft apart. Portal 4 is shown in figure 6. The portal openings are 21 ft wide by 24 ft high and are identified in figure 2.

The surface facility consists of--

- the area above the underground workings, including the gas analysis building, compressor building, and fan house.

- nearly 4 acres of level quarry floor located at the base of a 1,500-running-foot highwall. The highwall ranges in height from 130 to 40 ft (shown in figs. 7 and 8).

- a 7,200 ft^2, Control-Support Building (fig. 4).

The underground workings are located in the Greenbrier Limestone Formation. Figure 9 shows a representative stratigraphic column for the strata above and below the underground workings. The cover over the new workings ranges from 180 to 310 ft, while the cover at the ventilation shaft is 284 ft. The appendix contains a series of photographs showing Lake Lynn Laboratory in different stages of completion.

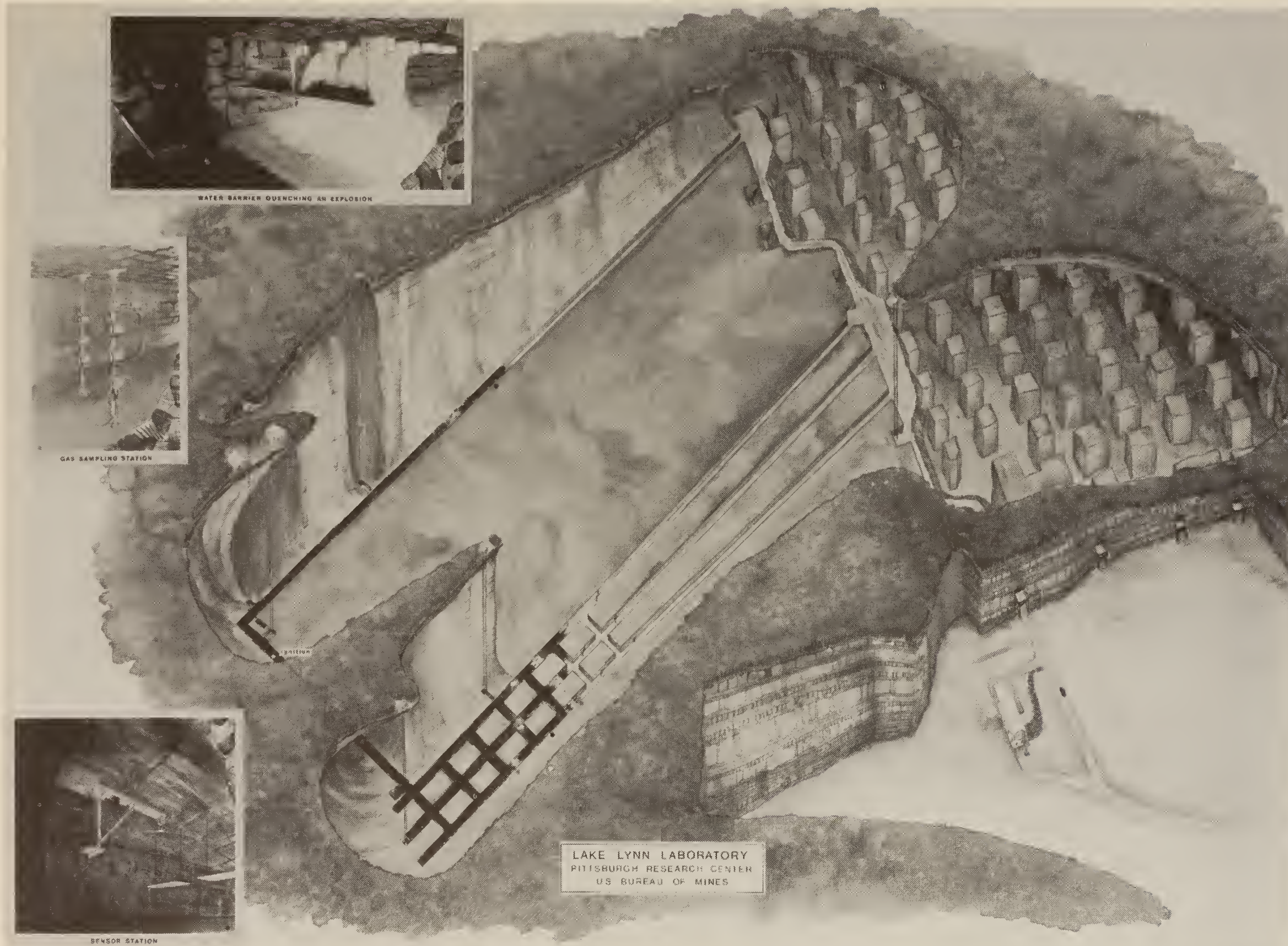

FIGURE 5. - Artist's rendition of the underground drifts.

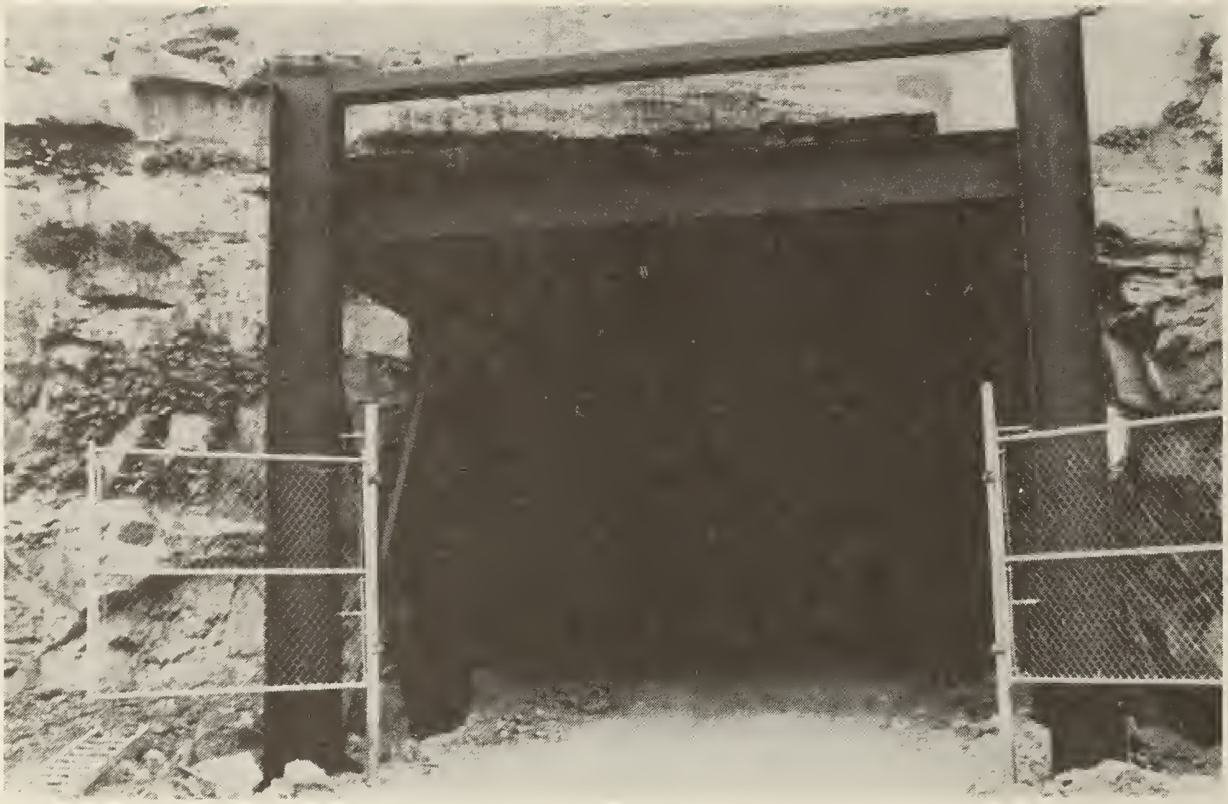

FIGURE 6. - Portal canopy illustration as built.

FIGURE 7. - View of the site in summer 1981.

FIGURE 8. - Aerial view of the Lake Lynn site.

SPECIAL FEATURES OF THE UNDERGROUND FACILITY

The new workings of the Lake Lynn Laboratory were designed and equipped to provide researchers with a flexible, highly sophisticated in-mine test facility. The special features of the Lake Lynn Laboratory are discussed in the sections that follow.

EXPLOSIONPROOF DOORS

The new underground workings at Lake Lynn Laboratory include two movable explosionproof bulkheads. The location of these bulkheads are shown in figure 10. These bulkheads are 67-ton concrete and steel structures that can be positioned anywhere from fully retracted to fully blocking the entry. Figure 11 is a diagram of the bulkhead. Figures 12 and 13 show the bulkhead in a partially constructed and partially closed stage. The bulkheads ride on a track (fig. 14) and are moved by 5-ton pneumatic winches (fig. 15) using 3/4-in-diam wire rope. The bulkheads were designed to withstand 100 psi of static pressure.

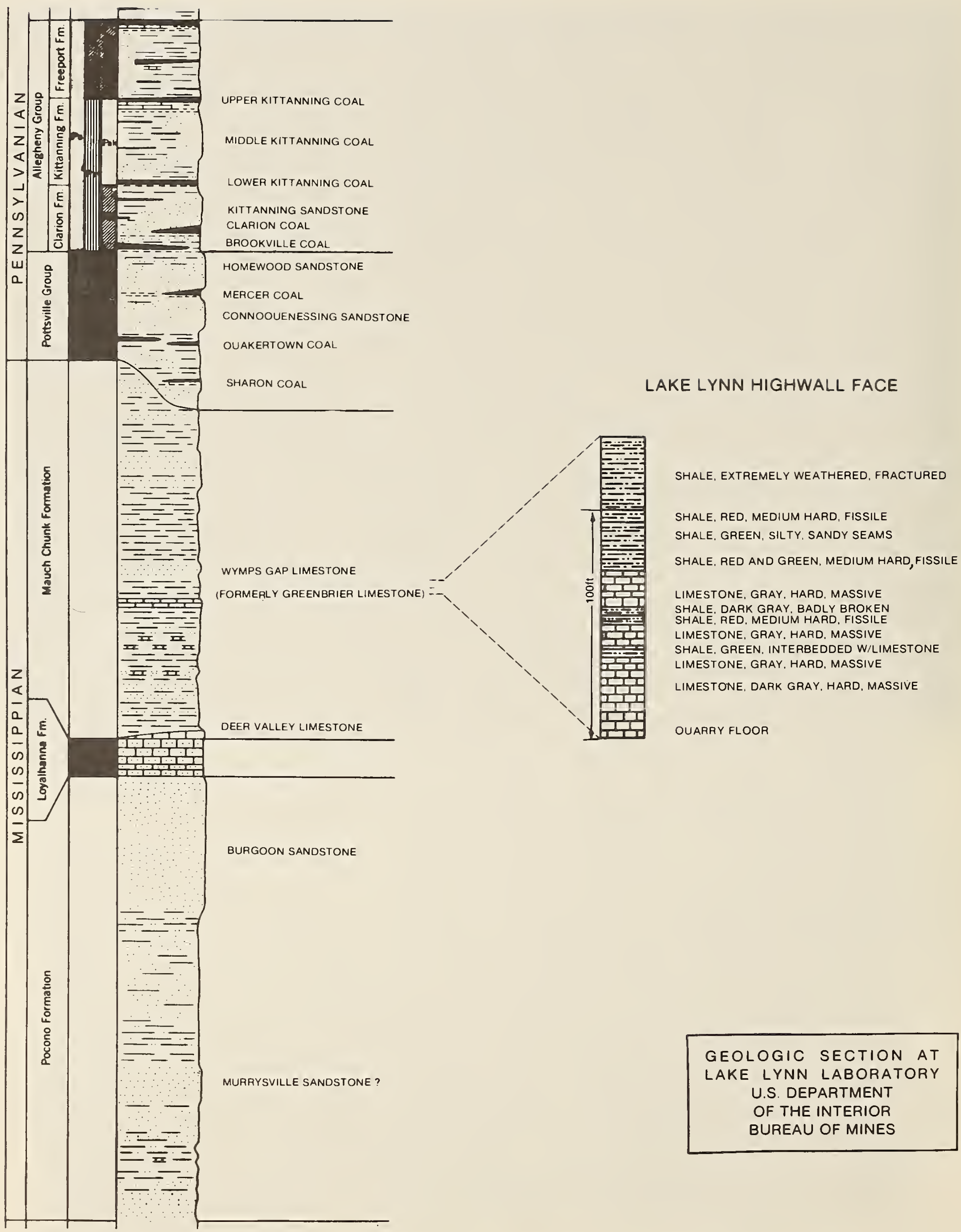

FIGURE 9. - Geologic column of strata in vicinity of Lake Lynn Laboratory.

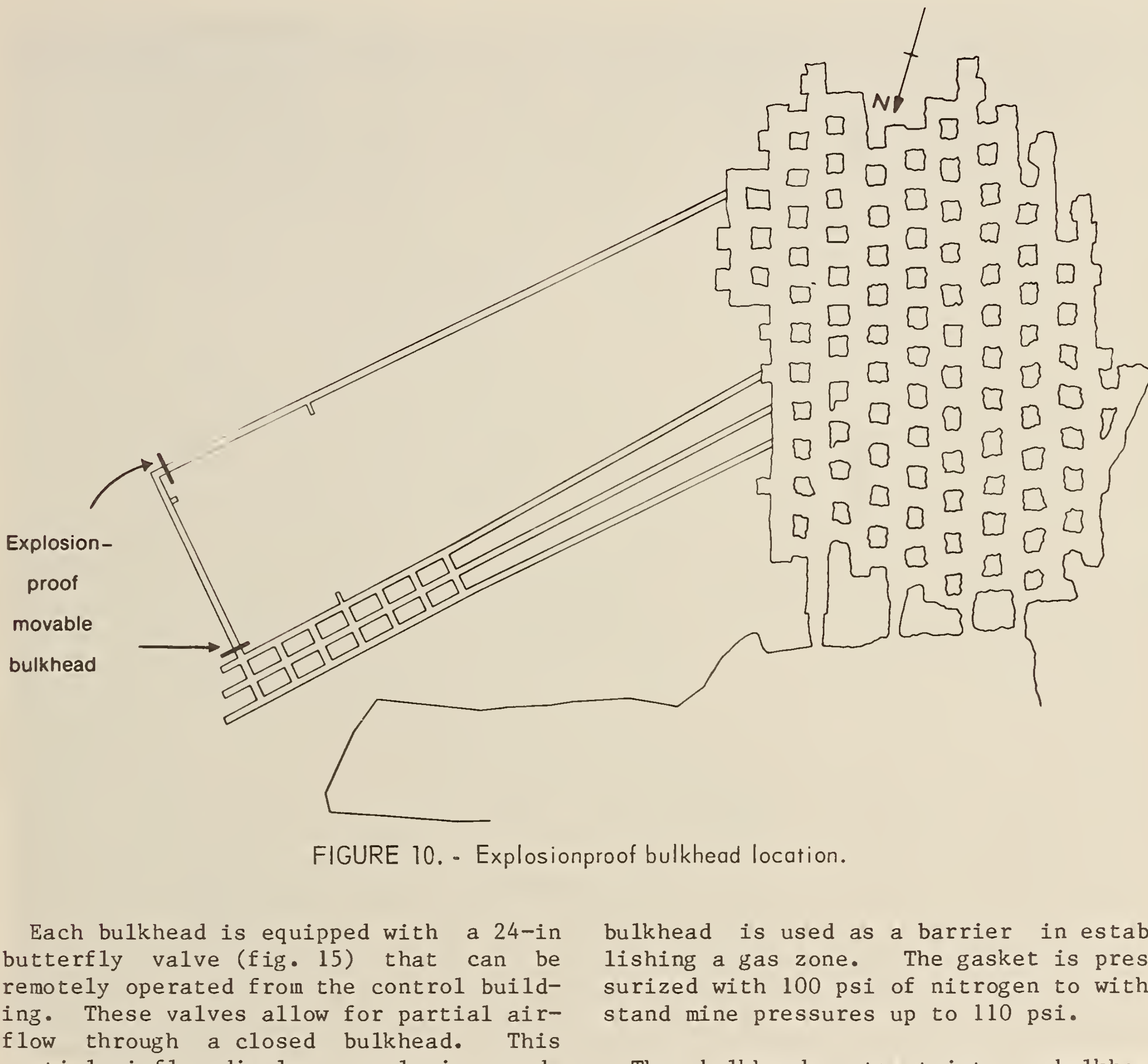

FIGURE 10. - Explosionproof bulkhead location.

Each bulkhead is equipped with a 24-in butterfly valve (fig. 15) that can be remotely operated from the control building. These valves allow for partial airflow through a closed bulkhead. This partial airflow displaces explosion products from a test zone following an explosion and prior to workers' reentering the mine.

The circumference of each face of each bulkhead is fitted with an inflatable gasket to insure gas containment when the bulkhead is used as a barrier in establishing a gas zone. The gasket is pressurized with 100 psi of nitrogen to withstand mine pressures up to 110 psi.

The bulkheads retract into a bulkhead chamber (fig. 15), which also houses the winch and bulkhead controls. The E entry bulkhead chamber is located in the solid E entry rib. The bulkhead chambers are separated from the entries by 100-psi marine doors that are similar to the marine door shown in figure 17.

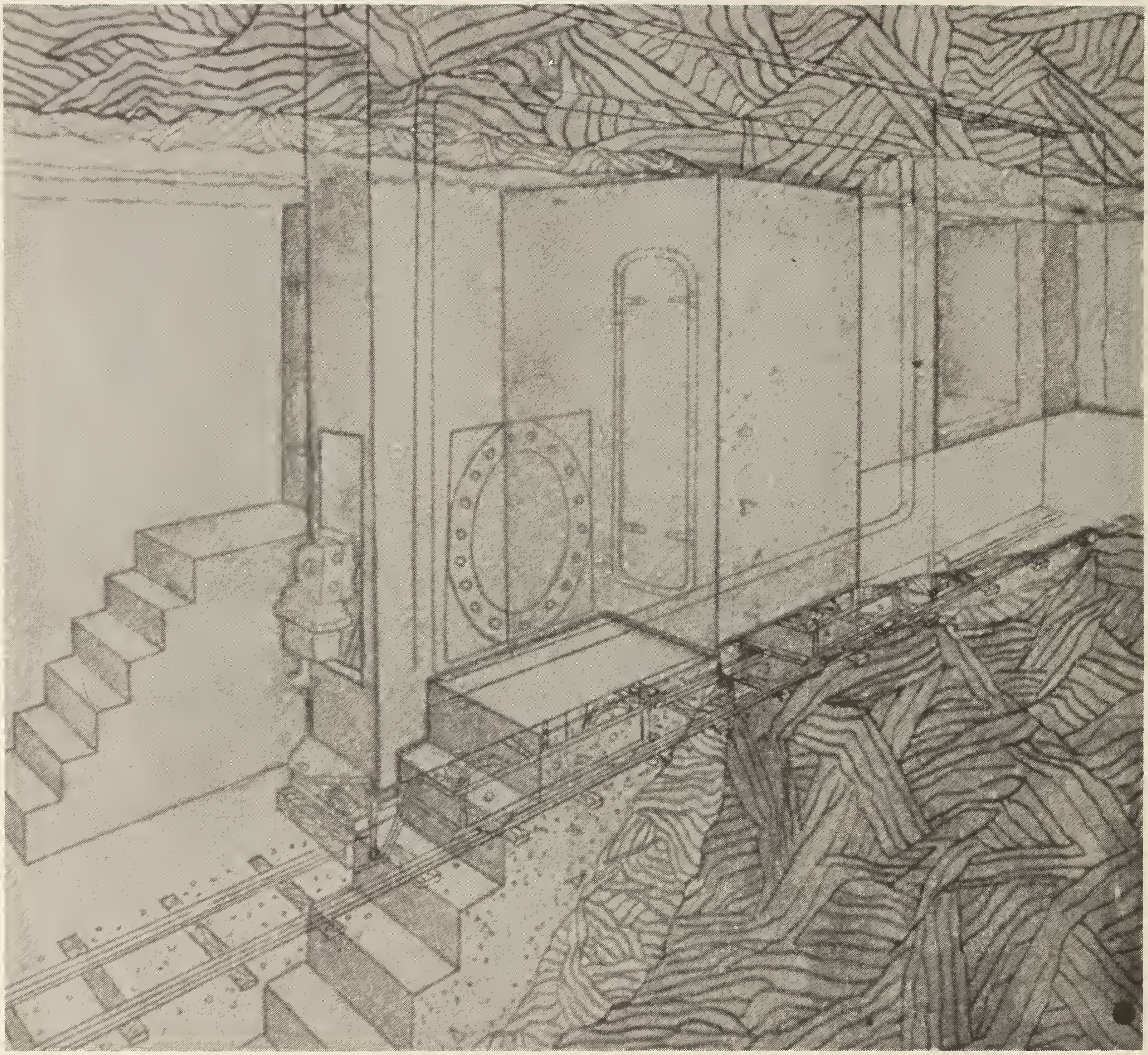

FIGURE 11. - Movable bulkhead room.

FIGURE 12. - Movable bulkhead before installation of reinforcing rods and pouring of concrete.

FIGURE 13. - Movable bulkhead in partially closed position.

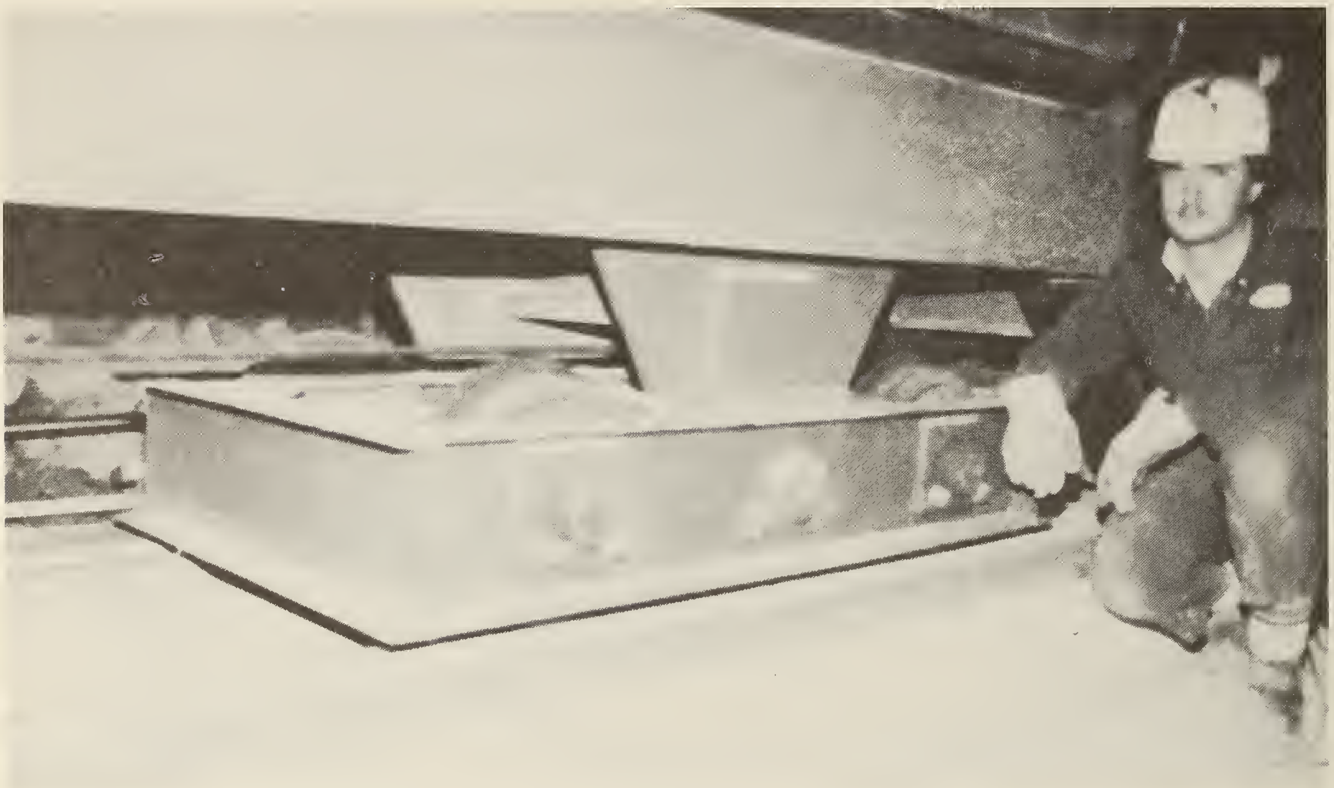

FIGURE 14. - Set of trucks that carry the movable bulkhead.

FIGURE 15. - Air tugger in movable bulkhead room.

FIGURE 16. - Remote-controlled 24-in butterfly valve installed in movable bulkhead.

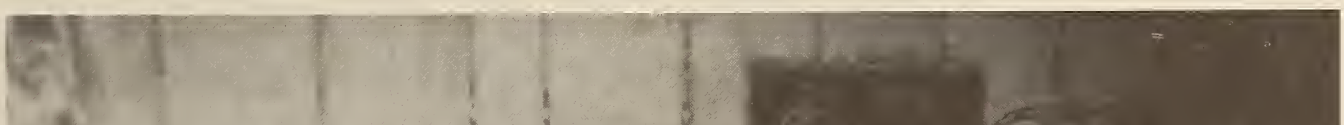

FIGURE 17. - Instrument room in C drift illustrating the locations of conduits and showing marine door.

FLEXIBILITY OF UNDERGROUND LAYOUT

The full underground layout of the new workings is shown in figure 2. By selectively closing each of the two explosionproof movable bulkhead, four partial underground layouts can be realized. These configurations are outlined in table 1, including reference to the particular figure that shows that configuration.

TABLE 1. - Underground configurations

Configuration	Description	Bulkhead position		Figure
		D entry	E entry	
1............	Full mine........	Opened.....	Opened.....	2
2............	Single entry.....	Closed.....	-	18
3............	Triple entry.....	-	Closed.....	19
4............	Longwall face, single entry.	Opened.....	Closed.....	20
5............	Longwall face, triple entry.	Closed.....	Opened.....	21

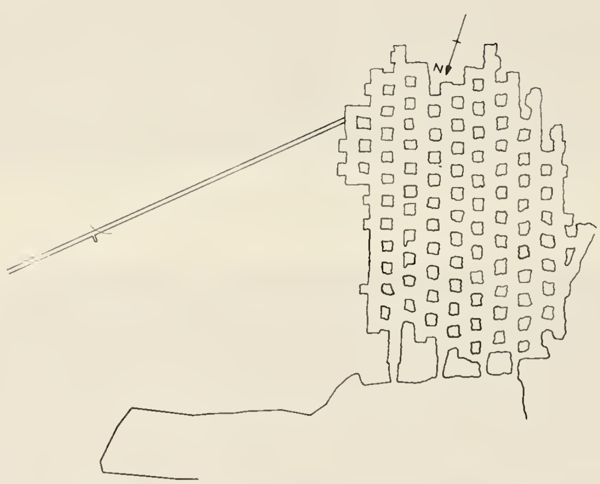

FIGURE 18. - Single-entry configuration.

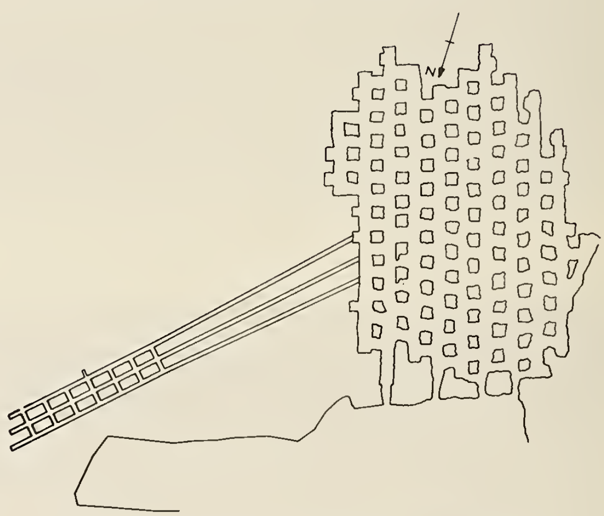

FIGURE 19. - Triple-entry configuration.

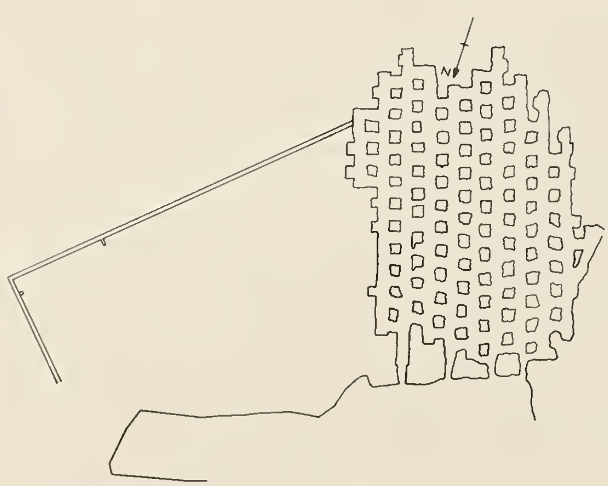

FIGURE 20. - Longwall face—single-entry configuration.

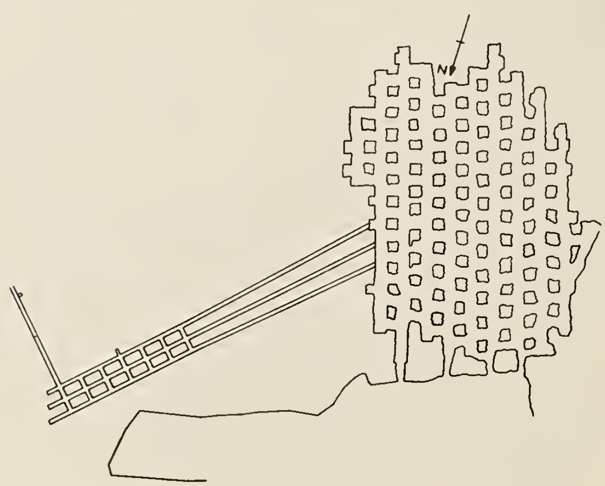

FIGURE 21. - Longwall face—triple-entry configuration.

GAS-MIXING STUBS

There are two gas-mixing stubs in the new workings. They are located at the head of B entry and in the solid rib side of D entry (outby the explosionproof bulkhead) at the positions shown in figure 2. The gas-mixing stubs are separated from the entries by 3-ft-thick reinforced concrete bulkheads designed to withstand 100 psi of static pressure.

The gas-mixing stubs (fig. 22) provide for the remotely controlled (from control building) release of natural gas at the mixing stub location. This release can be extended to any point within the mine using appropriate piping. This piping passes through pressure seals in the bulkheads separating the stubs from the entries and through preexisting conduits that bypass the movable explosionproof bulkheads. Gas can be released at controlled rates from 0 to 34 cfm. Gas zones can be developed anywhere within the underground workings using various combinations of the following six barriers: rib, roof, floor, face, explosionproof bulkheads, and polyethylene-wood diaphragms.

Provided at each stub are 2 bundles, each containing 12 gas-sampling tubes. These tubes can be routed to any point(s) in the mine using the same paths as defined for the gas release. The tubes are 3/8-in-OD polypropylene.

VENTILATION SYSTEM

The new workings are ventilated by a four-speed reversible, 100-hp, 60,000-cfm fan located at the top of the ventilation shaft. The fan can be remotely operated from the control building as well as directly from the fanhouse.

Figure 23 shows an explosionproof door that can separate the ventilation stub from E entry. Also shown in figure 23 is the circular ventilation door, which can be remotely operated from the control building, that is designed to withstand a static pressure of 150 psi. Incoming air can be conditioned with 240 tons of refrigeration capable of removing up to 30 gpm of water. The old workings can be selectively ventilated using exhaust fans and ventilation tubing located at portals 3, 2, and 1.

DATA-GATHERING (DG) PANELS

Located throughout the "new workings" of the Lake Lynn Laboratory are 50 DG panels. The locations of these panels are shown in figure 24. Figure 25 is an artist's drawing of such a panel, and figure 26 shows an actual panel.

A DG panel is a permanent instrument box connected to the control room by 15 pairs of wires. The box is recessed into the rib and serves as a fixed location for a static pressure transducer and a flame sensor. There are 110 V and 220 V ac power available at each panel, as well as a voice communications link to the control room.

At each panel there exists the ability to issue control instructions. The devices that can be controlled from a DG Panel include--

- movie (or TV) camera.
- triggered barriers.
- calibration of all instruments from control room.
- operation of grab-sampling probes.
- local ignitions.
- activation of compressed air to purge windows of optical dust probes.

Instruments that can be monitored from a DG panel include--

- wall pressure transducers (static pressure).
- infrared phototransistors (flame arrival).
- photomultiplier tubes (flame radiation in visible and ultraviolet).

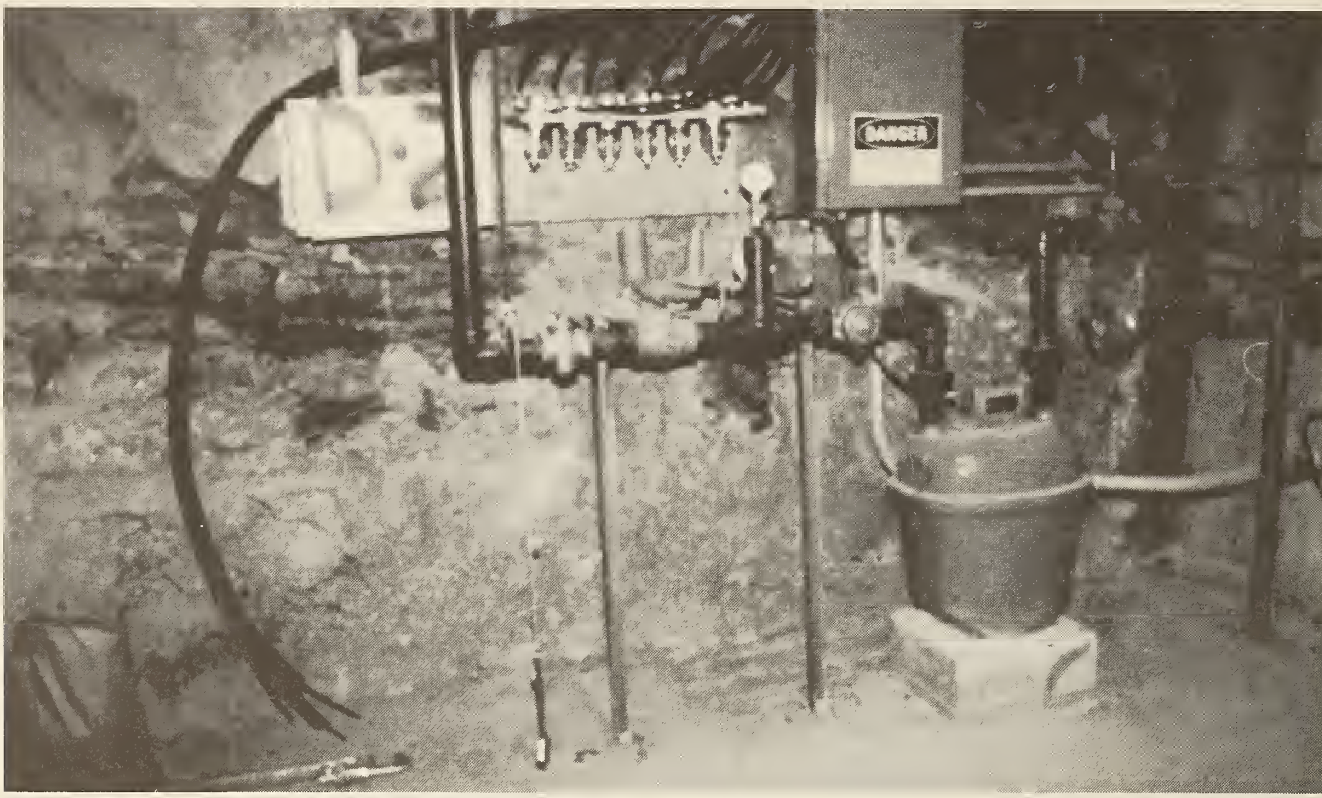

FIGURE 22. - Gas mixing room—D drift.

FIGURE 23. - Remote-controlled circular ventilation door is on the right. A marine explosion-proof door is on the left.

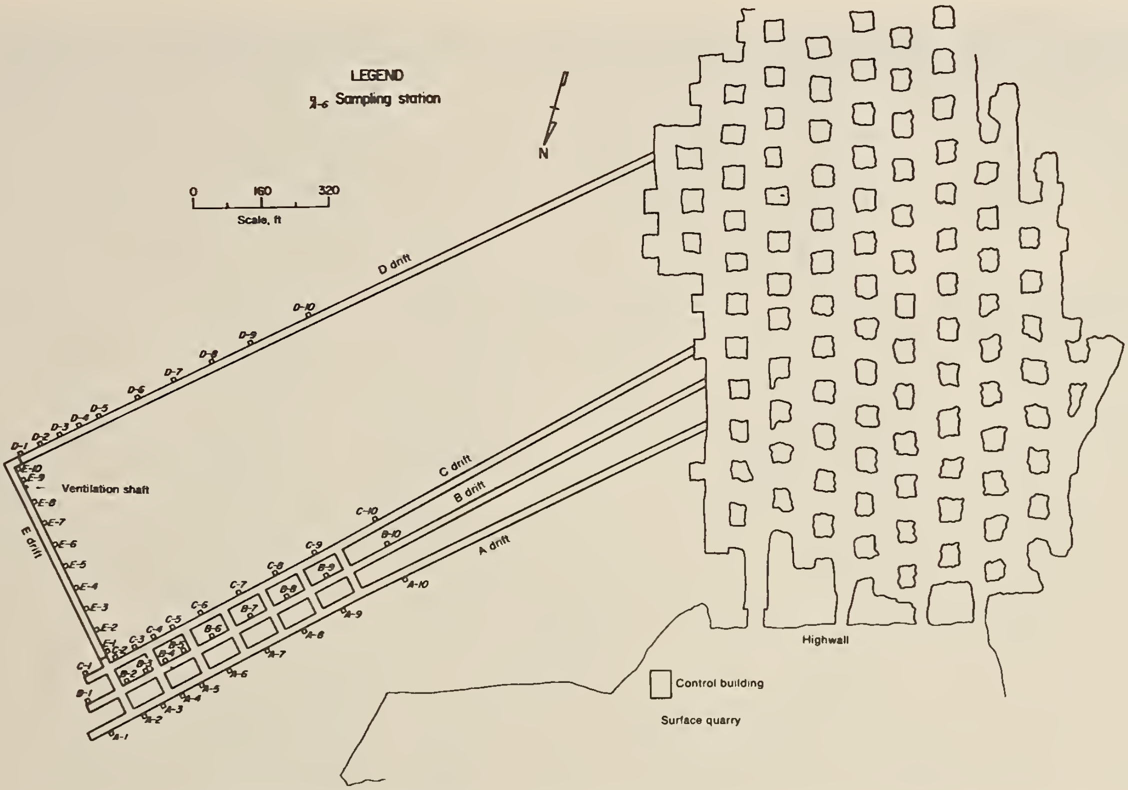

FIGURE 24. - DG panel (sampling station) locations.

FIGURE 25. - DG panel—complete communication system.

FIGURE 26. - DG panel with completed concrete.

- photomultiplier tubes (flame radiation in visible and ultraviolet).
- dynamic pressure transducers (pilot probes and drag probes for velocity measurements).
- optical dust probes (instantaneous concentration of dust in air).
- grab-sampling probes (for gas and dust samples).
- thermocouplers (for gas temperatures).
- three-color pyrometers (for dust cloud temperatures).
- strain gages (for bulkheads).

SENSOR MOUNTING PLATFORMS

There are 38 sensor mounting platforms located throughout the new workings of the Lake Lynn Laboratory. Figure 27 shows the location of these platforms.

A sensor mounting platform is a centrally located rigid structure suspended 3 ft from the mine roof. The structure is retractable and can be "folded" up into the roof. When extended, the platform provides a 1-ft^2 horizontal working platform upon which to locate hardware for "through" measurements. The platform will be located approximately 3 ft below the mine roof at the center of the entry. Figure 28 is an artist's rendition of a sensor mounting platform.

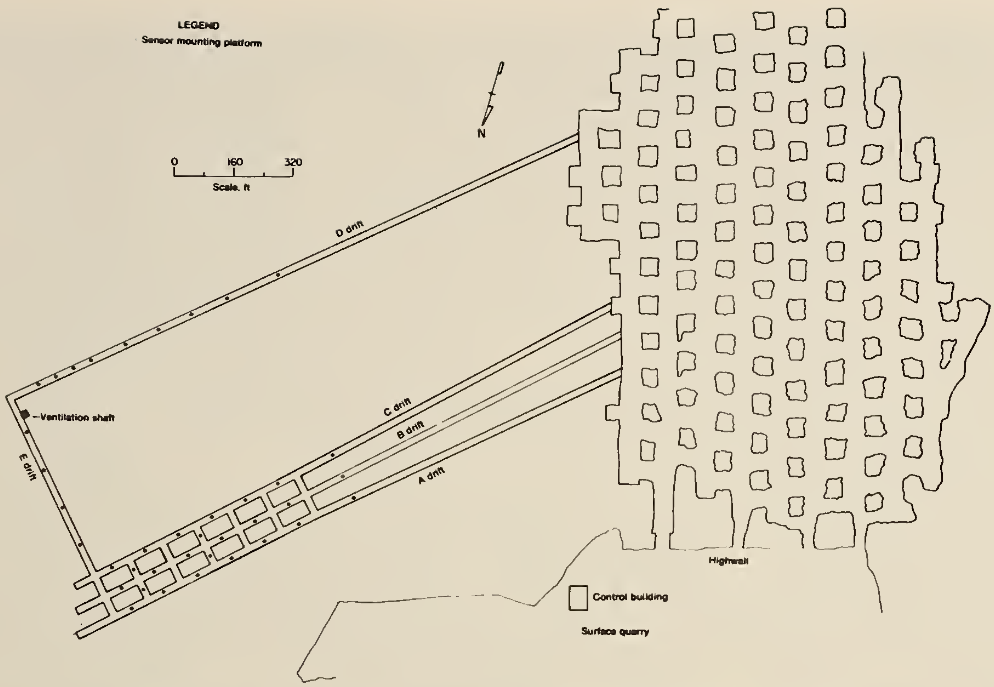

FIGURE 27. - Instrument platform (sensor mounting platform) locations.

FIGURE 28. - Instrument platform that retracts into the roof of the entries—there are 38 such platforms installed in the facility.

SHOTFIRE CIRCUITS

There are two shotfire control boxes located underground. One is located in the bulkhead chamber of the D entry bulkhead, the other in the B entry gas-mixing stub. The associated binding post panels are located on the internal rib of D entry outby the movable explosionproof bulkhead and on the B entry rib outby the gas mixing stub. Each control box activates three independent shotfire circuits. One of these circuits results in the time-delayed activation of two sets of binding posts. The time delay is programmable. The shotfire circuits provide 24 V dc (10 amp) to the binding posts. The shotfire control boxes incorporate multiple safety interlocks and can only be activated from the control building.

Figure 29 shows the shotfire box in the D entry bulkhead chamber. Figure 30 shows the associated binding post panel.

INSTRUMENTATION CABLE DISTRIBUTION

Figure 31 is an artist's rendition of the utility trenches and vertical boreholes serving the underground workings. The trenches and boreholes contain the instrumentation cables, the 440 V-ac power circuit, water lines, gas lines, air lines, and communications. There are two instrument rooms located underground (fig. 32). One room is located on the solid rib side of C entry approximately 240 ft outby E entry intersection. The second is located approximately 400 ft from the D entry explosionproof bulkhead location, along the solid rib. The instrument rooms are accessed through 100-psi marine doors. On the surface above each instrument room is a utility pit. The instrument rooms and utility pits serve as distribution points for the instrumentation cable.

The path of the instrumentation cable is as follows:

- The cable leaves the control room and travels in a covered trench into the mine (through portal No. 4) to the base of a borehole located 200 ft inby No. 4 portal.

- The cable travels up a 12-in-diam borehole to the surface.

- The cables travel in covered trenches to the following borehole locations. The number of 15-wire pair cables that descend at each location is listed below:

  Borehole above D entry instrument room--21.

  Borehole above C entry instrument room--31.

  B entry gas-mixing stub--1.

  D entry gas-mixing stub--1.

  Borehole parallel to ventilation shaft--1.

- The cables travel through conduits encased in concrete in the mine ribs (fig. 33) to DG panels as required.

In all, there are 1,620 miles of No. 18 instrumentation wire in, above, and around the Lake Lynn Laboratory.

UTILITY DISTRIBUTION

The primary power supply brought into the underground workings (through 24-in-diam boreholes) is 440-V-ac, 3-phase, 110-amp service.

Available at each DG panel is 220-V-ac, single-phase (on a 30-amp breaker) and 110-V-ac, single-phase (on a 20-amp breaker) service.

Available throughout the new workings at approximately 150-ft intervals are--

- air at 900 cfm and at 120 psi from a 200-hp compressor.

- water at 190 psi and 47.5 gpm.

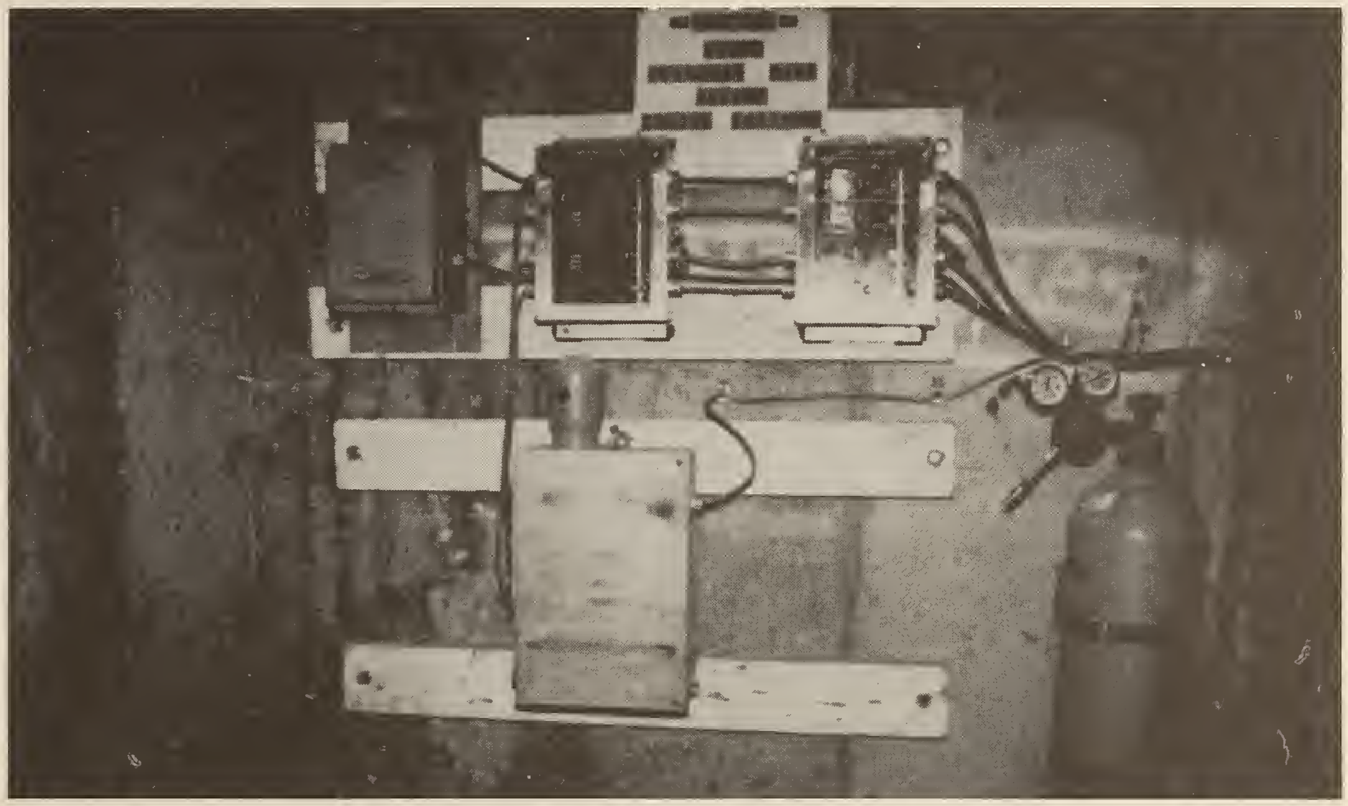

FIGURE 29. - Shotfiring panel.

FIGURE 30. - Binding post panel.

FIGURE 31. - Artist's rendition of utility trenches and vertical boreholes into underground workings.

FIGURE 32. - Underground instrument room.

FIGURE 33. - DG panel—before pouring of concrete fender.

FIGURE 34. - Forming and reinforcement for the concrete fenders underground; these fenders encase the air and water lines and the power, communication, and instrument cables.

RIB, ROOF, AND FLOOR CONDITION

The entire floor area of the new workings is covered with nominally 6-in-thick, reinforced, 3,000-psi concrete. There are approximately 840 yd^3 of concrete in the floor.

Along one rib of A, B, C, D, and E entries is a nominal 10-in-thick, reinforced concrete fender. The fender is 4 ft-high throughout the area where DG panels are located and 18 in high in the remainder of the entries. In the DG panel areas, the fender houses air and water lines as well as power, communication, and instrument cables (fig. 34). In the remainder of the entries, the fender houses only air and water lines. There are approximately 980 yd^3 of concrete in these fenders.

Figure 35 shows the floor and rib-fender condition underground.

CONTROL AND DATA ACQUISITION SYSTEMS

DATA ACQUISITION SYSTEM

The Lake Lynn Laboratory is equipped with a computer-controlled data acquisition system (DAS). The sampling rate of the DAS is 3,125,000 samples in an 8-sec interval. There are 132 input channels to the DAS. The system has a storage capability of 4 complete runs (approximately 12 million samples).

There is a dedicated communications link from the Lake Lynn Laboratory system to the PDP 11/34 computer located at the Bureau's Bruceton facility. Onsite interface capability to the Bruceton system is available at Lake Lynn, as is the ability for onsite data reduction (including preparation of plots).

FIGURE 35. - View of a completed drift showing concrete floor and rib with concrete fender.

GAS ANALYSIS SYSTEM

The gas analysis system has the following features:

- gas analysis (for methane and CO) is performed by a nondispersive infrared analyzer.

- samples are drawn at 8 lpm at a vacuum of 6 in Hg.

- each tube can automatically be individually, selectively, or sequentially scanned.

- the response time, from request for data for receipt of result, is less than 1 min.

- each time a sample is drawn, there is an automatic check for volume flow and vacuum.

HIGH-SPEED ANALOG RECORDERS

The Lake Lynn Laboratory is equipped with three high-speed light beam analog recorders. The recorders can operate with selected chart speeds up to 120 ips. A total of 82 analog signals can be simultaneously recorded.

CONTROL SYSTEM

The following operations can be controlled from the Control-Support Building:

- main fan
- gas release
- shotfire circuits
- gas sampling
- ventilation shaft door

CONCLUSIONS

The Lake Lynn Laboratory presents a flexible environment that will enable researchers to investigate a number of mining health and safety phenomena. The primary area of interest is, of course, fires and explosions. The facility is unique in that it accurately reproduces present mining conditions, including a longwall panel. Its utilization will, however, extend to virtually all research areas that require isolated surroundings for safe evaluation of new technology such as innovative roof control devices, new explosives, and improved drills. Thus, the Lake Lynn Laboratory is a tool that promises to significantly contribute to the improvement of the health and safety of our Nation's miners.

APPENDIX

TABLE A-1. - Contractors for the Lake Lynn Laboratory

Contractor or Supplier	Description	Time
MAJOR CONTRACTORS FOR THE LAKE LYNN LABORATORY		
Green International, Inc.......	General facility design..............	8/79-10/80
Gilbert Corp..................	Drift driving, installation of movable bulkheads, installation of remote control door, concrete on entry floor.	10/79- 2/81
Solomon & Teslevich............	Instrumentation and utilities.........	8/80-10/81
Weiss Brothers.................	Highwall construction.................	6/82- 9/82
SUBCONTRACTORS OR SUPPLIERS FOR THE LAKE LYNN LABORATORY		
T. Yezbak & Son................	Construction of control building, fan building, compressor building, security walls, and fences.	Spring 1980-Fall 1981
Colonial Ornamental Iron Co....	Movable bulkheads.....................	5/81
Baldwin Electric...............	Instrument communication and power cable installation.	10/80-10/81
Process Corp...................	Computers[1]...........................	5/81
Dennis Corp....................	Concrete supplier.....................	10/80-11/81
Motorola Corp..................	Radio communication system............	8/81
Tube Turn Corp.................	Remote control door...................	8/80
Honeywell and Bell & Howell....	Analog recorders and data amplifiers..	6/81

[1]PDP 11/34 with 96 kw of memory, RP04 disk drive storage units (80 MB), 4 Analogic A/D converters, 13-bit resolution input = ±10 V 250-KHz sampling rate, 4 Monolithic external memory units with 256 KB of semiconductor memory computer. Manufacturer: Digital Equipment Corp.

Figure A-1 shows a plan view of the Bruceton Experimental Mine. The mine is a twin-parallel-gallery arrangement. The galleries (main entry and air course) are 1,300 ft long. The cross section is rectangular, 6 ft high by 9 ft wide. Each gallery is lined with concrete and has mine-car tracks layed down the center. Within 600 ft of the face, the following instrumentation is installed:

- dynamic pressure sensors (3)
- pyrometers (3)
- static pressure sensors (10)
- dust concentration probes (3)
- light sensors (16)

Figures A-2 and A-3 show the general condition of portal 4 and the highwall prior to the start of construction. Figures A-4 through A-20 show various stages of the facility construction.

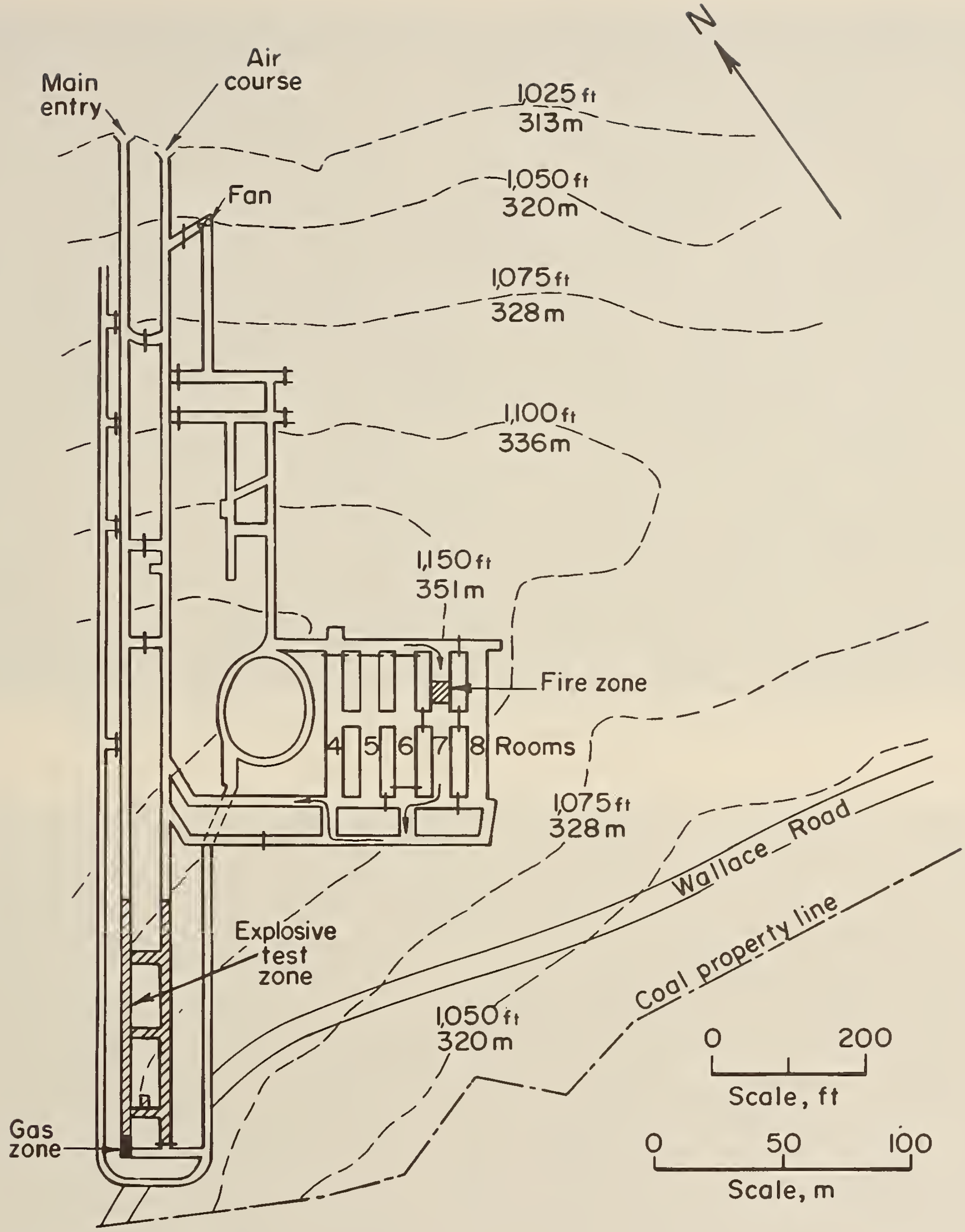

FIGURE A-1. - Plan view of Bruceton Experimental Mine.

FIGURE A-2. - Portal prior to installation of canopy.

FIGURE A-3. - A very early view of the highwall and four portals.

FIGURE A-4. - Cutting utility trench in solid rock near the fanhouse.

FIGURE A-5. - Installing conduits from one utility pit to another.

FIGURE A-6. - Installing conduits in solid limestone paralleling the highwall between the control building and the underground workings.

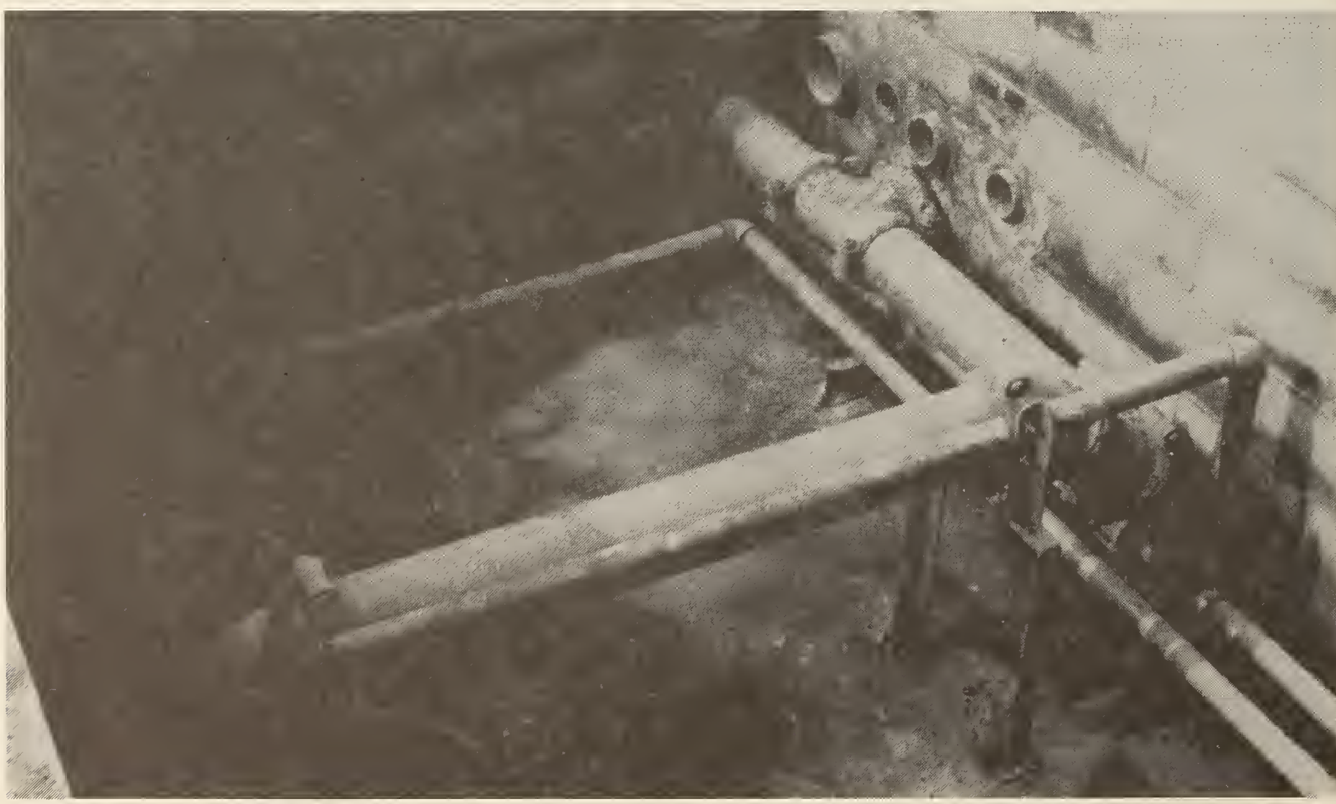

FIGURE A-7 - View of the inside of one of the five utility pits.

FIGURE A-8. - Conduits from underground entering computer room.

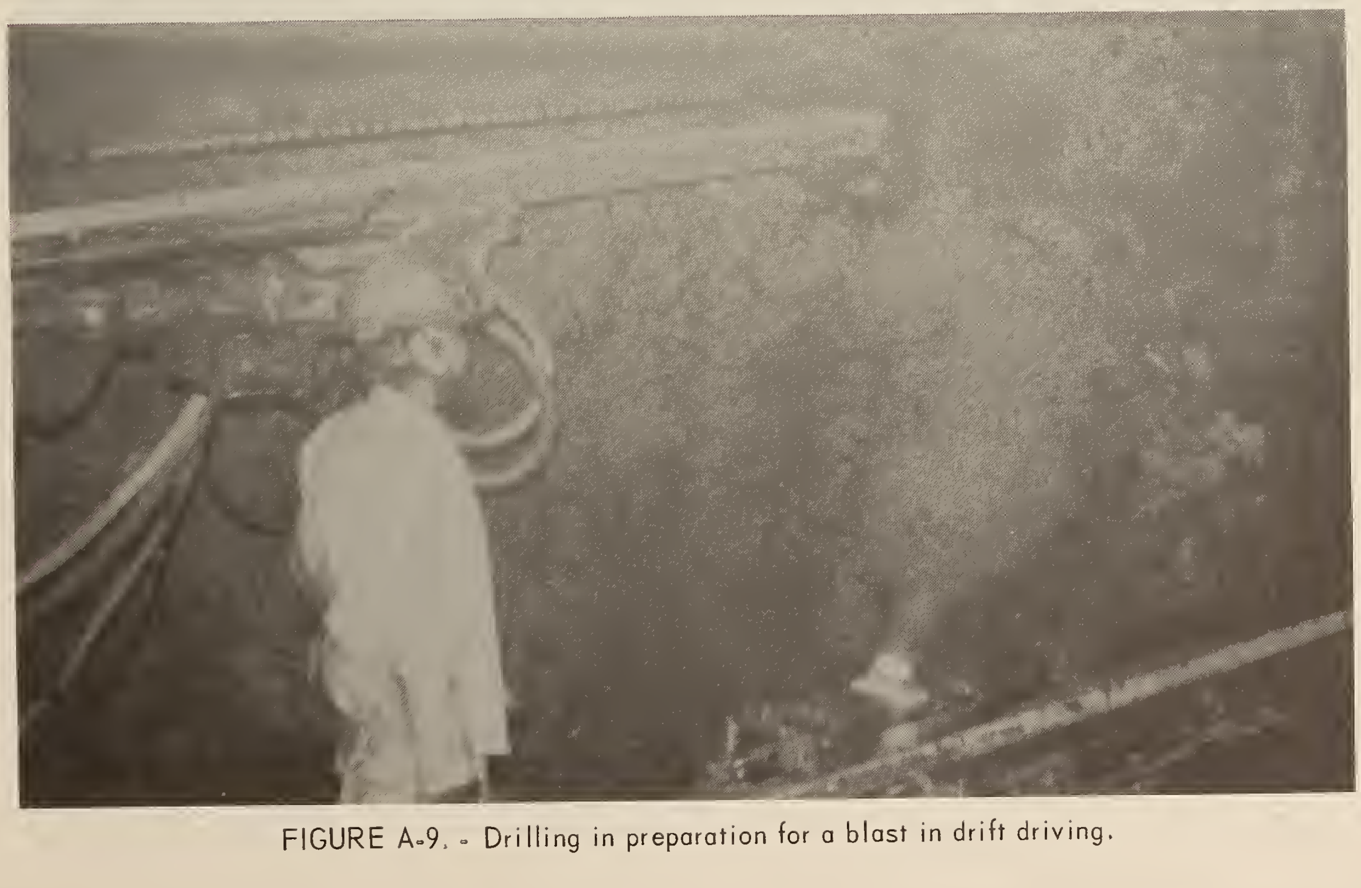

FIGURE A-9. - Drilling in preparation for a blast in drift driving.

FIGURE A-10. - Loading explosives into blast holes in the face of a drift.

FIGURE A-11. - S.T.3 mucking buggy—used in transporting blasted limestone material out of the drifts.

FIGURE A-12. - Small bulldozer used for distribution of materials hauled out of the drifts to the underground ramp.

FIGURE A-13. - Two cranes lowering a 2-ft casing into a vertical borehole.

FIGURE A-14. - Five-foot-diameter rock drill used to bore the vertical borehole for the ventilation duct. Raise drilling method was used.

FIGURE A-15. - Ventilation duct being installed underground.

FIGURE A-16. - Installing gunite (fibrous) on a fault in B-drift.

FIGURE A-17. - Installation of 4-ft roof bolt in a drift.

FIGURE A-18. - Roof bolt pattern in the old workings in areas being used as transporting routes.

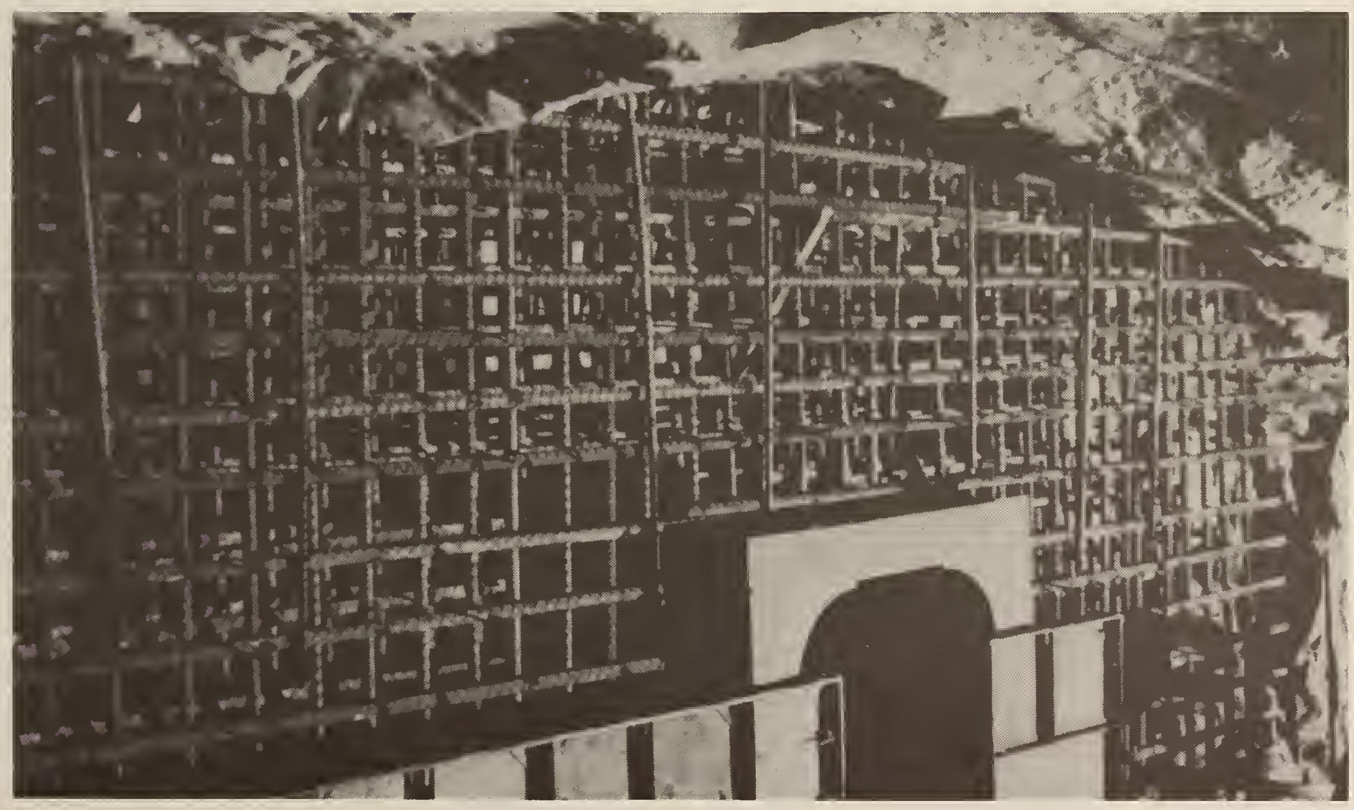

FIGURE A-19. - Reinforcement rods prior to pouring of concrete to construct bulkhead for an underground instrument room.

FIGURE A-20. - Forms to hold wet concrete for fender to protect instrumentation and utility, power, air, and water lines.

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