FIFTY-NINE COAL-MINE FIRES

HOW THEY WERE FOUGHT
AND WHAT THEY TEACH

BY

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PREFACE

In December, 1907, a series of disastrous explosions in coal mines killed 698 men and so aroused public attention that Congress, in 1908, authorized the technologic branch of the United States Geological Survey to undertake an investigation of the causes of explosions in coal mines. The Bureau of Mines, which in 1910 took over the work on mine explosions, was directed by its organic act to conduct investigations relating to the increase of safety in mining. In the course of the work it has done the bureau has investigated many mine explosions and fires and has published much information on the causes of mine disasters and the methods of prevention. This bulletin, compiled from the records of the bureau, deals with that ever-present hazard, fire, and presents data relating to 59 fires.

Fires in coal mines, as this bulletin shows, have a variety of causes, some of which would hardly be credited if the facts were not on record. Mine fires are dangerous to fight; they generate asphyxiating gases and in gassy mines they may cause explosions. To extinguish a mine fire, to prevent its spreading, or to seal it is a task that demands care and skill. In discussing the fires mentioned, the authors of this bulletin describe practical methods of fire fighting, and make recommendations on fire prevention. One reason why this bulletin should be of service to persons interested in lessening the hazards of mining is that the descriptions of the fires and the fire-fighting methods not only cover a period of 16 years, but relate to widely separated mines that differ greatly in underground conditions and range from anthracite to lignite mines.

Scott Turner, Director.
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FIFTY-NINE COAL-MINE FIRES: HOW THEY WERE FOUGHT AND WHAT THEY TEACH

By G. S. Rice, J. W. Paul, and M. W. von Bernewitz

INTRODUCTION

This bulletin abstracts and reviews essential details of reports on 59 fires in different coal mines in the United States, describes the circumstances of origin and the methods of controlling or extinguishing the fires, and points out the lessons taught. In all, the fires caused great damage to property and killed nearly 400 men. The data have been compiled from the records of the Bureau of Mines, which cover most of the major mine accidents in the United States since 1908. The names of the mines concerned and of the persons connected with the management of those mines have been omitted in accordance with the usual policy of the bureau. The bureau hopes that this bulletin will be of service to all persons interested in lessening the fire hazard at coal mines and to all who may be called on to fight a mine fire.

ACKNOWLEDGMENTS


The compilation of the report in its present form was made at the suggestion of E. A. Holbrook, formerly assistant director of the bureau.
THE FIRE HAZARD AT COAL MINES

Coal mines can not be altogether freed from the fire hazard. The mineral mined is combustible; in many mines there is inflow of inflammable gas from the coal measures; wooden timbering is necessary to support the roof; doors and brattices to afford ventilation are present; and more or less inflammable or explosive substances, such as explosives, oils, and electric insulation, are in use. The hazard can, however, be so minimized that there will be little danger of fires disastrous to life and property.

As this bulletin indicates, fires have occurred in all kinds of coal mines from anthracite to lignite and in nongassy as well as gassy mines. Some coals when mined are subject to spontaneous firing, but this is not an index of relative liability to disastrous fires, for such fires have occurred at anthracite mines which are not subject to spontaneous fires.

The factors involved in mine fires are so numerous—they include different sources of ignition present, the presence of methane, the arrangement of the mine and its equipment, and most of all the discipline maintained and the mine organization employed—that no generalization as to relative hazards can be made to apply to a specific mine.

CLASSIFICATION OF MINE FIRES BY CAUSES

A classification of the causes of the 59 mine fires described in this bulletin would not represent even a small fraction of all the coalmine fires that started during the period 1908 to 1924; the classification applies only to certain typical fires at which representatives of the Bureau of Mines were asked to give aid. Every year hundreds of fires start in coal mines, but, as they are promptly extinguished before they do damage, no permanent record of them is kept by the mine management. This is particularly true of mines where black powder, dynamite, and open lights are used, or of those mines subject to spontaneous fires, where the prompt sealing off of workings extinguishes the fire before it becomes dangerous. Therefore, the classification of the causes of the 59 mine fires that is printed on a later page does not provide an index of the relative frequency of fires or the liability to fires of different kinds of coal mines.

The relative liability of a mine changes from year to year, with changes in mining development and mining equipment. For example, 25 years ago only a few mines used closed or safety lamps and no permissible explosives were available, consequently open lights and black powder were almost the only causes of mine fires, except spontaneous fires.

At that time electricity was little used; now its use is almost universal in coal mines in this country, and it has become one of the
important causes of ignition. More gas (methane) is being encountered as mines go deeper and are worked more intensively. On the other hand, permissible electric miners’ lamps and permissible electric machinery have been widely introduced, better ventilation and panel systems of working have been adopted, safety measures generally have become popular, and the development of highly efficient oxygen breathing apparatus and gas masks—effective aids in fire fighting—has been accompanied by systematic organization of fire-fighting and recovery crews.

Thus it will be seen that although in recent years natural hazards and some additional sources of ignition have tended to increase the possibility of mine fires originating, other factors have tended to lessen the number of fires. Whether there has been a gain or loss from year to year is not susceptible to statistical analysis because, as stated, only a small fraction of the fires that start is recorded.

With conditions as they are—two-thirds of the coal mines using open lights, a similar proportion using black blasting powder and dynamite, the larger number of mines using nonpermissible motors and electric cables, and many mines having badly installed electric circuits—the senior authors of this report believe that to-day the relative order of igniting agencies in the causation of underground fires is as follows:

1. Open lights igniting methane.
2. Black blasting powder and dynamite igniting gas or coal.
3. Electric sparks from nonpermissible motors igniting methane.
4. Electric shorts from power lines or trolley lines igniting timber or coal.
5. Spontaneous gob fires.
6. Fires caused by explosions of gas or coal dust.
7. Frictional heating of bearings igniting wood or oily material.
8. Flames or burning brands from surface fires.

LOCATION OF FIRES AS AFFECTING HAZARD TO LIFE AND PROPERTY

Most fires that have caused loss of life and great loss of property and have involved sealing the whole mine have occurred in the vicinity of shafts or of entrances to sections of mines and have shut off the escape of men. These fires have largely been started by open lights or electric arcs igniting timber, oil, or other inflammable material.

Some fires at the face have caused explosions of gas which have killed men and destroyed property, but except in gassy mines fires at or near the face rarely cause loss of life or much damage, for usually they can be quickly put out by water or with a portable fire extinguisher.
Spontaneous fires in the gob have sometimes caused explosions, especially when areas in gassy mines were being sealed, but in general gob fires have been sealed with little difficulty.

**METHODS OF LIMITING IGNITION**

As being of primary importance in preventing serious fires the following measures are proposed, beginning at the surface:

Use incombustible material for buildings near mines and especially avoid the use of wood in shaft and fan structures.

Use incombustible material for shaft linings, the lining of shaft bottoms, and the entrances to slopes and drifts. If wood is used, install emergency steel fire doors or trapdoors which can be closed from outside the mine from a suitable distance by wire or cables or other mechanical means.

Main pump rooms, transformer and motor rooms, stables, and places where oil is stored should have incombustible linings and be provided with steel or concrete fire doors which can be closed from outside.

Main supply electric cables should be armored and where feasible placed in a channel cut in the floor and sealed over. Other electric lines should be installed so as not to be in contact with wood, brattice cloth, or walls. Approved junction boxes and switches should be used instead of twisting or hooking wires together.

Overcasts, door frames in main haulageways, stoppings in crosscuts of main entries, and permanent seals of fire areas and of abandoned or unused parts of mines should be made of incombustible material.

Emergency fire doors at divisional points and panel entrances would be, under some conditions, of great value in controlling a fire.

**PRINCIPAL AGENCIES FOR FIRE FIGHTING**

Necessary equipment includes ample water supply on the surface; water lines about the mine buildings and extending into and through the mine, with frequent taps and hose and nozzle; also portable fire extinguishers, stored at strategic and divisional points in the mine, and fire buckets. Besides small hand apparatus, well-equipped mines now have chemical extinguishers mounted on trucks. These have large tanks filled with water. The pressure of carbon dioxide gas, generated by the action of sulphuric acid on sodium bicarbonate, expels the water and carbon dioxide through a hose.

Main fans should always be on the surface and should be “reversible.” Booster fans should be used rarely, and then only to meet special needs. The Bureau of Mines believes that auxiliary fans should not be used as a substitute for the regular coursing of air currents.
Supplies of brattice cloth and matched boards for emergency stoppings should be kept in special stations or refuge rooms at strategic points.

Rock dust, kept in barrels or sacks, is an efficient aid in fighting a fire at the start.

Telephone lines from the surface to all strategic points and underground cabins are invaluable for giving warning and for transmitting instructions.

Gas detectors, carbon monoxide detectors, and gas-analysis apparatus are important aids in ascertaining danger and in the control of ventilation.

**FIRE-FIGHTING ORGANIZATION**

As most mine fires are caused by carelessness, education and discipline of mine employees will do much to prevent them.

Matches, patent igniters, and smoking tobacco should not be permitted in mines.

The most intelligent men should be grouped into fire-fighting crews. Drills should be held periodically, at least monthly, in different parts of the mine and should cover different kinds of fires and different places of origin.

Skeleton maps for use in fighting fires should be prepared. They should show the position of pumps, water sumps, water lines, and taps, the direction of ventilating currents, all control doors and regulators, and all entrances and exits. These maps should be fastened up at various points and especially in underground offices or cabins.

The direction of escapeways should be shown by standard enameled signs.

Direction charts of what to do in case of fire should be framed behind glass and placed at shaft bottoms and all principal underground stations.

**WHEN FIRE OCCURS**

Anyone discovering a mine fire which he can not put out at once with the means at hand should shout “Fire” to those within hearing, run to the nearest telephone, calling to men encountered en route, notify a mine official of the fire, and state briefly its location and the circumstances, then follow the instructions of the officials according to rank.

The underground foreman or mine manager should notify the superintendent or surface foreman, who should take appropriate action. Promptness is essential; most fires at the start could be extinguished with a bucket of water.

In the absence of instructions, hoisting engineers, fan engineers, and mechanics should stand by at their posts, alert for immediate action.
The hoisting of coal or the lowering of miners should be stopped immediately. Miners should be notified to come out if the fire is blazing or if there is a body of gas in the vicinity of a gob fire.

Fire-fighting crews (which should have been organized previously), on the surface and underground, should get hose and other apparatus ready immediately and then stand by for instructions.

The surface ventilating fans should be kept running normally until instructions to the contrary have been directly given by the responsible officials.

Discipline of the men and quick, firm decisions on the part of the management are vital in preventing a fire that seems insignificant in the first minutes from turning into a disaster.

REVERSAL OF FAN

Fans should rarely be reversed in the event of a fire or explosion if men are in the mine. Such reversal may trap men going to or already in the intake passages.

Exceptionally, when and where there are special conditions, reversing a fan may save life and prevent the spread of the fire. At one mine fire, which is described in this bulletin, had the fan been reversed within the first 15 minutes after the fire started at the foot of the downcast shaft more than 250 lives might have been saved; shortly afterward the fire was short-circuited to the upcast shaft and only other means of escape and set that on fire. Then reversing was too late. This indicates strikingly how short the time for making a vital decision may be.

If a fire occurs in or near the foot of a downcast shaft, like the fire just cited, quick reversal may save not only men but the whole mine, at the expense of losing only the shaft, if that is lined with wood. If a fire occurs in or near the foot of an upcast shaft, to reverse the fan is fatal. These views presuppose that the mine has two adequate means of escape, a precaution called for by every State mining law, but too often wretchedly fulfilled. Also, the views here given apply only when the intake and return air are in separate shafts.

INTAKE AND RETURN IN SAME SHAFT A BAD PRACTICE

The practice of putting the intake and return in the same shaft and separating them by only a wood partition is highly dangerous and has contributed to many disasters in this country. The Bureau of Mines considers that the practice should be made unlawful in every State, as it is in several European countries. Even if the shaft is fireproofed and the partition is of concrete, experience has shown that an explosion will wreck it; and in the event of fire, if the lining
and partition resist hot flames from burning material below, connecting passages at the foot of the shaft will permit fire to pass to the other compartment. Furthermore, at the top of such a combination upcast and downcast fan, the smoke and fumes will whip around if there is no wind, or if the wind is from the upcast toward the downcast intake. This is one of the reasons why the mining laws of some States call for the placing of shaft exits 300 feet apart.

**FIGHTING A FIRE BY DIRECT ATTACK**

If a pipe line and hose, or portable extinguishers, or even fire buckets and mine water in a sump are available near by, the fire should always be attacked directly. Sand is useful in extinguishing fires in electric insulation and has been used extensively in certain mines in England for sealing around gob fires.

Rock dust has been used successfully by a company in Illinois for smothering the blaze of incipient fires and has given favorable results in tests made in the experimental mine at Bruceton, Pa. Although rock dust will extinguish the flame, if men can approach close enough to shovel or throw it directly on the hot coals, water must be used to extinguish the coals beneath the coating of dust. Every effort should be made to extinguish a mine fire by direct attack before resort is had to sealing.

**SEALING A FIRE**

As is made clear by the summarized accounts on later pages, sealing a strong fire is often difficult and in a gassy mine is dangerous. Gob fires, before they burst into active flames, can usually be sealed with little difficulty and in certain mining districts that are subject to spontaneous fires in the gob hundreds of such incipient fires are sealed annually with little comment made and no permanent records kept.

**LOCATION OF FIRE SEALS**

In the simplest examples of gob fires, those discovered when in their early stages, the closer the seals can be set in the adjacent crosscuts and room necks the better is the chance of quickly extinguishing the fire by cutting off the air. Some oxygen is consumed by the fire and more is absorbed by the coaly matter present, consequently if the seals are reasonably tight the oxygen content of the sealed area rapidly drops below the explosion limit of methane—about 13 per cent. However, if carbon monoxide is produced in quantity the explosive limit of the mixture may be lower. In any event, slow combustion will continue until the oxygen content becomes less than 5 or 6 per cent.
There is a popular belief that carbon dioxide has a special extinguishing effect, but its advantage as compared with nitrogen is slight and is due to an insignificant difference in the specific heats of the two gases. The real index of the extinguishing effect of the gases in a sealed area is the percentage of oxygen present.

**CARBON DIOXIDE IN FIRE FIGHTING**

Many attempts have been made to use carbon dioxide in fire fighting by introducing it behind seals. More recently, following investigations by the Mellon Institute, University of Pittsburgh, carbon dioxide snow has been proposed for fighting a fire directly.

In some of the earlier attempts to employ CO₂ behind stoppings, as at the Engleville mine in Colorado, about 25 years ago, the CO₂ was made at the mouth of the mine by sulphuric acid applied to limestone in water in closed vats and was blown through a pipe that extended through the fire stopping. At the Engleville mine the attempt failed because breaks in the strata over old workings extended to the surface and the area could not be sealed tight. At other mine fires tanks of liquid CO₂ have been used.

The only advantage from the use of CO₂ is that the pressure created by moving the gas into a fire area tends to keep external air from entering if the ground is so broken that the sealing can not be made tight. When the seals are reasonably tight, the rapid absorption of oxygen by the coal makes the use of CO₂ unnecessary.

**USE OF STEAM BEHIND SEALS**

In the Pennsylvania anthracite region steam has been used to advantage in extinguishing fires behind seals. In that region, because of the number of beds worked at the same mine and the general absence of beds of soft shale and clay, which would help to seal joints and cracks in more brittle rocks, it is difficult to make tight seals. Under such conditions the extensive introduction of steam, like the introduction of CO₂ gas, creates pressure within the sealed area, and this pressure helps to keep fresh air from entering.

**DANGER IN SEALING AN AREA IN A GASSY MINE**

**USE OF ROCK DUST**

Danger of an explosion always attends the sealing of an active fire in a gassy mine. Before seals are erected the vicinity of the seals should be thoroughly rock-dusted, the dusting should be carried as close to the fire as possible, and should be rapidly extended outby in all passages. Such a measure probably prevented a violent explo-
sion of gas in a sealed area in an English mine¹ being extended by coal dust. The explosion killed 27 men who were reinforcing stoppings, but the rock-dusting saved men in other parts of the mine. A similar benefit was noted during the sealing of a fire in the Horn- ing No. 4 mine of the Pittsburgh Terminal Co. on February 3, 1926. The management publicly reported that a gas explosion, which broke down the nearly completed seals and killed 20 men working on them, might have been propagated by coal dust and endangered 400 men had not the fire area been rock-dusted.

Sealing extensive fires presents many difficulties, such as working in hot gases and smoke on the return side. Also, there is the danger that as the air current is cut off, either by falls or by seals, explosive proportions of methane may accumulate before the oxygen content of the area becomes too low for an explosive mixture to form.

Many experienced men believe that the larger the fire in a gassy mine the more extensive should be the area inclosed by the seals, in order that an explosive mixture of gases at the seat of the fire will not form until temporary brattice seals are erected and the men withdrawn.

**CONSTANT TESTING FOR GAS WHILE SEALING**

A matter of primary importance is to have, at every return stop- ping being erected, one mine official to test the condition of the atmosphere in order that men can be withdrawn if the percentage of gas nears the critical point. The testing should be done with the flame safety lamp, the methane detector, and the carbon monoxide detector. It is also advisable that samples of the atmosphere be taken and analyzed with a portable gas-analysis apparatus set up in fresh air or at the surface. The samples should be numbered, the time and place of sampling recorded, and reports of the analyses should be sent by special messenger or by telephone to the mine official in charge of the sealing.

**SEALING FIRST ON THE INTAKE OR THE RETURN**

Whether the intake or the return side should be sealed first is a much debated question. To seal the intake side first is comparatively easy and to seal the return first is difficult because of smoke and fumes. It is safer, and generally necessary, for the men to use breathing apparatus or carbon monoxide masks in sealing the return if enough oxygen (17 per cent) is present, as shown by the con- tinued burning of the flame of a safety lamp, for masks to be used without danger.

¹ Mottram, Thomas, C. B. E., Report on the Causes of and Circumstances Attending the Explosion which Occurred at the Maltby Main Colliery, Yorkshire, July 28, 1923. 1924.
The authors believe that it is better to close the intake first and thus keep oxygen from going to the fire. If the return is sealed first, the products of combustion and the distilled hydrocarbons tend to back up over the hot coals and form an explosive mixture there.

SEALING INTAKE AND RETURN SIMULTANEOUSLY

In gassy mines it is safer, in the opinion of the authors, to erect doors, preferably hinged at the top and closing by gravity, on the intake and return, to allow the air current to continue moving in practically normal proportions until the doors are closed and to provide some mechanical means for closing the doors simultaneously. Long wires may be used to pull out supports, or counterweights and ropes over pulleys may be used to hold the doors open. The counterweights may be tubs filled with water and having small holes in the bottom; before the draining of the tubs allows the doors to close the men can get out of the mine. Still another plan is to use a few ounces of permissible explosive, fired electrically from the surface or a safe point, to break whatever may be used to hold the door open.

CONSTRUCTION OF FIRE STOPPINGS

As the first seals need to be erected hastily they are usually made of brattice cloth. If the fire is extensive and a gas explosion threatens it may be necessary to withdraw the men for 24 hours; then the atmosphere behind the seals should be sampled through the pipe provided. If the analysis indicates that the danger of an explosion is not acute, the more permanent seals should be built outby the first.

These seals may be of matched flooring or of brick. If a cement gun is available an excellent tight, fireproof stopping can be quickly built by using burlap or brattice cloth nailed firmly to a frame and then pinning with long nails chicken wire on the face of the cloth. “Gunite” is then applied with the gun to a thickness of one-half to three-fourths inch. A sampling pipe should, of course, extend through the stopping.

If the second seals are not tight or if circumstances render it advisable to put in stoppings that are strong, solid concrete walls 18 inches thick, keyed into the ribs, make stoppings that will resist all but the most violent explosions.

Brick or rock stoppings, unless they are arched and are keyed into the walls, have little strength. Gob stoppings, despite their thickness, are extremely weak. The reason for this is that they fail in detail; that is, the gases under pressure penetrate through the loose material and carry it off, the material on the far side probably being carried away first.
PIES AND VALVES IN STOPPINGS

As already indicated, every fire seal, no matter how flimsy, should have a pipe extending through it; the flimsier the stopping the farther the pipe should extend into the fire area. If the stopping is leaky, the pipe should extend inside at least 40 to 60 feet.

The pipe should be of small diameter (one-half inch is satisfactory), as a large-diameter pipe of some length necessitates much pumping (a bicycle or automobile pump may be used) to insure that the sample obtained represents the atmosphere inside the seal. The inner end of the pipe should be hung near the roof but not in a pocket in the roof. More permanent stoppings should have two sampling pipes, one at the top and one at the bottom, and a short pipe for a water gauge.

If the area makes much water and the stopping or pillar is not strong enough to act as a dam, a U-shaped water-sealed outlet may be placed at the bottom of the stopping.

VALUE OF GAS ANALYSES DURING MINE FIRES

While a coal-mine fire is burning, analyses of samples of the atmosphere in the inclosed fire area often indicate whether the fire is increasing or abating. Samples taken soon after the area is inclosed usually contain relatively high proportions of oxygen and carbon dioxide, a dangerous proportion of carbon monoxide (ranging from 0.5 to 3 per cent), some hydrogen, and varying proportions of methane. If the coal or the adjacent strata normally give off methane the percentage of this gas may be expected to be high, but if the mine is really as nongassy the methane will be low. As the fire progresses the oxygen in the atmosphere of the fire area diminishes, partly through the combustion of coal or timber but mostly through absorption by the coal.

When the seat of the fire becomes surrounded with an atmosphere that contains as little as 12 to 15 per cent of oxygen, active flame subsides but combustion continues until the oxygen is reduced to 5 or 6 per cent. Until this stage is reached carbon monoxide gas is evolved, but in diminishing quantities as the fire lessens. Methane and some hydrogen are evolved by the fire as long as fresh coal comes in contact with the heated coal. When the oxygen content of the surrounding atmosphere decreases to less than enough to support active flame, the fire begins to cool; the rapidity with which the temperature declines depends upon the mass of material that has been heated and whether it is covered with falls of coal or roof material.
Some mine fires that had been sealed for as long as a year and gave no inclination of active combustion at the end of that time revived when the sealed areas were reopened and ventilated and showed such active combustion that resealing was necessary. This condition occurs where fires made so much headway before the area was sealed that a large mass of material became heated. This heated mass may be covered with falls of coal and roof that do not allow the conduction or radiation of heat. In consequence of an adjacent hot fire in loose combustible material, it is not uncommon for the solid coal to become red hot for 2 or 3 feet in from its surface.

In a fire area that has been well sealed the absolute pressure within the sealed area remains nearly constant, whereas the pressure of the mine air outside the seals fluctuates with barometric changes in the atmosphere outside. Due to the changing (barometric) pressure of the atmosphere, the pressure of gases inside the seals may be more or less than that of the air outside them. Seals may be made practically gas-tight when built of concrete or thoroughly plastered or united, but coal pillars and adjacent strata are more or less permeable to gas, hence there is a tendency for the sealed area to exchange air with the unsealed part of the mine. This exchange of air is commonly called "breathing" and may be confined to low or high places, especially in a pitching bed of coal. The heated gases press outward at the high points and air tends to leak inward at the lower points of the closed area. Where seals have to be hastily and faultily constructed, as often happens, the amount of gases forced in and out of a sealed area may be considerable, as indicated by some of the descriptions in this bulletin. In sampling gases through pipes in seals it is therefore important to record whether the pressure is inward or outward. If the pressure is inward—especially in dipping workings at low elevations—samples are not likely to give the true composition of the gases near the seat of the fire. When the pressure is outward and has been so for an hour or two before sampling, truer results are obtained.

After the oxygen content of the fire area had become as low as 2 or 3 per cent and carbon monoxide is not detected by analysis, the introduction of fresh air will, if the fire rekindles from hot coals, cause the samples to show more carbon dioxide and some carbon monoxide.

When an explosive proportion of inflammable gas is not present, to open an upper and a lower stopping and ventilate a fire area would apparently be safe if temperature readings and air samples, to detect possible rekindling of the fire, are taken at the opening when the gases flow out.
At this point reference may be made to several carefully prepared papers on the sealing and unsealing of mine fires, published in the Mining Congress Journal for 1926 and 1927 and all presented at the annual coal convention of the American Mining Congress at Cincinnati, Ohio, in May of those years.

USE OF SELF-CONTAINED OXYGEN BREATHING APPARATUS

When the Government began its study of the causes of mine disasters in 1908 it gave attention to apparatus that would enable men to work in irrespirable atmospheres and began training men in the use of such apparatus. Subsequently the Bureau of Mines took an active part in developing self-contained oxygen breathing apparatus and trained many thousands of men in the use of such apparatus during recovery or rescue work in mines. In this bulletin, which gives many examples of work done and explorations made in noxious atmospheres, self-contained oxygen breathing apparatus are termed breathing apparatus, and men equipped with the apparatus are termed apparatus men.

CAUSES OF THE 59 FIRES

A study of the reports of the Government engineers who investigated the fires indicates that the main causes of the 59 fires discussed in this bulletin were as follows:

1. Shots of black blasting powder (fires Nos. 1 to 11) 11
2. Spontaneous heating (fires Nos. 12 to 21) 10
3. Arses from electric wires (fires Nos. 22 to 25) 4
4. Open-flame lamps igniting gas (fires Nos. 26 to 28) 3
5. Open-flame lamps igniting inflammable structures (fires Nos. 29 to 31) 3
6. Oil ignited underground (fires Nos. 32 to 34) 3
7. Shots of dynamite (fires Nos. 35 to 36) 2
8. Open-flame lamp igniting hay (fires Nos. 37 to 38) 2
9. Electric motor of underground fans (fires Nos. 39 to 40) 2
10. Gasoline engine of fan (fire No. 41) 1
11. Gas or coal-dust explosions igniting coal (fire No. 42) 1
12. Burning material from surface structures (fire No. 43) 1
13. Gas from gas well (fire No. 44) 1
14. Undetermined (fires Nos. 45 to 58) 15

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Shots of black blasting powder were responsible for 11, spontaneous heating for 10, and open-flame lamps for 8 of the fires. These three causes accounted for 28 of the 44 fires whose causes were determined.

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The reader should note that the foregoing table does not represent the actual frequency of different causes or even the relative importance of the main causes of fires in coal mines, neither does it include all causes. In mines working bituminous coal, especially coal that is high in volatile matter and is more easily ignited, by far the larger proportion of the fires start at the face, but nearly all of them are extinguished before they become strong enough to require such measures to control them as are described in this bulletin. Besides the causes named in the table, ventilating furnaces at small mines and forest and other fires above ground have been responsible for fires in coal mines.

This bulletin discusses fires that were investigated by Government engineers, fires that were disastrous or stubborn or of such character that the engineers offered or were asked to render assistance or give advice. The fires are grouped by causes, as in the table. That grouping has been chosen because it permits comparison of the different methods used which necessarily varied with the location and intensity of the fire, the layout of the mine, and the underground conditions. It also helps to stress the imminence of the fire hazard in coal mines and the need of observing all precautions to prevent the start of a fire.

Means of preventing mine fires from starting are discussed only generally in this report, which deals primarily with how the specific fires were handled after discovery—the methods of extinguishment or sealing. It is almost obvious, however, that most of the fires could have been prevented by care and the use of proper devices or methods, such as closed permissible miners' lamps, permissible explosives fired electrically, permissible electric motors, and switches to prevent ignition of gas which in turn ignites the coal, keeping unarmored power lines and nonapproved trailing cables out of working places and return airways in gassy mines, good ventilation of abandoned working places to allow daily inspection and prevent spontaneous fires starting or else the secure sealing of such places, and, finally providing every mine with two separate ways of escape.

By these and other approved means, virtually all of the fires described in these pages could have been prevented and great loss of life and property avoided.
ABSTRACTS OF REPORTS ON THE 59 FIRES

FIRES CAUSED BY SHOTS OF BLACK BLASTING POWDER

The 11 fires given under this head show that black blasting powder not only will cause blown-out shots and explosions but will set fire to coal, especially coal that is high in volatile matter. Seven of these fires could have been prevented if fire runners, or watchmen, had followed the shot firers. In one mine a shot merely cracked the coal and then ignited it; in another the powder was damp and burned instead of exploding, naturally setting fire to the coal. In general, if black blasting powder is used, the workings should be examined for possible fires shortly after the shots are fired.

1. A DELAYED SHOT STARTS A FIRE

MINING CONDITIONS

Figure 1 shows part of the workings of a new mine where the lower 71/2 feet of the 9-foot coal bed was being mined at a depth of 630 feet. Rooms were driven 25 feet wide and the entries 12 feet. F black blasting powder was used, with clay stemming and squibs. In rooms five shots were fired, two “busters” and three top shots, and in entries two busters and two top shots. According to the agreement between the operators’ and miners’ associations, no hole was to be drilled within less than 10 inches of the back of the undercut nor less than 10 inches of the rib and no buster more than 34 inches from the top of the undercut.

ORIGIN OF FIRE

One evening the squib failed to ignite the charge of one of the top shots at the face of the fourth southeast entry. The shot firers let this place stand while they shot the remainder of the mine, and on their return they fired a second squib which ignited the charge. The fire bosses did not examine this face after the delayed shot had been fired but remained at the shaft bottom. Here they soon detected smoke—the fan was a blower—and reported a fire. The superintendent, mine manager, and a number of day men organized themselves as fire fighters and arrived near the fire 40 minutes after the delayed shot had been fired. They could not get within fighting distance of the fire because of the heat, smoke, and foul gas, so they
erected five stoppings, A, B, C, D, and E (fig. 1), made of two thicknesses of shiplap boards coated with asbestos-fiber plaster. This work took 10 hours.

**FIRE-FIGHTING METHODS**

The company obtained two sets of breathing apparatus, each with supplies for a 4-hour run. The men made a door in the outer wall of the air lock, broke a hole through the inner wall, and examined the scene of the fire. The air in the area inclosed by the stoppings was free from smoke but contained much methane and carbon dioxide. At the face the roof to a height of 15 feet and back about 50 feet had fallen, and from there back 120 feet the top coal had come down. The roof was still warm, but no other evidence of live fire was found.

The mine manager thought that water should be played on the fall at the face for two hours, which would put out the fire; and that the stoppings at A, B, and C should then be removed and ventilation in the sealed area restored. The Bureau of Mines representative on his arrival suggested: (1) With the aid of breathing apparatus the placing of a heavy canvas curtain within the last crosscut on the fourth southeast entry, to seal off the heavy fall of roof at a point 50 feet from the face where the fire had been; (2) the opening of the stoppings at A, B, and C, and the removal of the dangerous and explosive gas by restoring the ventilation; and (3) the loading out of the fallen roof, keeping it cooled with water, or the replacement of the canvas curtain by a more permanent stopping. These suggestions were adopted, and the explosive gases were removed two days later. The next morning men began cleaning up the débris.

2. **REOPENING A LARGE SEALED AREA CONTAINING EXPLOSIVE GASES**

In the mines of one district the danger from fire is so great that where black blasting powder was used fire hunters (runners) often followed shot firers and inspected each face as soon as possible after
it was shot. The coal contains much volatile matter and is highly inflammable. The superintendent of one mine of 2,500 tons capacity said that the fire hunters discovered and extinguished about 20 fires each shift. A fire that gains any headway is sure to cause dangerous conditions. Ordinarily as the oxygen content decreases the black damp will extinguish flames of a fire in a sealed area in a few days to 60 days, the length of time depending on the size of the area. In this district, as the stoppings leaked and the strata were porous, it was difficult to obtain tight sealing and fires had burned much longer. Methane gradually fills these areas and forms an explosive mixture when air enters after seals are broken.

MINING CONDITIONS

In the mine in which this fire occurred the coal, worked at a depth of 410 feet, is 9 to 14 feet thick, with gray shale above and fire clay below it; 18 to 30 inches of coal was left as roof. The workings made a little gas and were ventilated by a fan running as a blower. At 9 o’clock one night the shot firers fired a charge of black powder in the top coal of room 27, on the second south entry off the main east entry, at that point marked $x$ in Figure 2. At 2 a.m. it was found that the blast had ignited the coal.

FIRST EFFORTS TO SUBLUE FIRE

Efforts to fight the fire with water proved unsuccessful, and the management decided at 8 a.m. to seal it off. The rooms on 50-foot centers had been driven east and west off each pair of butts. They were “holed through” into the rooms of the adjacent entries—a practice that seriously hinders the sealing of a mine fire. Stoppings quickly built of two thicknesses of 1 by 12 inch shiplap boards and made tight with gypsum products and wood-fiber plaster were erected at points where the heavy line showing the fire area in Figure 2 crosses entries and crosscuts. At 4 p.m. the fire was considered under control, and 12 hours later the sealing was completed. Then the room necks on the first south entry off the main east entry were bratticed. This sealing inclosed the four south entries off the main east entry and also the rooms thereon, which required 29 stoppings. Sealing an area of about 40 acres with 60 working places greatly curtailed production; moreover, the sealed area filled with methane was a constant menace to the miners.

WORK OF BUREAU OF MINES ENGINEERS

Mining was resumed in the other parts of the mine, but the fire continued to burn. Seventy-five days later in answer to a call a Bureau of Mines rescue car arrived. The stoppings had been care-
fully built and well plastered, but it was found that the plaster of many had dried and cracked, permitting leakage. A sample of the gases in the sealed area contained 3.6 per cent carbon dioxide, 5.6 per cent oxygen, and 0.01 per cent carbon monoxide.
The plan of campaign adopted included (1) reversal of the air current in order that the gas should go up the air shaft, leaving the hoisting shaft, pump-room stables, and main entries on the intake, and (2) building an air lock in an entry crosscut near the point of origin of the fire so that inspection of the fire area by apparatus men would involve minimum admission of fresh air. The air lock, which is indicated by a circle in Figure 2, near E, consisted of two board stoppings 8 feet apart with a door in the outer stopping.

On the second day after the air lock was completed three apparatus men with three electric lamps and four flame-safety lamps entered the mine. The inside brattice was cut out, room 29 was examined, and other work was done. The reports of all examinations showed no fire, no smoke, and no heat.

**Removal of Gas**

In spite of the reported absence of heat, a heavy fall in room 28 indicated danger from a buried fire, in view of the manner in which fires continue for long periods in sealed areas. To open the area so as to restore ventilation to its usual course seemed unsafe for these reasons: (1) Hundreds of thousands of cubic feet of explosive gas would pass over the fall in room 28, (2) the ventilation would fan into blaze any smoldering fire, (3) contact of the explosive gas with the flame would cause an explosion, and (4) removal of this body of gas would take a long time, and should the fire revive men could not safely enter and begin to clean up the fall and fight the fire.

In order to remove the body of gas from the fire region and pass as little gas as possible over the fall in room 28, this method was adopted: (1) The room-neck brattices along the first south entry were made tight enough to pass all the air needed along that entry; (2) the stopping on the south end of the sealed area, at the point marked A (fig. 2), was removed; (3) a canvas curtain was hung across the first south entry just south of the crosscut containing the air lock, as shown at E; (4) the stopping at the extreme north end of the sealed area at B was removed; and (5) the doors of the air lock were opened, allowing ventilation to enter, to split as soon as it had entered the fire region, and part to travel north and part south, as shown by the dotted arrows in Figure 2. This procedure was carried out successfully and the gas was removed by the air currents without passing over the fall in room 28. Then the work of cleaning up was started.

The big fall of roof found in room 28 probably had been caused by the heat and flame from room 27, the heat having been carried by the air current through the last crosscut between rooms 27 and 28
and into room 28. The men cleared the track of the top coal, which had fallen 150 feet back from the big fall, and started to load out about 500 tons of shale. Shortly after this work was well under way smoke was seen coming from the fall in room 28. At 2 o’clock on the third morning glowing coal was found, and from that time on until about midnight, when the fall was completely removed, chemical extinguishers were used to control the fire.

REMARKS

The recovery of this sealed area shows how the uncertainties connected with mine recovery can be lessened by having experienced apparatus men make a careful reconnaissance. A minimum rescue squad should consist of 10 men—5 to enter and examine the mine and 5 in reserve to give aid if an accident happens to the others.

In the district that included this mine there seemed to be a general tendency to use coal-cutting machinery and avoid shooting off the solid as much as possible, in spite of the small advantage in cost in favor of the machine-cut coal. Permissible explosives were being introduced and results were proving their value. At one mine, where all the coal was cut by machinery, 75 per cent of the coal was shot with a permissible explosive. After this plan was adopted neither blown-out shots nor fires occurred and the roof was not damaged, although it had been frequently damaged in shooting off the solid with black blasting powder.

3. SYSTEMATIC SEALING OF FIRE AREAS BY APPARATUS MEN

Two fires in the same mine were sealed by a Bureau of Mines rescue corps within six days. A fire on the second south entry (fig. 3), eight and one-half months before these fires, was put out with little trouble by apparatus men of the Bureau of Mines who used portable extinguishers and dug out the hot coal.

MINING CONDITIONS

The coal bed being worked is 6 feet thick; it is overlain by a strong gray shale and underlain by a hard flinty limestone up to 6 inches thick, below which is a soft white clay. The bed was reached by a shaft 412 feet deep, which had two 9 by 17 foot hoisting compartments and a 3½ by 7 foot air compartment. This arrangement of downcast and upcast compartments in one shaft is much used, but it is considered hazardous by the Bureau of Mines, for in the event of the destruction of the curtain wall by fire or explosion all ventilation is cut off. An escape shaft was situated at the head of room 3 off the first north, east side. Development was by the room-and-
pillar system. The mine was considered free from gas. A 12-foot paddle-wheel fan, run as a blower, supplied ventilation. Black powder was used for blasting, which was done by shot firers.

**FIRE IN FIRST NORTH ENTRY OFF MAIN EAST**

The first fire started during blasting, but was not discovered until the fire boss was making his rounds about 10 hours later. The fire was fought during the next 17 hours, until the roof started to fall,

![Diagram of mine workings](image)

**Figure 3.—Plan of workings, showing two fire areas, fire 3**

... when the miners quit. A Bureau of Mines safety station received a call two hours later, and a rescue car reached the mine within four hours, or about 34 hours after the fire started.

Five men with apparatus entered the mine about 6 a.m. and found that the fire was in room 10 off the first north entry of main east (fig. 3). The return air went to the main shaft. Fumes from the fire prevented other men from entering the mine, and the apparatus men were in great danger in getting out, as they had to travel from the first north off the main east entry through the smoke to the top of the shaft. A trip was made to the fire area through the second
north, which was the intake side of the first north and therefore was in comparatively fresh air.

Previously a line brattice had been put up into room 10, first north (east side), crossing the entry from the east rib, and the mine crew had tried to carry all the air to the fire, so they could fight it with water, using a hand pump and hauling the water from the sump at the shaft bottom. Measurement in the entry showed that 7,680 cubic feet of air per minute was going directly to the fire.

At the suggestion of the Bureau of Mines engineer the pump and all tools that were handy were taken out of room 10 and the line of canvas pulled down to cut all air off the fire. This work required about 20 minutes. Then a curtain was put across the neck of room 10 about 12 feet from the rib of the entry; it shut all air off the fire and kept the smoke back in the room, thus permitting the rescue corps to see the entry roof, which was in bad condition. Then it was decided to seal the fire.

At 7.30 a.m. a party of four apparatus men and six men without apparatus reentered the mine. The smoke had cleared considerably at the bottom of the shaft, and men without apparatus could carry material into the second north entry. At 8.15 a.m. a stopping in the neck of room 10 was begun, and at 10.30 the first seal was completed. It was built of 3/2-inch shiplapped lumber on a frame of 3 by 4 inch oak; the crossbar at the top was hitched into the rib at the roof, and the posts were cut into the ribs, making a seal that was tight when plastered with clay. After the ribs and roof adjacent to the stopping had been well clayed posts and crossbars were set for the second brattice 2 1/2 feet outside the first, and it was constructed like that. The space between the stoppings was filled with clay. A pipe with a valve had been inserted through the stoppings to permit sampling.

At 11.15 a.m. two men donned apparatus and tried to put a curtain across the breakthrough between rooms 9 and 10, but the roof was falling; so it was decided to seal room 9 and the breakthrough between rooms 8 and 9. This confined the fire to rooms 9 and 10 and required only two seals. By 12.15 p.m. men wearing apparatus put a canvas stopping across the neck of room 9 and in the breakthrough between rooms 8 and 9. The stopping at the mouth of room 9 was completed at 4.30 p.m. This seal was 2 1/2 feet thick and was made of double wood brattices filled between with clay.

A fresh crew was procured to work on the stopping between rooms 8 and 9. At 7 p.m. two men wearing apparatus put up the frame for the stopping in 45 minutes; men without apparatus then completed it. The opening to be sealed was only 4 by 4 feet. The point of the pillar was only 3 feet thick, and the seal was made 2 feet thick. Like the others, it was made of two wooden brattices.
filled between with clay. To prevent any leakage, a wall of shale was built 3 feet outside the seal, and the space between the seal and the wall was also filled with clay. The fire was completely sealed off at 10 p.m., and all men went out of the mine at 10.30, or 17 hours after the Bureau of Mines men arrived.

At 10 a.m. on the following day temperature readings were taken at the seals and at the shaft bottom. All of the seals were tight, and the temperatures were: Surface, 62° F.; seals, 66° F.; and bottom, 66° F. At 12 noon the mine was clear of smoke and all seals were holding well. Two days later the mine was opened for producing coal.

FIRE IN SECOND NORTH ENTRY OFF MAIN EAST

At 6.10 a.m. of the fifth day after the work just described was finished another fire broke out in the second north entry off the main east entry. The fire soon was beyond control by direct fighting. Smoke poured from both shafts, but when the Bureau of Mines car arrived at 12.20 p.m. the mine officials had temporarily sealed off the hoisting shaft to turn the smoke up the escape shaft.

In order that the hoisting shaft might be used, it was decided to shut off the return air by erecting stoppages at e and f. This work required the use of self-contained breathing apparatus. At 1.15 p.m. a party of five wearing apparatus went into the mine and built seals e and f (fig. 3) of shiplap lumber and clayed the ribs, completing the job at 2.45 p.m. These seals turned the smoke and fumes up the manway shaft, and the seal could be removed from the hoisting compartments.

At 5 p.m. a party of eight, half with apparatus and half without, went into the mine to build other seals. The whole party was able to go on the intake side of the fire as far as room 7 on the second north entry. As there was no breakthrough between rooms 6 and 7, the ventilating current normally was directed up room 7 and passed through successive breakthroughs to room 10, thence back to the second north. By 5.30 two apparatus men had put up a canvas stopping in the neck of room 7, which kept the smoke back so that men without apparatus could build a double stopping of shiplap lumber. The space of 18 inches between the stoppages was filled with clay. This work was completed by 7.45 p.m.

At 8 p.m. the apparatus men put a canvas stopping across the neck of room 8, and men without apparatus built the seal there by 10.30 p.m. This seal was of shiplap lumber hitched into the ribs 4 inches, and the 3 feet between stoppages was well filled with clay.

Bad roof along the entry had to be timbered with crossbars and props up to room 9, where the fire started. Two apparatus men put

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a canvas stopping across the neck of the room about 10 feet in from the entry rib. The canvas was tight at the roof and ribs, so it kept the smoke back well. A board stopping 5 feet thick filled with clay, like those built at rooms 7 and 8, was completed at 2 a.m. A 1-inch pipe with valve was fitted in it for sampling the air. The roof was in bad condition inside of room 9 along the entry, for the heat there had been intense. The temperature was 115° F. when the seal of room 9 was started; when the seal was completed the temperature of the air outby it fell to 74° F.

The entry was timbered to room 10. The men had little trouble in erecting the stopping in the neck of this room as the roof there was in good condition. The same two apparatus men put up the canvas stopping; men without apparatus built the board and clay stopping, 18 inches thick, in front of it in an hour. This completed the sealing of rooms 7 to 10, which were connected by breakthroughs. One hour and 20 minutes later, 4.35 a.m., all seals were holding tight, and the entire party left the mine.

At 8.30 a.m. a party of six men, all carrying flame safety lamps and electric flash lamps, inspected the seals. They found the sealed area on the first north entry in good condition. The temperature of the air near the seals was 66° F.; at the surface that day it was 62° F.

REMARKS

The variety of work that can be done in the noxious atmosphere of a sealed fire area by trained apparatus men is well indicated by the foregoing summary, as is the systematic manner in which the work should be conducted.

4. REMOVAL OF BURNING COAL AND USE OF EXTINGUISHERS

MINING CONDITIONS

A coal bed 5 feet thick was opened by a shaft 285 feet deep. More than 1,000 tons of bituminous coal was mined daily, and 280 men were employed underground. Black blasting powder was used exclusively, and fires caused by shots were rather frequent. Some of the coal was undercut and some was shot off the solid.

At a point 2,200 feet from the shaft bottom a shot, apparently a heavy charge, fired off the solid at 2 a.m. released gas that was ignited by the open light of the fire runner. The burning gas set fire to the coal. The fire was reported at once.

Parties of four men fought the fire from about 5 a.m. until 1.10 p.m. and had it under control when three Bureau of Mines engineers arrived with apparatus, fire extinguishers, and a canary. The
men had already been shoveling out the coal from the face and had sprayed the fire five times with charges from an 8-gallon extinguisher (soda and sulphuric acid). A sixth charge was being played on the fire when the apparatus men arrived. A canvas brattice had been built to within 12 feet of the face, with heavy cross timbers to hold the roof, which was treacherous. The work was completed at 3.35 p. m. Men in other parts of the mine were not withdrawn, and coal was hoisted during the whole period of fighting the fire.

REMARKS

The bureau does not consider it a safe practice to continue operating a mine, especially a gassy mine, in which there is an active fire.

Some lessons to be drawn from the fire are as follows:
Permissible explosives should be used.
Safety lamps should be carried by shot firers and fire runners in order to test for gas and to avoid igniting it.
Extinguishers are often effective when men are able to get close to a fire and play on it before it spreads.
Oxygen breathing apparatus and men trained in its use should be available at all mines or at a central rescue station so near that the mine can be reached within half an hour.

5. SYSTEMATIC EXPLORATION OF A FIRE ZONE

ORIGIN OF FIRE

Two shot firers finished work at 5 p. m. and left the mine without seeing any evidence of fire. At midnight the watchman saw thick smoke coming from the hoisting shaft (upcast). He thought it an unusual quantity of powder smoke and speeded up the fan, thus undoubtedly fanning the fire. The smoke was dense at 5 a. m., when the fire boss arrived, and he sent for the superintendent.

At 8 o'clock the superintendent, fire boss, and three others were lowered in a cage 185 feet to the bottom, where they found the smoke very dense. They went through a crosscut to the intake airway and succeeded in going with the air 560 feet through the main airway to a crosscut opposite the abandoned third south entry. (Fig. 4.) They broke down the door in this crosscut from the main airway to the main haulage way, but the smoke and fumes drove them back through the airway and to the shaft. All suffered considerably from the effects of the smoke.

The party then sealed off the shaft with a double covering of plank and clay. After 10 days the seal was broken and the fan was run at 50 r. p. m. for 36 hours. The intensity of the fire was increasing, so no attempt was made to descend the shaft, which was again
Figure 4.—Plan of fire zone, fire 5
sealed at the top. After three days the Bureau of Mines was notified, and a rescue car reached the mine.

No trained men were available locally, but the two bureau engineers found a timberman who knew the mine and had taken some training with breathing apparatus. These three, wearing apparatus, prepared to investigate the shaft bottom, which normally carried a return air current, to determine the conditions. The seal was removed from the shaft, which had two hoisting compartments and an air compartment. The ventilating current was downcast in the air compartment and upcast in the hoisting compartments. At 9.30 a.m. on the third day after the second sealing, the cage, containing one canary, one flame safety lamp, and a thermometer, was held at the bottom for two minutes. Evidently some air from the surface had entered through the shaft seals. When the cage was raised, the thermometer registered 45° F., the lamp had been extinguished, and the canary showed some signs of distress.

DETAILS OF EXPLORATIONS AND WORK WITH BREATHING APPARATUS

First stage, apparatus work, third day after sealing.—Period, 30 minutes; apparatus men, 3; fan not working. The men were lowered slowly to the bottom of the shaft. Ten feet from the bottom all three lamps went out, and the canary lowered in the preliminary test fell from its perch. At the bottom a second bird fell in its cage, apparently lifeless. Along the main east haulage way smoke was noticeable and the temperature was 50° F. Smoke increased as the party advanced. The temperature was 92° near a heavy fall of roof 400 feet in. (See "First exploration," fig. 4.) The main airway was clear of smoke. The men returned to the surface and resealed the shaft, which remained sealed three days. During that time 10 other men, who later rendered valuable aid, were trained in the use of apparatus.

Second stage, apparatus work, sixth day after sealing.—Period, 25 minutes; apparatus men, 5. State inspectors had arrived. The seal was removed. The cage, bearing a pigeon and a safety lamp, was lowered; when it was hoisted, after eight minutes, the bird was dead and the lamp was out. Two apparatus men proceeding along the main east airway found dense smoke 150 feet in and falls beyond the one seen at 400 feet during the first exploration. The temperature was 95° F.

Third stage, apparatus work, 1 hour after second stage.—Period, 40 minutes; apparatus men, 5. The fan was run at 86 r. p. m. for 30 minutes and until 15 minutes before the men were lowered. Two men went 560 feet along the main east to the crosscut opposite the third south entry. Hot, thick smoke poured through from the
main airway; the temperature was 105° F. Smoke issued from crevices in the chain pillar, and the fire seemed near.

Five men followed the two to the same point. They decided to erect temporary canvas brattices across the main east entry and the main airway at the crosscut 150 feet from the shaft to short circuit the natural ventilation there, so that men could work without apparatus and carry brattice material to the parties in advance. Places under good roof were selected for the brattices.

Fourth stage, apparatus work, 3 hours after third stage.—Period, 40 minutes. Seven apparatus men erected the two stoppings, which cut off fresh air from the fire and gave a working base at the shaft.

Fifth stage, apparatus work, seventh day.—Period, 30 minutes. Four apparatus men tried to start the pump to remove water along the main east airway. The smoke was heavy.

Sixth stage, apparatus work, 15 minutes after fifth stage.—Period, 50 minutes. Six apparatus men uncovered the pump valve by removing 3 feet of falls, and started the pump.

Seventh stage, apparatus work, 3 hours after sixth stage.—Period, 2 hours 10 minutes; 9 men with apparatus and 7 without. Two of the former party explored the third south entries twice for a distance of four crosscuts, and although the smoke was thick and the heat intense they saw no evidence of fire. The smoke and heat seemed to be coming from the main airway. They could not explore the main airway farther because of a high fall just beyond the third south. Along the main east entry about 200 feet in by the main side track the thermometer registered 130° F., although the smoke was not thick. (See "Seventh exploration," fig. 4.) From the "shelling" of the top and the slight cracking of the chain pillar the fire was evidently in the main airway. Because of the bad roof the men did not go farther but returned to the main party, which was constructing canvas brattices, one across the main east at B, one across the main airway at A, and one across the third south.

Eighth stage, apparatus work, 2½ hours after seventh stage.—Period, 2 hours 20 minutes; 5 men with apparatus and 5 without. The men worked on the three brattices and built a fourth across the mouth of the fourth north off the main east. Then, by opening the door in the crosscut in line with the third south and between the main east and the air course, at A, the air current was short-circuited 500 feet from the shaft bottom. Additional brattice material was brought to that point. The heat from the fire was still intense. As the chain pillar in the main airway about 50 feet in by the brattices seemed to be smoldering, two apparatus men played a fire extinguisher on the rib; they decided to wait until the next day to see whether the bratticing had diminished the intensity of the fire or whether brattices should be built farther up the main entries.
Ninth stage, apparatus work, eighth day.—Period, 3 hours 10 minutes; 5 men with apparatus and 6 without. Tight wooden brattices in front of the four temporary canvas brattices were built to seal off the fire, as the heat and smoke were undiminished. To permit sampling, 2-inch pipes with valves were fitted in the brattices across the main east and the airway.

Tenth stage, apparatus work, 1½ hours after ninth stage.—Period, 4½ hours; 5 men with apparatus and 6 without. All wooden brattices were plastered with clay and filled in with gob and clay. Another wooden brattice was built in by the one on the main airway, as that one leaked.

The management was asked to inspect the brattices daily with a flame safety lamp, not to permit any open lights in the mine, and to keep the fire sealed for 12 days.

REMOVAL OF BRATTICES

On the sixteenth day after the brattices were finished three bureau engineers and three other men, all wearing apparatus, were lowered into the mine; the fan was started at 20 revolutions per minute to provide them with fresh air on the main airway. The men advanced up the main entry (return air) 560 feet to the brattice at B and removed the 2-inch pipes from the brattices on both the main entry and main airway. They then tested at the hole in the main-entry brattice; in 10 seconds a canary was near collapse, and in 40 seconds two safety lamps were extinguished.

Two of the party cut and went through a hole 3 feet square in the wooden brattice at B, in the main entry. With their safety lamps they tested for methane in the inclosed atmosphere but got no certain indication of it. At the top of the shaft the temperature was 17° F., outside the brattice it was 38°, and 50 feet inside, 68°. When the apparatus men entered the fire area their safety lamps at once went out. Two of the men, carrying flash lights, advanced 200 feet along the main entry inside the first area explored. They found the roof bad and were blocked by a heavy fall at a wide place in the entry. Here the fumes affected their eyes somewhat, although there was no sign of smoke. The thermometer registered 68° F. at the point where it had registered 130° F. on a previous exploration.

TESTS AFTER VENTILATION OF FIRE AREA

The fan was speeded up to 80 revolutions per minute for three hours to drain some of the gas from the fire area before the brattice on the main airway at B was opened. After three hours six apparatus men advanced along the main entry and the fire boss, without
apparatus, went in on the main airway (intake); all met at the crosscut opposite the third south and tested conditions inside the fire area on the main entry. Two men advanced 200 feet, where their safety lamps burned brightly and the temperature was 66° F. The party then put up a temporary canvas stopping in the crosscut between the main entry and main airway and tore down the two wooden brattices and one canvas brattice on the airway, thus turning the air through the fire area. The safety lamps that had burned brightly on the main entry (return) before the removal of the stoppings on the airway (intake) went out five minutes after the stoppings were removed. The fumes that came through the 3-foot hole in the main-entry brattice extinguished the lamps immediately.

Three apparatus men made a larger opening in the main-entry brattice at B, permitting fumes from the fire area to drain out rapidly. There was no indication of smoke nor any rise in temperature. The men removed the wooden brattice across the fourth north, permitting fumes from the fire area to pass out of this opening also. Some mist that appeared was caused by the warm atmosphere (66° F.) from inside the fire area meeting the cool air (34° F) in the main entry. The party returned to the surface. The fan ran steadily at 50 revolutions per minute.

Three hours later three apparatus men proceeded to the point where the brattice openings at B had been made, 560 feet from the shaft, and found all conditions favorable. Inside the fire area safety lamps burned well, the temperature was normal, and there were no indications of smoke or fire. The fan was run at 50 revolutions per minute over night. The State inspector advised the mine foreman that in the morning he could begin to clean up, but only safety lamps should be used.

6. APPARATUS MEN PLAY WATER ON A FIRE

A bad shot fired at 4.15 p.m. ignited the coal in a bituminous mine, but the fire was not discovered until about 15 hours later. A paper cartridge of black blasting powder had been exposed to the air for three days and had become damp. This damp cartridge was half of the charge put into the left hole in room 16½; the other half was fresh, dry powder; in all there was a length of 2½ feet of black powder in the hole. The coal had been undercut the full width of the room to a depth of 5½ feet, and two other holes had been drilled in the face, one in the center and one on the right rib. All three shots were ignited, but in one shot some of the powder burned. The shot on the right rib blew through a thin pillar into room 16. The hole on the left rib, which contained the damp powder, had been drilled 18 inches beyond the back of the cutting or mining; in other words, was
18 inches "in the solid." As the room was narrow, the center shot probably did all or most of the work from the center to the left rib. The damp powder in the left hole, which extended into "the solid," evidently burned slowly and set fire to the coal.

Room 16 (fig. 5) had caved badly; about 5 feet of rock had come down nearly the entire length. Room 16½ was turned off room 17 off the first west entry and was advancing in the pillar between rooms 16 and 17. The thin pillar between rooms 16 and 16½ was shot through in several places. Room 16½ was narrow, about 14 feet wide, but was to be widened when it extended beyond the face of room 16.

By the evening of the day the fire was discovered the intake airway had been so cleared of smoke that the seat of the fire could be determined. The fan did not run at night.

**FIRE-FIGHTING METHODS**

To get near the fire without sending considerable air over it was difficult, so two members of another company's rescue crew were asked to bring oxygen breathing apparatus with them. Wearing the apparatus they got near enough to the fire to play water on it through
a pipe and hose from the pump shown in Figure 5. The nozzle was fastened so as to keep the stream on the fire, and the men retreated to the entry because the roof was bad. Later they set a few posts. Men without apparatus then strung canvas from the last crosscut between the first west main and back entries up room 17 and into room 16½, as shown. They also set a number of posts.

Next morning the apparatus men believed that the fire could be handled without apparatus after the work they had done and returned to their own mine about 5 miles distant. That same night three of the crews came back and while using breathing apparatus put out the fire. The mine management was certain that it was by their use of breathing apparatus that the men were able to get at and extinguish the fire.

REMARKS

At this fire the direct application of water was a success, but the fire fortunately was confined to a working face, and the air could be conducted close to the face without danger of the fire spreading.

7. DIFFICULT EXPLORATIONS BY APPARATUS MEN

To seal off a fire, Bureau of Mines men constructed nine stoppings in five days by the systematic use of breathing apparatus. Six apparatus men averaged 13,850 feet of travel daily for five days.

MINING CONDITIONS

The mine, opened by a three-compartment shaft 592 feet deep, employed 125 men and produced 400 tons of bituminous coal daily by the room-and-pillar system. The bed averaged 34 inches thick; roof and floor were hard shale. About a quarter of the coal produced was undercut by mining machines, and the remainder was shot off the solid. Permissible explosives were used for narrow work, black blasting powder for shooting coal in rooms, and dynamite and black powder for brushing rock. Shots were fired by shot firers after all men were out of the mine. A fire runner was employed to look for fires after shooting time.

The coal gave off methane, but the mine was not considered gassy. Miners used open lights, mainly carbide, exclusively. A 5 by 20 foot steam-driven exhaust fan supplied ventilation. Water lines with frequent hose connections were available for sprinkling and fighting fires.

PROGRESS OF THE FIRE

The fire, which could not be reached because of roof falls, started on a Saturday after the shot firers had completed their rounds. Because of labor troubles the mine was not examined for fire that
FIGURE 6.—Plan of workings, showing fire areas and points where brattices were erected, fire 7.
evening. The fan had been stopped and was started again at 1 p.m. the next day. At 4 p.m. the manager and foreman entered the mine, but at the first south entry (fig. 6) the manager was overcome and was dragged out by the foreman. The fan was stopped again.

At 11 a.m. on the second day the fan was started, and at 1 p.m. smoke was coming from the air shaft. Officials who entered the mine found that an explosion had occurred, but the smoke and after-damp compelled them to return. The Bureau of Mines safety station near-by was asked to give assistance, and both shafts were sealed.

These seals remained intact for 14 days; then the one over the hoisting shaft was removed, and bureau men wearing breathing apparatus made three exploration trips. No smoke or evidence of fire could be found, so the seal was removed from the air shaft and the fan was started. After the fan had been running for 40 minutes an explosion within the mine shook the fan house violently, and black smoke poured out of the fan house for two hours. The mine was again sealed for 26 days. During the six days after the mine was re-opened Bureau of Mines men wearing apparatus made 17 exploration trips into it. Ventilation was restored, and on the seventh day the entire mine, except the second north entry, which was sealed off, was explored without apparatus.

DETAILS OF EXPLORATIONS

A sample of the air below the seal on the hoisting shaft, taken after the arrival of the Bureau of Mines rescue car, contained 3.8 per cent carbon dioxide, 1.6 per cent oxygen, 0.1 per cent carbon monoxide, and 54.3 per cent methane.

First exploration.—Period, 43 minutes; apparatus men, 3. When the second set of seals was removed at 10.20 a.m., the crew went down the shaft to test for gas. The safety lamp went out 10 feet from the top of the shaft. The crew went down again and explored the main north entry as far as the head of the slope, the slope as far as the first south entry (fig. 6), that entire entry and air course, and every room on the entry, and found no fire. The crew then explored about 200 feet of the second north entry and returned to the surface at 11.15, nearly exhausted after 43 minutes. The men recommended that the next crew explore the second north. While crew 1 was down the mine, crew 2 was in reserve at the head of the shaft.

Second exploration, 17 minutes after first.—Period, 50 minutes; apparatus men, 3. This crew explored the second north entry as far as room 7 and found no fire. The men returned to the surface at 12.22 p.m. and reported that the entry and air course were so caved from room 7 that they could not get to the face of the entry; they
seemed to think that the fire had been in this entry and air course near the face.

Third exploration, 5 minutes after second.—Period, 53 minutes; apparatus men, 3. The crew explored the second north entry as far as room 6, when one of the apparatus men complained that his legs were getting weak, so the crew started back at once. When they reached the slope this man could not stand on his feet. One of the others examined his apparatus and could not find anything wrong, so he increased the flow of oxygen through the reducing valve and in a few minutes the man was able to help himself a little. The others helped him up the slope, which was difficult to travel because of low roof and falls of rock, and reached the surface at 1.20 p.m. The man was given oxygen with an inhalator, and after about 15 minutes' rest and treatment he was able to go home.

Fourth exploration, 1 hour and 40 minutes after third.—Period, 35 minutes; apparatus men, 3. The men explored the main north; they found everything in good condition and no fire.

Fifth exploration, 5 minutes after the fourth.—Period, 9 minutes; apparatus men, 3. Crew 5 took two samples of air, one at the foot of the shaft and the other at the head of the north slope, that analyzed as follows:

<table>
<thead>
<tr>
<th></th>
<th>First sample</th>
<th>Second sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide (CO₂)</td>
<td>3.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td>6.8</td>
<td>11.7</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Methane (CH₄)</td>
<td>40.1</td>
<td>25.1</td>
</tr>
</tbody>
</table>

The crew took a chicken with them. At the top of the slope the bird closed its eyes and began to get rigid. A man wearing an apparatus which was giving an excess of oxygen revived the chicken by placing its head near the release valve of the breathing bag and squeezing the bag.

Sixth exploration, 41 minutes after fifth.—Period, 40 minutes; apparatus men, 4. Crew 6 built about half of a stopping at the top of the slope. One of the men bumped his apparatus, thus loosening the connection between the oxygen bottle and the reducing valve, and lost nearly all his supply of oxygen. The whole crew went to the surface with him; he was nearly exhausted when he reached the head of the shaft.

Seventh exploration, 25 minutes after sixth.—Period 40 minutes; same crew as in the sixth. The men completed the stopping (shown in Figure 6 as brattice No. 1) built of 1-inch boards, with a slide in it.
The stopping fitted tightly to the walls, and was plastered to make it air-tight.

Eighth exploration, second day.—Period, 40 minutes; apparatus men, 4. Crew 8 went down the shaft at 11.10 a.m. and built a stopping on top of the air course of the north slope.

Ninth exploration, 1 hour after eighth.—Periods, 50 and 55 minutes; apparatus men, same as for the eighth. Crew 9 plastered the stopping on top of the slope but came out at 1.40 p.m. because the oxygen in one set of apparatus ran out. The same crew, with the exception of one man, entered the mine at 2.25 p.m. and built a stopping (No. 3) on the intake of the slope.

On the third morning a man not connected with the recovery work went into the fan house and lighted a match near the seal on the air shaft. Gas which was leaking through the seal was ignited; the resulting explosion burned this man, another bystander, and two carpenters who were working on the fan house.

Tenth exploration, third day.—Period, 42 minutes; apparatus men, 4. Crew 10 entered the mine at 9.55 a.m. and explored the main north, built a canvas stopping (No. 4) on the north plane, explored the main south, and returned to the surface at 10.37 a.m. Before the seal on the air shaft was broken a sample of the atmosphere within showed 3.2 per cent carbon dioxide, 5.1 per cent oxygen, 0.1 per cent carbon monoxide, and 43.8 per cent methane. After the seal was broken the fan was started, at 11.10 a.m., and ran until the next day, thus ventilating the entire mine except the north slope.

Eleventh exploration, fourth day.—Crew 11, the same as for the tenth exploration, entered the mine; the men wore apparatus but did not use oxygen. They went as far as the head of the slope before finding gas; there a ½-inch cap showed in the safety lamp. At the top of the return air course of the slope, at the canvas stopping, the lamp was extinguished.

Twelfth exploration, fifth day.—At 9.25 a.m. two engineers without and four men with apparatus went as far as the head of the slope. They built a second air lock (No. 5) without apparatus. Three of the apparatus men, using oxygen, went down the slope to the second north, went in 100 feet, and measured for stopping No. 6. The party then returned to the surface for materials.

Thirteenth exploration.—At 1 p.m. five apparatus men and the two engineers mentioned entered the mine. The crew carried the materials for the stopping to the head of the slope and the apparatus men carried it down the slope and into No. 2 north where they erected the frame for No. 6 stopping in 42 minutes.

Fourteenth exploration, 35 minutes after the thirteenth.—At 2.40 p.m. the same crew went down the slope with more material. Three men remained at the second north to build the stopping while two
went back for more material. At 3.15 the stopping was completed, except for the pulp plaster to make it air-tight. Coming up the slope the apparatus men were nearly exhausted because the air in the apparatus was so warm. They arrived at the head of the slope at 3.25 p. m. and were unable to do any more apparatus work that day.

_Fifteenth exploration, sixth day._—The same crew as in the fourteenth exploration entered the mine at 9 a. m., accompanied as far as the head of the slope by two other men without apparatus. At 9.10 the apparatus men turned on their oxygen, went down the slope, and entered the second north entry, where two of them completed the No. 6 stopping begun the day before, while two others explored the entry as far as room 9, where a large fall of rock that filled the entry and air course prevented further advance. They found no fire, but the entry was sweating considerably and was very warm. The crew returned to the head of the slope at 9.50 a. m.

_Sixteenth exploration, sixth day._—The crew made another trip down the slope; three of the men put up two canvas stoppings (Nos. 7 and 8) at the first south entry, and two put up a canvas stopping (No. 9) between the slope and manway at the first north. Then all came out except two, who stayed down to make arrangements to turn an air current down the slope when the men on top stopped the fan. They took down the canvas stopping (No. 3) on the intake of the slope and shut the door on the main south entry, then came to the surface and started the fan. After the air had been going down the slope for 22 hours ventilation was turned on the whole mine except the second north entry off the north slope.

_Seventeenth exploration, seventh day._—Four men entered the mine at 8.40 a. m. without apparatus. They explored the entire mine except the last 300 feet of the second north entry and air course, which were sealed by falls, but found no fire. The temperature on the slope and on the south side was 76° F. and at room 9 of the second north entry 82° F. The men returned to the head of the shaft at 12.30 p. m., satisfied that there was no fire in the mine. It was decided, however, to keep the last 300 feet of this entry and air course sealed for another week.

8. **BAD SHOTS CAUSE FIRE AND AN EXPLOSION**

Because the State regulations on charging holes and blasting were not observed in one mine, a shot started a fire and part of the workings had to be flooded. Three months later a shot firer was killed. Both accidents were caused by blown-out shots. The miners tamped their own shots, and the shot firer neglected to inspect the shots that blew out. Figure 7 gives some details of the fire and explosion.
A slope (12 to 18°) opens a coal bed 40 to 54 inches thick that lies in hard shale. The coal is dry. Entry roadways were thoroughly sprinkled and occasionally the rooms. Some gas feeders were cut at the faces of advancing rooms and entries, but the 40,000 cubic feet of air delivered by a 16 by 4½ foot exhaust fan kept the workings fairly clear of gas. Open-flame carbide and oil lamps were used.
Virtually all coal was shot off the solid, but in one entry an overcutting puncher was used. FF black blasting powder was used in rooms, and a permissible explosive was supposed to be used in narrow work. Dynamite was not supposed to be used.

**ORIGIN OF FIRE**

At about 4.30 a.m. one day the fire boss discovered a fire in the ninth east entry. He and two miners vainly tried to reach the fire, and at 7 a.m. asked a Bureau of Mines safety station for assistance. Meanwhile the fan was stopped. As apparatus men could not reach the fire, the mine was sealed and the lower entries flooded. Five days later apparatus men explored the mine and found the fire area under water.

The fire is supposed to have been caused by a blown-out shot at the face of the ninth east air course. (Fig. 7.) Three miners had worked in the entry the night before, and one had drilled a double-cracker shot in the face, each hole being 6$\frac{1}{2}$ feet deep and one 12 inches above the other, both on the solid for the full length. The lower hole had been charged with six sticks and the upper with five sticks, 1$\frac{1}{2}$ by 8 inches, of 40 per cent dynamite. Although the rope rider was supposed to act as shot firer for the night shift, the miners preferred to tamp and fire their own shots and did so that night; they left the mine at 3 a.m. The fire traveled up the slope and into the eighth east air course as far as room 7 before it was extinguished by flooding.

**9. APPARATUS MEN EXTINGUISH FIRE WITH CHEMICALS AND WATER**

A mine was working a bed of hard bituminous coal 3 feet thick, lying between a shale and sandstone roof and a fire-clay floor. The roof scaled without warning when once broken and exposed, which made fire fighting dangerous. No gas had ever been detected. The mine shaft was 107 feet deep. Virtually all of the coal was shot off the solid with FF black blasting powder. All entries and room necks were sprinkled daily.

**ORIGIN OF FIRE**

The fire broke out at the face of the eighth north entry (fig. 8) at about 6.30 p.m. A charge of black powder in a deep shot sprung and cracked the coal without throwing it out and set it on fire. The left side of the entry had passed through a "horseback," and the shot that did the damage was placed in good coal while the right side of the entry was still in the horseback. Gas had not been detected. The day before the fire was found a small pile of coal had been
shoveled to the right side of the entry to make room for placing the heavy shot on the left side. A brushing shot had been placed directly over this pile of coal, so when the fire was discovered (13 hours later)

not only was the coal in the hanging shot burning but the pile of coal was afire, with the rock from the brushing shot lying on top of it.

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The 4 by 16 foot fan, working as an exhaust, supplied 40,000 cubic feet of air per minute, but leakage was large. The normal speed of the fan (90 revolutions per minute) was reduced to 10 or 15 revolutions per minute during shot firing. The fan had been run slowly during the 13 hours before the fire was discovered, but had furnished enough air to give the fire a good start.

DETERMINING POSITION OF FIRE

Attempts were made to reach the fire, once from room 4, off the ninth north entry intake, but the heat and smoke were too heavy. The State mine-inspection department and the nearest Bureau of Mines rescue station were notified, and in one and one-half hours, at 11 a.m., three men arrived with five sets of apparatus and extra two-hour charges, liquid extinguisher (carbon tetrachloride), and ordinary portable fire extinguishers. The apparatus crew and five men without apparatus went into the mine. At the bottom of the shaft they were taken by motor to the seventh north. When they opened the door into the seventh north, which here is on the return, the air was very smoky, but did not affect the flame of the safety lamp. The apparatus men left the cars on the motor side track and walked in as far as the eighth north. As the smoke became too strong here, they went through the door into the intake, where they left both the men without apparatus and the extra supplies, put apparatus on, and entered the smoke again.

As the men advanced up the eighth north straight entry the smoke became thicker and the heat increased until they turned into the back entry through the curtain; there the air was fresh and cooler, but it became smoky again 30 feet farther in. From this point in the smoke and heat were almost unbearable, but by keeping close to the bottom the men advanced; they found a small fall of rock just outby the third room from the face of the entry, a pile of coal opposite the second room, and another small fall outby the room nearest the face. Just inby this last room were two loaded cars with a large slab of rock lying on them. To get by these cars the men had to stand up, and the heat was so intense near the roof that some of them were almost overcome.

The leader advanced to within 20 feet of the fire, which filled the entire face of the entry, and emptied a quart of liquid extinguisher (carbon tetrachloride) on it. He called for more, and the mine inspector brought him two 1-quart pumps, which were played on the fire; the surface of the burning coal was blackened, but glowing coal could be seen for a depth of 4 feet in cracks. The burning in the cracked coal was not extinguished by the limited supply of ex-
tistinguishing material. As the supply of this material was exhausted, the party returned to the fresh-air base on the stub entry.

**FIGHTING THE FIRE**

More extinguishing liquid arrived at 2 p.m. The crew then advanced to the fire and used two fire extinguishers and two tubes of extinguisher powder on the fire, which became noticeably less strong but continued glowing over the entire face of the entry. Then the crew retreated and rested. The men without apparatus built canvas stoppings, so as to bring all the air coming into the mine into the fourth room from the face of the back entry, the last room connected by a crossecut. Two water cars full of water, 200 feet of hose, and a large hand pump were brought in, the falls cleaned up, the base moved to the fourth room from the face, and the hose laid when the second supply of extinguishing liquid arrived at 7 p.m.

The apparatus party put 3 quarts of the liquid on the fire and retreated, and after about 10 minutes advanced and put on 3 quarts more. This so cooled the fire that the application of water was considered safe. The pump was started at about 8 p.m., and by 9:30 the fire was believed to be out. Two slight falls occurred, but the apparatus men were careful to keep close to the ribs and were not injured.

During the fighting of this fire 10 hours' supply of regenerators and oxygen was used. All of the apparatus men and several others were sick at different times because of the excessive heat, but all were out for work at the usual hour the next morning.

**10. A FIRE EASILY SEALED**

Another fire, also due to the ignition of coal from a bad shot of black blasting powder, was not discovered for 5½ hours, when it had obtained a good start at the point marked in Figure 9. The bed of high-volatile inflammable coal was 4 feet thick. Methane was detected occasionally in this mine, although it was an open-light mine.
A seal was made a short distance inby the first cut-through. Then the stopping in this cut-through was removed and the air directed through it and up the parallel entry (normally a return entry) a short distance to permit the erection in it of a stopping in fresh air. Little trouble was experienced in building the seals in 2 hours. The fire was entirely bratticed off within 14½ hours after it started.

The seal was made of rough oak boards, which were not set in cuts in the ribs, but the joints and cracks were plastered with clay; dry spots were moistened, and fresh clay was added from time to time. These seals were very effective, as the following analyses (Table 1) of the atmosphere behind them shows:

<table>
<thead>
<tr>
<th>Days after sealing</th>
<th>Place</th>
<th>CO₂</th>
<th>O₂</th>
<th>CO</th>
<th>CH₄</th>
<th>N₂</th>
<th>H₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Per cent</td>
<td></td>
<td>Per cent</td>
<td></td>
<td>Per cent</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Second north</td>
<td>6.38</td>
<td>1.41</td>
<td>1.10</td>
<td>16.69</td>
<td>74.10</td>
<td>0.12</td>
</tr>
<tr>
<td>12</td>
<td>First north</td>
<td>6.41</td>
<td>1.25</td>
<td>0.59</td>
<td>17.76</td>
<td>73.90</td>
<td>Trace</td>
</tr>
<tr>
<td>30</td>
<td>Second north</td>
<td>4.70</td>
<td>2.70</td>
<td>0.30</td>
<td>24.90</td>
<td>67.40</td>
<td>Trace</td>
</tr>
<tr>
<td>30</td>
<td>First north</td>
<td>5.30</td>
<td>2.40</td>
<td>0.50</td>
<td>24.10</td>
<td>67.70</td>
<td>Trace</td>
</tr>
</tbody>
</table>

Because of the high methane content of the area behind the seals the opening of the entries and the draining of the gas as soon as possible were desired, lest the gas might leak out and come in contact with the open lights of miners. No breathing apparatus was available for exploring the fire area, but three of the mine officials and a Bureau of Mines engineer opened the seals on the thirtieth day. The seal on the return was opened, and a strong current of air was directed through these workings. Figure 10 shows the weakened roof and a fall where the fire had been. Figure 11 shows the normal condition of the roof.

**REMARKS**

The need of fire runners to follow shot firers is evident; this fire was not discovered until 5½ hours after a shot had ignited the coal.

Use of permissible explosives decreases the liability of fires from blasting and the chances of dust explosions.

The work of sealing and reopening was done rapidly and efficiently. By constant attention roughly constructed seals may be made as efficient as many carefully built seals.

**11. DISASTROUS EXPLOSIONS IN FIGHTING FIRES**

Eighteen men, while building a stopping to seal off a fire area, were killed by an explosion; seven hours later 41 men, who were engaged in recovery work, were killed by a second explosion. Only
Figure 10.—Condition of roof near fire, fire 10

Figure 11.—Normal condition of roof, fire 10
five bodies were found. All the men carried safety lamps. The mine was completely wrecked. Timbers 12 inches square and 12 to 16 feet long were blown 550 feet from both pit mouth.

MINING CONDITIONS

The mine in which the disaster took place was in a bed of sub-bituminous coal that lay in an oval trough and the mine mouth was in the western outcrop of the bed on a hillside. The main heading ran almost due east, dipping 14° for about 3,000 feet and then rising 22°, and came to the surface on a wide flat. The eastern outcrop was 8,000 feet from the western. Boilers and engines were at the mouth of each slope, but coal for market was hauled up the west slope only. Analysis showed the coal contained 6.38 per cent moisture, 48.43 per cent volatile matter, 36.37 per cent fixed carbon, and 8.82 per cent ash.

The mine, which was worked about three days in the week, liberated much gas, and feeders were often found. The miners used open-flame lamps. A fan was in use at each slope. Seven gas watchmen and four shot firers were employed. The mine was not considered dusty. All entries were sprinkled, a precaution that does not insure protection from coal-dust explosions.

One Friday a watchman found fire at the face of an entry about 10 hours after the last shots had been fired. Nobody had entered the mine meanwhile. Two brattices were erected that day, and one was placed in an advanced position five days later. The position of the other was being advanced on the seventh day, when the whole crew was killed by an explosion. Another crew then started rescue work, bratticing crosscuts and entries as it went in, and soon reached the entry where the first crew had been killed. Evidently the latter had some warning of the explosion, as all were face downward with arms over their heads. Shortly after this the second explosion killed the rescue crew, which had intended to stop off the entry.

No breathing apparatus was used by either crew. One of the second crew, who had left the mine to get into the fresh air and thus escaped, said that only two, himself and another member of the second crew, had felt the effects of afterdamp when he left the party before the second explosion of gas.

REMARKS

If a mine is operated intermittently there is especial need of inspection for fires after shot firing.

Open lights should not be used in a gassy mine, however well ventilated it may be.
Men fighting fires should wear breathing apparatus to inspect for bodies of gas in the vicinity of the fire before stoppings are erected. Sealing a fire in a gassy coal mine is always hazardous, and in the erection of stoppings especial care must be taken not to move bodies of gas to the fire. Rock dusting should be done as close to the face as possible before the seals are erected. Determinations of the content of inflammable gas in the return air from the fire should be constantly made.

FIRES CAUSED BY SPONTANEOUS HEATING

As will be seen, most of the 10 fires cause by spontaneous heating were gob fires and were difficult to subdue.

12. DRIVING A CROSSCUT TO GET BEHIND A FIRE

The shaft was 215 feet deep. The coal averages 6 feet thick; the roof is black slate 2 feet thick, above which is a cap rock (conglomerate) about 2 feet thick. The main entry runs east and west, but because of many faults the west side was not developed. The output was 600 tons a day. Haulage was by mules only. The mine was ventilated with an exhaust fan, the hoisting shaft being the downcast. The room-and-pillar panel system of mining was used.

ORIGIN OF FIRE—FIRE-FIGHTING METHODS

Spontaneous heating caused a fire in the gob in an abandoned room. After the fire was discovered no attempt was made to control it until the next day, when water was hauled to it in barrels and eight portable extinguishers (sodium bicarbonate) were used. Loading the hot material into cars was abandoned as the top began to cave badly in the room neck. Then a curtain of brattice cloth was placed in the room neck to keep out the air.

An opening into the room where the fire was burning was driven through the pillar of an adjoining room. Meanwhile a 2½-inch pipe line was laid 1,100 feet from the shaft bottom and 1,100 feet of hose, part rubber and part canvas, laid from the end of the pipe to the fire. Laying of pipe and hose was completed on the night of the fifth day of fighting the fire. When water was turned on the pipe burst in two places and the hose in three; repairing these breaks took nearly all the next day.

Meanwhile the Bureau of Mines had been asked to assist, and an engineer with three State rescue men and four breathing apparatus arrived on the fourth day of fire fighting. While the pipe line was being repaired the bureau corps trained the mine superintendent, foreman, examiner, and two timbermen in the use of the breathing apparatus.
On the sixth day the hole through the pillar between the rooms was completed, but a big fall of cap rock on the gob delayed progress. The rock had to be blasted with dynamite before it could be loaded. After 25 cars of rock and gob material had been loaded out the fire was reached. Water was then turned on, and as fast as the rock that had fallen over the gob fire cooled it was loaded into cars and hauled outside. The use of dynamite should be considered dangerous. Use of a permissible explosive, if it had been available, would have been safer; plenty of air was passing over the rock fall, but ignition of dust was possible.

The fire did not blaze, but was a glowing bed of shale and gob about 2½ feet thick and about 2 feet above the floor of the room, covered by 4 or 5 feet of gob and rock. Owing to the bad condition of the top, which required the use of props and crossbars, loading did not progress rapidly. The fire was under control on the eighth day.

13. HAZARDS FROM SPONTANEOUS FIRES IN A SUBBITUMINOUS MINE

The subbituminous coal in this mine is near the surface; it fires spontaneously and when once burning is hard to extinguish. Analyses of the coal show 22.9 per cent moisture, 31.8 per cent volatile matter, 40.1 per cent fixed carbon, and 3.2 per cent ash.

MINING CONDITIONS

The bed dips slightly and is about 8 feet thick; the roof is shale and the floor is clay which softens and swells when wet. Figure 12 shows the system of mining at the time of the fire.

The coal was undercut by electric chain machines and blasted with FF black powder. The main entry of the mine was driven parallel to a "sand roll" and just west of it; consequently the cross entries were turned only to the west, with the exception of a few short east entries, and were driven at an angle of about 45° to the main. The territory opened up by the first, second, third, and fourth west entries had been worked out, was afire, and was walled off from the rest of the mine.

Rooms had been turned off the main entry, near the pit mouth. When these had been driven about 300 or 400 feet, the pillars were drawn back to the entry. Almost immediately the gobs fired. After that the company fought the fire continually by building rock walls along these old rock necks, and cutting in to put water on the places when the fire "ate" through the pillars. The fires on the west entries continued to break out and cause trouble, because the cover there was thin and the fires could not be kept tightly sealed.
First Attempt to Fight Fire

Smoke was discovered one day at 5 a.m. Soon after 7 a.m. orders were issued for all workmen to leave the mine immediately as conditions appeared dangerous. One man was overcome with smoke and black damp, but was revived. The fire was discovered two hours later in the abandoned sixth west entry, where it was burning along the entry for 300 feet.
As the fire could not be approached, board stoppings were hastily built to check the current of air feeding it, but these stoppings quickly burned out. Moving outby, the fire soon communicated with cave holes to the surface. Stoppings were begun in the chain pillar between the seventh and eighth west entries, with the intention of sealing off the sixth, seventh, and fifth west entries, but early on the third day an explosion blew out two stoppings, one concrete and one rock, at the head end of the work; then the fire area connected with the whole mine.

"Baffling" of Ventilation—Explosions

The smoke issuing from the fifth west prevented replacement of these stoppings at once. Attempts were made to drive back the smoke by speeding up the fan, but the air current on the main entry was reversing every few minutes, in spite of the pressure produced by the fan. Therefore the men were again ordered from the mine. It was intended to open the cave holes outside to give more vent and better control of the air. The men had been withdrawn only 30 minutes when a terrific coal-dust explosion blew rails out of the manway entrance (70 entry).

The opening of the cave holes an hour later did not give enough vent for the gases generated, and two more violent explosions occurred on the next day, 14 and 22 hours after the first explosion. Then the mine was sealed so that enough inert gas might form to extinguish the fire.

Later Attempts to Fight Fire

A Bureau of Mines rescue car and crew arrived five days later to assist in fighting the fire. While a hole was being cut for apparatus men to enter the mine, temperatures taken at a borehole in the main entry, 14 or 20 feet from the pit mouth, were 95°F. when the air was intaking and 105°F. when the air was forced out by changes in pressure. When the apparatus men entered, the temperature increased so rapidly as they proceeded inby that they had to retreat before they had gone 200 feet. They saw no fire, but the entry was so full of smoke and steam that any flame in the vicinity could not have been seen.

On the two following days apparatus men were able to go in about 400 feet. A line of hose to cool the place was suggested but was not tried, as the management feared the effect of water on the coal roof. Then it was suggested that a small blower be set up at the pit mouth to cool the air, so that the men could reach the first cross-cut that could be conveniently opened to short-circuit the air when
the large fan was started. It was planned to advance by bratticing up the middle of the entry with two cross curtains ahead in successive advances. After the party had advanced in this way for about 200 feet the blower would not clear out the smoke; the management became impatient and started the large fan. The smoke from the return soon became blacker; the fan was stopped and the entry sealed. It was decided to enter from another point.

While a new entrance was being made the company sent men to the rescue car for training in first aid and the use of breathing apparatus. When these men had been trained the car left for another district, as the new opening would not be ready for several weeks.

**EXPLORATION OF FIRE AREA THROUGH NEW OPENING**

At the request of the company the same car and crew returned 75 days later to assist in reopening the mine. A new opening had been made and the mine cleaned up inby to the point where 70 entry joins 66, and the seventh and eighth west entries had been cleaned up west of 71. Concrete stoppings had been put up on the seventh and eighth west, and doors with concrete frames on the 66 and 67 entries, as indicated in Figure 12. The old pit mouth was tightly sealed. A fan at the new opening was in fairly good order for ventilating that section of the mine. The doors on 66 and 67 entries were taken down first, and the party, by placing temporary canvas stoppings in the breakthroughs between 66 and 67 entries and taking the air in with them, advanced to the third butt off the ninth west shortly after noon on the second day. Here, three men put on breathing apparatus and advanced to a point on the ninth west between 30 and 31 cross entries, where they found an electric haulage motor slightly damaged. Ventilation was then established as far as the motor, which was recovered.

**EXPLORATION THROUGH MAIN ENTRY**

The management wished to close this end of the mine and investigate the main entry, going in through the old pit mouth; accordingly the doors in 66 and 67 were closed and the old pit mouth was opened. After two or three attempts an apparatus crew reached the doors in the breakthrough between the main entry and air course, between 4 and 5 west entries, and propped these open. The temperature was 91° F. opposite the second west but was lower at the doors; it was nearly always high at the first and second west, where masonry arches kept the old fire from the main entry.
After as careful an examination as was practicable with breathing apparatus a bureau engineer said that he thought it would not be dangerous nor difficult to try to advance along the main entry after the fan was started. In accordance with this proposal lines of hose were connected and placed at the pit mouth, the air course was unsealed, the old fan was started, and a party went in dragging the hose. Several small fires blazed up but were quickly extinguished. The hose was played on the fire on the fall at the second west until it was somewhat cooled; then cleaning out was started.

Meanwhile an exploring party tried to enter the airway from the outside, but encountered caves. The men then advanced down the main entry, past the blazing fall at the second west, and took air samples near the doors inby the third and fourth west, marked in Figure 12. They found the main entry tightly blocked by a large fall just out by the fifth west.

Before the fall at the second west could be completely cleaned up, fire broke out in the airway somewhere between the doors and the fan. It burned so rapidly that the management decided to abandon the attempt to enter from this end of the mine. Both the main entry and the fan shaft were tightly sealed.

Through a misunderstanding, the airway to the fan shaft was left unsealed, except for one poorly fitting door. The next morning a slight explosion blew the top off the fan shaft. This shaft and the air course were immediately resealed and everything remained quiet.

Twenty-four hours after this last explosion the crew entered through the new opening to put up stoppings and secure the part of the mine recovered from that end. After this was done, coal was mined and loaded from that section of the mine. Eventually the sealing smothered the fire in the old section.

**REMARKS**

Spontaneous fires are very liable to occur in lignite and subbituminous coal mines and are hard to extinguish. In such mines it is advisable to leave thick pillars on advance working, lay out rooms in panels surrounded by thick pillars with a minimum number of openings for ventilation and haulage, and provide niches for storage of material for prompt erection of fire stoppings.

14. APPARATUS MEN INSPECT A SEALED AREA

**ORIGIN OF FIRE**

At 7 o'clock one Monday morning an assistant mine boss discovered a fire, which seemed to be burning fiercely across the west entry 600 feet from the pit mouth (fig. 13). This boss had not
made his usual Sunday inspection of that section of the mine, and the fire had presumably been burning all that day, with the fan running. There had been two gob fires in the abandoned workings in the area marked "previous fire," and it was thought this fire came from an old one. The right rib along the "west entry" separating it from room 15 off the twelfth west was only 2 feet thick in places, and, although all of the cut-throughs had been bratticed off with brick stoppings, it was thought that the old fire in the gob had burned through the thin rib and broken out on the west entry.

FIRE-FIGHTING METHODS

After the fire was discovered four officials went into the west entry against the return air current, but were quickly driven back to the pit mouth by the hot smoke and fumes.

Brattice men were set at work at once, and an air-tight wooden brattice was erected on the west entry 200 feet in from the pit mouth (fig. 13). Other wooden and brick stoppings were erected on the fourteenth west entry, seventy-sixth and seventy-seventh south, eleventh and twelfth west, in 12 room necks off the tenth west, and in 3 room necks off the twelfth west, entirely sealing off the fire area.

After 6 days an exploration was made by 2 bureau engineers and 6 company officials, with breathing apparatus; their equipment, including 6 breathing apparatus, 6 flame safety lamps, 6 electric flash lights, 1 oxygen resuscitator, 1 life line (a light rope on a reel for guidance on retreat), and 1 thermometer, was carried on 2 mine cars behind an electric motor into the workings through the sixteenth west entry to the seventy-sixth south. Here the breathing apparatus was adjusted and put on, and the party of 6 explored the fire area. The fan was not running, hence no air current was being forced into the inclosed fire area.

An opening was made through the wooden stopping marked A on the seventy-sixth entry, where a reserve party of 6 remained without apparatus. The 6 apparatus men advanced 400 feet on the seventy-sixth south to the fourteenth west entry, where 3 apparatus men remained as a reserve; the other 3 proceeded along the fourteenth west entry 400 feet to the old air shaft, which had been sealed at the top. At an outby crosscut marked B they repaired a wooden brattice. They found no smoke and little heat and returned to the seventy-sixth south. The safety lamps burned brightly, and the temperature remained at about 70° F.

The entire party of six then continued along the seventy-sixth south to the tenth west entry, chalking the course on the roof and ribs.
Figure 13.—Map giving details of explorations, the 14. Route of exploration shown by dashed line.
At the tenth west junction three remained as a reserve party, while the other three proceeded along the tenth west through room 13 to the twelfth west entry and into an old room (16) on that entry. There they found a fire extending across the entry but not burning fiercely. The first indication of smoke was on turning into the twelfth west entry; then the lamps held close to the floor burned low and were finally extinguished, thus indicating the presence of CO₂. At the mouth of room 16 the temperature was only 80° F.; the smoke hung a foot from the top. The roof was in good condition. Another seal near this point might have checked the fire more effectually.

The advance party then returned by the same route, rejoined the reserve party at the tenth west junction, and the entire crew of six returned to the starting point on the seventy-sixth south. The total distance covered was 5,800 feet in 1 hour and 45 minutes.

As all working places in this section of the mine were abandoned, the management decided to keep the fire area closely sealed for at least 30 days.

When the area was opened later, the fire was found to be extinguished.

**REMARKS**

The mine was not planned with a view of isolating a fire, although one might occur in any part of it.

The plan of the mine was such that a fire in almost any part necessitated sealing a large area.

By prompt use of breathing apparatus the seat of the fire could have been determined and then inclosed within a relatively small area.

**15. FIRE SUBDUES BY SAND FLUSHED THROUGH BOREHOLE**

Fire caused by spontaneous heating broke out in the gob of a mine working a nearly vertical bed of coal. The clay and board stoppings built (fig. 14) were 4 feet thick. Water was pumped through the upper stoppings on the fourth and succeeding days after the outbreak of the fire.

On the sixth day, as the water was still issuing warm at the lower level while smoke and gases were coming from cracks in the coal above the upper bulkhead, it was evident the water was not reaching the seat of the fire. It was then decided to put down a borehole from the surface, a depth of about 40 feet, and flush the "stope" or chamber full of sand. No lives were in danger during the fire fighting, and the sand filling was successful in extinguishing the fire.
18. NEED OF BREATHING APPARATUS IN SEALING A FIRE

ORIGIN OF FIRE

Spontaneous heating caused a fire in an abandoned section of a mine. During the slack season this section was allowed to fill with water. In the autumn steam pumps removed most of the water, and the workings were gradually drying as the weather became colder.

Chemical and physical reactions in the roof, gob, coal, or floor during drying generated heat and gradually raised the temperature to the ignition point.

MINING CONDITIONS

The bed, which was being worked at a depth of 175 feet, averaged 4½ feet thick; it had a roof of shale, which fell in slabs, and at times spontaneous heating took place under these falls. Analysis of a composite sample of coal bed showed 4.33 per cent moisture, 40.55 per cent fixed carbon, 45.94 per cent volatile matter, 9.16 per cent ash, and 2.86 per cent sulphur. The raise workings in the mine were relatively dry, but the dip workings soon filled with water. Gas in explosive proportions was found occasionally. Miners used open lights, and fire bosses used unapproved flame safety lamps. A force fan supplied ventilation, and the air current was divided into five splits. The mining system was room and pillar. Coal was shot off the solid with black blasting powder, set off by shot firers.

FIRE-FIGHTING METHODS

Three men were overcome while attempting to seal off the fire and three others were slightly burned two days later by the flames or hot gases from the last of three explosions. The shafts were sealed on the third day, but were reopened by the State mine inspectors and
representatives of the Bureau of Mines on the sixth day. Then the fire area apparently was sealed effectively by men wearing apparatus. A Bureau of Mines car arrived at the mine on the seventh day with 10 sets of rescue apparatus and accessories, enough for two crews of five men each.

Workings were explored, curtains were hung, board stoppings were erected, and the area was completely sealed on the tenth day after the outbreak of the fire. Then the fan began to force air through the other workings at about half the normal speed.

Table 13 gives analyses of samples of the air behind the seals 43 and 55 days after the seals were finished.

<table>
<thead>
<tr>
<th>Table 13.—Analyses of air behind seals</th>
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<tr>
<td>AFTER 43 DAYS</td>
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<tr>
<td>Number</td>
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<table>
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<th>SAME PLACES, AFTER 55 DAYS</th>
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<td>Number</td>
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These analyses illustrate the difficulty in sealing areas tightly. They also indicate the variation in composition of gas samples taken at stoppings at different times, due to the "breathing" in and out of a sealed area with changes in barometric pressure. The low percentage of methane in the gases behind the seals showed that the old abandoned and caved workings did not liberate much gas.

Evidently fresh air did not reach the seat of the fire, as eventually the fire went out and no more trouble was experienced.

17. FILLING A FIRE AREA WITH SOIL

Under certain conditions a mine fire can be extinguished by flushing in clay and fine gravel from the surface. This was done at a large mine where a fire in a worked-out and abandoned section had
been burning, although under control, for about 40 years. Incidentally, the filling put into the workings helped to support the bed of a creek and a railroad bridge immediately above the fire area.

MINING CONDITIONS

The 7-foot bed of bituminous coal was opened by a main shaft 122 feet deep and an air shaft 111 feet deep. The workings were extensive. In the newer workings the mining system was double-entry room and pillar; but in the old workings, especially in the fire area, it was single-entry room and pillar. The mine was rated as nongassy. Ventilation was by a 25 by 8.6-foot fan run as a blower.

As the fire in its first stages had not seemed to menace the safety of the mine and as it was inaccessible, no attempts had been made to extinguish it. However, about 1902 the fire broke into the workings of an old water-level entry about 3,000 feet northeast of the main shaft. This entry had been maintained as a travel way or a second outlet to the mine, and its maintenance as such was necessary. Concrete and brick stopplings were constructed in the crosscuts off this entry; although badly crushed later by the settling of the roof, they kept this travel way clear for 15 years. In 1917 the fire broke through the stopplings and renewed efforts had to be made to check it.

FIRE-FIGHTING METHODS

Men wearing breathing apparatus were able to reach room 17 on the travel way, but could not build a stopping there because of the smoke and fumes. They tried to construct a temporary wooden brattice at room 13, but before the brattice was completed a fall of roof injured three men. Finally five brick stopplings were built in room 9 and on the entry between rooms 8 and 9, thus sealing off all workings inby room 9.

The fire area was beneath a creek and a railroad track and bridge. The cover under the creek was about 80 feet thick. Cracks that appeared on the surface dangerously near the creek indicated danger to the mine and miners from flooding. To prevent further subsidence of the surface above the fire area it was decided to sink boreholes, erect bulkheads underground, and use hydraulic filling. Prior to the time of the investigation a well rig had drilled 21 boreholes from the surface to the fire area, and one more was to be drilled. These holes were cased with 8-inch wrought-iron casing, which was capped at the surface to prevent leakage of air.

"Retaining" and "distributing" bulkheads were built of timber, as shown in Figures 15 and 16. The former were so placed on entries as to keep the filling materials away from sections of the mine.
other than those under the creek. Advantage was taken of the dip of the coal bed in placing these retaining bulkheads, which were impervious to solid material but would allow water to pass through.

Drainage boxes to permit the escape of water extended from the bulkheads along the entries to the inby ends of workings being filled. Distributing bulkheads were built across the rooms, just outby the
last breakthrough, to permit material to be conveyed from the bottom of the borehole to all rooms to be filled. Where, because of falls in rooms, the roof was lower in breakthroughs than in the adjoining rooms roof had to be shot down to insure filling materials passing from room to room. At the time of the investigation filling was being run down No. 1 borehole.

The material used for the hydraulic filling was the clay top soil, about 4 feet thick, on land owned by the company. The clay was washed from the bank with a hydraulic giant having a 2½-inch nozzle and using about 2,000 gallons of water per minute at a nozzle pressure of 50 pounds per square inch. (See fig. 17.) A double-stage centrifugal pump, belt driven by a 400-horsepower motor, sup-

![Figure 16.—Projected plan of distributing bulkhead, fire 17](image)

plied the giant with creek water through a 12-inch cast-iron flanged-joint pipe. The pressure at the pump was 420 pounds. A 12-inch wooden pipe carried filling material from the clay pit to the top of the borehole. The material and water entered this pipe at a point about 50 feet below the hydraulic giant. A large cast-iron T connected the wooden pipe and the borehole casing. The top of No. 1 borehole was about 125 feet lower than the inlet to the wooden pipe, which was laid on the surface near the water pipe. About 200 feet of these pipes lay along the pitch of a steep hill. At a point halfway up the hill a solid concrete anchorage was built to prevent movement of the two pipes. Both pipes were carried over the creek and under the railroad bridge on a wooden trestle.
One man with a shovel at the inlet end and another man at the borehole prevented clogging by large material. No screen was used at the inlet end to keep large lumps from entering. It was estimated that the water used carried only 10 to 11 per cent of solids, so there was little trouble from clogging. Filling operations continued day and night and required the labor of seven men, one of whom was inside of the mine but in direct telephone communication with those outside.

The seepage from the area being filled ran to the mine sump and was pumped to the surface; it was muddy and apparently carried much fine material.

It was estimated that 100,000 cubic yards of material would be required to fill the workings and at 40 cents per cubic yard would cost $40,000. A later estimate indicated 35 cents a yard.

**REMARKS**

Ventilation of old workings during flushing operations is of advantage because gases may be forced out.

Regular inspection will detect any unusual conditions in time to remedy them.

There will not be sufficient seepage if the material is deposited continuously or at frequent intervals. Filling periods should not exceed four hours and much longer if the material is clayey or silty.

Continuous use of the hydraulic giant in the intermittent filling method recommended will be facilitated by the material pipe having several branch lines to alternately supply holes to different places.

Better results in filling will probably be obtained by providing the inlet pipe with a screen or system of screens to permit no material over 3 inches to enter, as the larger pieces tend to form a cone at the bottom which clogs free flow and prevents the water transporting the finer material horizontally in the mine as far as desirable.

Sandy material is considered much better than clay for filling. Clay holds water for a long time and permits considerable subsidence. Records indicate that with clean sand subsidence is only about 5 per cent of the excavation, whereas with clay it is 15 per cent or more.

**18. COMPLETE BULKHEADING AFTER UNSUCCESSFUL CAVING**

**MINING CONDITIONS**

A 9-foot bed of good lignite was opened by a main entry and air course and was mined by the room-and-pillar system. The cover was 100 feet thick in some places. One foot of the coal was left to support the clay roof, and 18 inches of coal was left for the floor. In rooms props were placed 5 feet apart with large headboards.
FIGURE 17.—Flushing top soil into mine with a giant, fire 17
The coal was moist, but the mine was generally dry. No gas had ever been encountered. Carbide lights were used. Ventilation was by a gasoline-engine driven fan of the Sirocco type stationed at the end of the main entry at the bottom of a "raise" to surface. This fan gave plenty of air, but its removal to the surface was recommended.

**FIRE-FIGHTING METHODS**

Fire, probably from spontaneous heating, started in the coal. The management purposely caved the roof with the intention of sealing the fire, but conditions were made worse. A large area of clay roof had also caved over the fire during the two weeks the company tried to fight it. When a Bureau of Mines engineer arrived, the fire had been burning four weeks. It was estimated that to mine out the burning coal would require expensive timbering and stoppings.

It was decided to smother the fire by sealing off the area. Four walls were built successfully.

**19. AN OBSTINATE FIRE THAT WAS EVENTUALLY SEALED**

A serious fire in caved pillar workings in a bituminous coal mine originated from spontaneous heating. The mine was worked while the fire was fought, and none of the usual crew of miners were considered to be in serious danger, but some of those within the fire area were affected by smoke at times. Working a mine while a serious fire is being fought can not, however, be considered safe practice.

Bureau of Mines engineers and a crew of a rescue car assisted during 61 days. Fifteen sets of breathing apparatus were available and four crews wore them at intervals for nearly 400 hours while erecting curtains and temporary stoppings to restore or adjust ventilation. The apparatus also was available for giving first aid to miners affected by gases.

Fifty-three days after the fire started it was getting beyond control. Air was excluded from the tunnels being driven to reach the fire (fig. 18), but combustion was continuing. It was then proposed to flood the area, which extended about 1,200 feet along the dip and 1,000 to 2,000 feet along the strike. But as pillars had been removed in a large part of the area and the overlying material had caved, it was believed that the entire area was squeezing and heaving so that dams would not hold water. Sealing was finally decided upon. Timber stoppings were used where there was any chance of ground movement, but concrete stoppings were used in solid ground. The fire was finally brought under control by the seals.
A fire due to spontaneous heating broke out between the sixth and seventh levels of a mine in a dipping coalbed. Stoppings 1 and 2, known to be on fire 61 days after outbreak, were built on the seventh and eighth levels, but as the air was not effectively cut off the fire continued to burn. Later an-
other stopping was built on the seventh level at 3, and at the top of the chute at 4. An angle chute, 6, was then driven through the pillar for ventilation, so that coal could be mined from the chute rib. The angle chute was holed at the intersection of the longwall rib and the seventh level, but as the fire was working toward this point the face of the rib had to be clayed. A short crosscut, 8, was started from the angle chute and came out about 15 or 20 feet below the mouth of the angle chute at the point 6. Canvas was then put up in the angle to turn the air through the crosscut.

About 25 days after the outbreak an explosion blew down a stopping (5, fig. 19) on the eighth level, pinning beneath clay and boards a miner who had been working at the stopping. The inside boards and props remained in place. Three men were slightly burned by hot ashes and coal blown out of the angle chute and crosscut where they were working (6, 7, and 8, respectively). Another man half way up the longwall face, 9, at the time said he saw a flash of fire behind the face between him and the chute. A few minutes before the main shock a couple of light shocks were felt, which might have been caused by falls of ground or small local explosions.

A Bureau of Mines engineer arrived at the mine on the following day. After conference with the superintendent it was decided to try to build a stopping on the seventh level inside of the longwall face to save the latter if possible. Brattice cloth was strung from the corner of the longwall to a point about 6 feet from the longwall face or chute coming up from the eighth level. The entry at this place was about 20 feet wide, as two skips had been taken off the rib and the track carried into the footwall so that coal could be loaded into cars from the chutes instead of being shoveled. The old entry as originally driven was squeezed nearly tight. As this brattice cloth carried the smoke back, a stopping was started at 10. Immediately after the explosion or concussion a heavy timber cog was erected on the eighth level and a 3-foot clay stopping, 11, was built on the outside of the cog. A hole was left in this stopping for air until
the stopping on the seventh level was nearly completed. Both stop-
pings were closed at the same time three days later.
No breathing apparatus was used in the work described, and work
in the mine was not stopped. Only one man was seriously injured.

21. MEN KILLED BY REVERSAL OF AIR IN NATURAL VENTILATION

Five men were killed while trying to seal off a spontaneous fire
in a lignite mine. The mine had never had a fan, ventilation was
natural, and reversal of the air current carried gases from the fire
to where the men were at work, 110 to 115 feet from the surface. One
other man lost his life while trying to rescue those who were
overcome.

The bed of lignite is 7 to 10 feet thick and almost vertical. Origin-
ally the mine was worked through a 45° rock incline which entered
the coal at a point about 100 feet vertically below the surface. From
this point a level was driven in the coal, and rooms were turned
toward the surface at intervals of 45 to 50 feet along the level.
Later a vertical shaft was sunk about 225 feet and a second level
started. As ventilation was natural, the direction of the air current
changed with the seasons of the year.

The disaster shows the folly of trying to work a coal mine, large
or small, without a fan, because the direction of natural ventilation
is governed by the wind and by the relative temperatures inside and
outside the mine.

Mining laws in all the older States require that all coal mines sub-
ject to regulations—those mines employing more than a specified
number (5 or 10) of men—be provided with a fan. This fire demon-
strated the need of such regulations.

FIRES CAUSED BY ELECTRIC ARCS IGNITING COAL OR WOOD

A short circuit from a defective electric wire installation and one
caused by a fall of rock were regarded as responsible for the fires
discussed below.

22. A DIFFICULT JOB OF SEALING AND RECOVERY

This fire was probably caused by a defective electric wire in a
gassy mine.

PRELIMINARY WORK

Apparatus men from the county rescue station had entered the
mine by way of the air shaft. The county station, which was sup-
ported by operators and supervised by an experienced mining man,
had 10 sets of oxygen breathing apparatus. The crew was able to
get on either side of the fire but not close to it, because it was hot.
Later indications were that the fire probably originated in the electrician’s shanty, off the haulage way. The fire was so near the bottom of an upcast hoisting shaft (fig. 20) that if the men had attempted to use water from inside (on the intake) with the air taking its normal course toward the shaft the fire almost certainly would have reached the shaft before it could have been extinguished. On the inside not far from the fire a partly sealed panel full of gas prevented the reversal of the air current and the fighting of the fire from the hoisting-shaft bottom. Near by, on either side of the main entry, were many acres of abandoned workings, sealed off but full of gas (60 to 70 per cent methane). The management had ordered the fan stopped and seals placed over both shafts just as

the Bureau of Mines men arrived and were given charge of the fire fighting.

**CONDITIONS IN SEALED AREA**

The shaft seals were covered with clay which was moistened and tamped from time to time. A pipe, with a gate valve, to sample the mine air and take temperature readings was inserted through the seal over the hoisting shaft. A recording thermometer lowered through the pipe showed the temperature at the shaft bottom. Systematic sampling was done. The samples collected were analyzed with a portable Orsat apparatus and in the laboratory. Some analyses were as follows:
FIFTY-NINE COAL-MINE FIRES

Analyses of samples from sealed shaft

<table>
<thead>
<tr>
<th>Days after sealing</th>
<th>( \text{O}_2 )</th>
<th>( \text{CO}_2 )</th>
<th>( \text{CH}_4 )</th>
<th>( \text{CO} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>\text{Per cent}</td>
<td>\text{Per cent}</td>
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<td>\text{Per cent}</td>
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<tr>
<td>1</td>
<td>19.70</td>
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<td>0.59</td>
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<tr>
<td>22</td>
<td>1</td>
<td>4.4</td>
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</tr>
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1 Analysis made with Orsat apparatus only.

EXPLORATIONS AND RECOVERY

An air lock was built over the air shaft. On the seventeenth day six apparatus men made an inspection for 600 feet from this shaft. Two days later crews began to carry in supplies and erect air locks and seals along the air course. The seals, marked in Figure 20, were made of 2 by 4 inch lumber, lath, and wood fiber.

After the two shaft seals were opened the fan was restarted as an exhaust. Five days after the inspection, the crews broke through the brick stoppings at \( A \) and \( B \), erected seals 10 and 11 and a tight curtain at \( C \), and removed the air lock out by the first east-south entry.

The fan was reversed, making it a blower (its normal operation), and the entire mine, excepting the sealed fire area, was cleared of gas. The fire area was allowed to cool for a few days, then seals 12 and 13 were erected, seals 7, 8, and 9 were removed, seals 10 and 11 were opened, and air was directed into the main south haulage and traveling ways. The men then advanced along the traveling way and built seal 14. Entering from the air course, they built seal 15 in the haulage road. Seals 10 and 11 were closed again, leaving the fire area closely sealed by 10, 11, 14, and 15.

In the first east-south entry were falls of roof for about 300 feet. These were cleaned up, but, as the falls in the haulage and traveling ways were so large, a new entry (indicated by dotted lines in fig. 20) was driven through a barrier pillar.

REMARKS

Accumulated water, fallen slate on the floor, bad roof, high temperature and humidity, and gob material piled against stoppings at breakthroughs increased the difficulty and danger of the recovery work.

Correct maps of mine workings should be readily accessible.

Regular sampling and analysis of the atmosphere of a fire area is important.

The value of breathing apparatus was clearly shown. A total of 30 sets of apparatus was used and more than 2,000 pounds of caustic soda consumed during the 54 trips into the workings.
23. SHORT CIRCUIT CAUSED BY A ROCK FALL IGNITES COAL

After the fire described here the three wires of an alternating-current power line that supplied a small hoist on an inside plane just below the mouth of the seventh west air course (fig. 21) were found burned through by a short circuit. It was decided that the short circuit ignited the coal. This part of the mine had not been worked for several years and was really abandoned, but was well ventilated by 70,000 cubic feet of air passing through.

![Diagram](image)

**Figure 21.—Plan of workings, showing fire and stoppings, fire 23**

**MINING CONDITIONS**

A bed of good bituminous coal, 4 feet thick, dips 10 to 11° at the outcrop and 5° at the lowest workings. The immediate roof is a sandy gray shale, the floor is a gray shale. At the time of the fire the daily capacity of the mine was 600 to 700 tons. Slopes and main haulage roads were lighted by electricity but employees carried open-flame carbide lamps. Only permissible explosives were used, and holes were shot by a shot firer. The mine was well ventilated by two blowing fans; it made little gas. Alternating current at 440 volts drove the mining machines.
EXTENT OF FIRE

The fire when discovered had been burning about 12 hours and had made considerable headway in the seventh west entry and the air course both east and west, up the plane, also in old rooms on the seventh west for 200 feet.

The first attempt to fight the fire was with portable extinguishers, 10 of 5-gallon and 1 of 30-gallon size. As the fire still gained, a hose and nozzle were tried. An electric pump on the 8½ west entry supplied the water. On the exhaustion of supply 5,000 feet of pipe line was laid from the mouth of the slope. The line was fed from two large tanks outside and gave a pressure of 100 pounds at the fire. The fire began to cause bad falls of the sandy shale roof. After the fire had been fought six days, five apparatus men, including a Bureau of Mines engineer, explored the fire area. It was decided to seal the fire.

SEALING THE FIRE

Construction of 16 seals on the low or intake side of the fire (fig. 21) took two days. A temporary canvas stopping was placed at the entrance of each opening, and the permanent seal was built a few feet out by the canvas. No apparatus was needed, but only picked men were used, as the heat and smoke were trying.

Two days later three canvas stoppings were started on the high side, the return side from the fire area. A fresh-air base was established on the sixth west air course, and the stoppings were placed in by this point in three open crosscuts between the sixth west entry and air course. The ventilating current was increased and the fresh-air base was advanced to within 150 feet of where old room 3 off the seventh west entry had been driven through to the sixth west air course. Stopping 17 was then built; nine apparatus men took 12 hours to clean out rock and débris for the stopping.

Next the men put up canvas curtains at the three remaining open crosscuts between the sixth west air course and entry, thereby forcing the air directly out of this air course into the plane or slope. Then the curtains at the last two crosscuts had to be removed, and the gases and smoke traveled out, as planned.

After 10 hours of hard work the apparatus men, working 20-minute periods, cleared a place for stopping 18, which was finally built by eight men in 8 hours on the following day. This left one large opening on the plane, where stopping 24 is shown, but as the gases in the fire area were exerting considerable pressure on the stoppings then erected, that opening was left for the time. Four days later a stopping of boards and canvas was constructed at the fresh-air base.
and carried to and placed in the plane at a point where the cross section was 14 by 6 feet. A 4 by 6 foot hole was left in the stopping for the escape of the heated gases. The temperature inside was 146° F. Twenty-eight days later, when the temperature inside was 112°, the hole was entirely closed. Several months later the temperature was only 80° F.

REMARKS

In all, a total of 24 stopings was built in the order given in Figure 21. Two-inch gate valves for sampling were placed in stoppings 3, 11, and 17. This fire was in what were practically old workings, and the area (2,000 feet around) was entirely surrounded by stoppings, some of which were at places difficult to reach. All of the old adjacent workings were carefully and regularly tested for methane, the ventilation was so arranged that it did not traverse old workings, and the apparatus men were never more than 100 to 200 feet from the fresh-air base where six or seven men were in reserve. The authors of this paper criticize, however, the leaving of stopping 24 unfinished for a while, since the prompt sealing of this exit would have completed the sealing of the area.

24. DRILL HOLE FREES FLOODED AREA OF GASES

ORIGIN OF FIRE

The origin of one mine fire is supposed to have been contact of an electric cable with a sulphur band in the coal bed. The fire started when current was switched on after being off two or three days. Two oil barrels near the supposed origin probably spread the fire. Although smoke was smelled early in the day no efforts were made to locate the fire until five hours later. The fire gained on the men, as they were inexperienced in fighting fires, and the mine was sealed about three days later. Bureau of Mines engineers arrived on the sixth day. No lives were lost.

MINING CONDITIONS

The coal bed in this mine is 5 feet thick and is separated from another bed 2 to 4 feet thick by 4 to 8 feet of fire clay, which falls in places. Several oil wells, one of which was 500 feet from the origin of the fire, penetrate the workings. The wells were reported by the State mine inspector to be thoroughly sealed from the mine. Open lights were used, although some methane was liberated which usually was detected only at the face of an entry. A 14-foot reversible fan, running as a blower, effected ventilation. About 100,000 cubic feet of air per minute entered the mine and 8,000 cubic feet reached the face.
Development and mining were through a two-compartment hoisting shaft and an air shaft, 1,000 feet apart and 180 feet deep. Water was pumped to the surface through a drill hole. The room-and-pillar system was used; when the rooms were driven the roof was allowed to fall and that area was abandoned.

**FIRE-FIGHTING METHODS**

The fire started in a pillar at a point having an elevation almost 50 feet above the bottom of the shaft and 3,700 feet from it, one of the highest points in the mine. To flood the fire without drilling a hole to allow the air to escape was impossible. A drill hole 120 feet deep, 3,700 feet from the main shaft, was completed on the sixteenth day. It was cased with 6-inch pipe to within 59 feet of the bottom. On the surface the casing was reduced to 4 inches and was fitted with a gate valve to permit temperature determinations and gas sampling. The seals over the main and air shafts each had a pipe for sampling the mine air.

**COMPOSITION AND TEMPERATURE OF ATMOSPHERE IN FIRE AREA**

From the sixteenth day samples were taken and temperatures read. The table gives some analyses of the mine atmosphere.

*Analyses of atmosphere in a sealed mine*

**AT TOP OF DRILL HOLE**

<table>
<thead>
<tr>
<th>Days after outbreak</th>
<th>CO₂</th>
<th>O₂</th>
<th>CO</th>
<th>CH₄</th>
<th>N₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per cent</td>
<td>Per cent</td>
<td>Per cent</td>
<td>Per cent</td>
<td>Per cent</td>
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<tr>
<td>17</td>
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<td>0.2</td>
<td>3.1</td>
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<tr>
<td>49</td>
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<td>0.2</td>
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<tr>
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<td>11.26</td>
<td>80.25</td>
<td></td>
</tr>
<tr>
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<td>5.78</td>
<td>0.48</td>
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<td></td>
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<tr>
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<td>5.86</td>
<td>0.60</td>
<td>12.76</td>
<td>80.78</td>
<td></td>
</tr>
</tbody>
</table>

**AT TOP OF HOISTING SHAFT**

<table>
<thead>
<tr>
<th>Days</th>
<th>CO₂</th>
<th>O₂</th>
<th>CO</th>
<th>CH₄</th>
<th>N₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>4.6</td>
<td>10.0</td>
<td>2.6</td>
<td>82.80</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>2.3</td>
<td>14.0</td>
<td>1.8</td>
<td>81.90</td>
<td></td>
</tr>
<tr>
<td>86</td>
<td>3.28</td>
<td>10.0</td>
<td>16.27</td>
<td>70.39</td>
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</tr>
</tbody>
</table>

**AT TOP OF AIR SHAFT**

<table>
<thead>
<tr>
<th>Days</th>
<th>CO₂</th>
<th>O₂</th>
<th>CO</th>
<th>CH₄</th>
<th>N₂</th>
</tr>
</thead>
<tbody>
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<td>24</td>
<td>4.1</td>
<td>9.9</td>
<td>2.5</td>
<td>83.5</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>2.0</td>
<td>14.6</td>
<td>1.8</td>
<td>81.6</td>
<td></td>
</tr>
</tbody>
</table>

The high oxygen content of the atmosphere in the shafts on the forty-ninth day was caused by a leak in the shaft coverings that permitted circulation between the shafts. This leak was stopped. Temperatures in the mine were determined with a maximum and minimum thermometer that was lowered through the borehole. On
the twenty-fourth day the temperature was 83° F, on the forty-ninth 70°, and on the seventh-eighth 67°. Water, which was run in at irregular periods, had been turned down the hole on the seventy-third day, and reduced the temperature considerably. The normal temperature of the mine was about 58° F.

On the two hundred and eighteenth day after the fire started the mine was unwatered. Temperatures in the mine when it was examined were 73 to 75° F. No explosive or asphyxiating gases were found 21 days later.

![Diagram of mine](image)

**Figure 22.**—Part of mine affected by fire, fire 25

### 25. OBSTINATE FIRE THAT CAUSED EXPLOSIONS

In a mine that made considerable gas and was producing 3,600 tons of coal daily from a 12-foot bed at a depth of 505 feet a fire broke out at the door in the crosscut between the first and third west C entries, opposite room 17. (Fig. 22.) A short-circuited trolley line is supposed to have started the fire, which caused the mine to be idle for 22 months, originated two explosions, and resulted in the death of 31 men. Recovery work lasted 46 days. The hazards met and the methods used to fight the fire are described below.
When discovered the fire had been burning about one and one-half hours. The air was going up the second west C south entry and returning through the third west C south entry. A rescue squad that entered the mine two hours later found that the fire had got to the neck of room 12. In two and one-half hours a stopping was built at the entrance of the second west C south entry. An hour later the flame was traveling along the third west C south and setting fire to the overcast across the south cut-off at the point H, Figure 22. The seven men in the mine reached the surface in safety, and by 10 o'clock the following morning both shafts were sealed.

Several attempts were made to extinguish the fire from the surface. A borehole was sunk to the crosscut across the south cut-off near the overcast at H, and water was pumped into the mine for five or six days. Then 31,222 pounds of sulphur was burned in a specially constructed furnace, and the sulphur dioxide gas generated was forced down the air shaft and borehole by means of a blower. Finally, steam under an initial pressure of 100 to 150 pounds was turned into the mine for five days through the borehole.

Meanwhile eight sets of oxygen-breathing apparatus (helmet type) were purchased. (This fire occurred before self-contained breathing apparatus had been developed to their present efficiency and before there were rescue crews trained by the Bureau of Mines.) Shortly after the steam was introduced a negro wearing one of the sets was sent alone into the mine to reconnoiter. He died. It was reported that the potash cartridges in the apparatus he wore were caked from previous use (there were no fresh cartridges on hand), and when his breathing grew difficult he became frightened and pulled off the apparatus.

**FIRST EXPLOSION**

Fifty-eight days after the mine was sealed the hoisting and air shafts were unsealed and the fan was started as an exhaust. Men entered by the hoisting (downcast) shaft and hung curtains across the first and third west C south entries and all the north workings but left the second west C south entry open. The work of establishing ventilation and cleaning up the mine was successful until the men reached a point where the double parting that connects the first west C south and the first west C north narrows down to a single entry, as shown by K in Figure 22. Fresh air coming from the first west C north passed through this point, thence to the first west C south, and returned through the third west C south. The upper end of each of these west C south entries was filled with methane, and when this was carried over the region where the fire had previously raged an ex-
explosion killed 26 men and wrecked the mine. The explosion was at midnight on the sixty-seventh day.

Two miners were brought out alive, and it is said that if there had been cartridges for the breathing apparatus 11 others might have been recovered. The rescuers were close enough to the injured men to hear their groans, but could not reach them on account of asphyxiating gases. Forty hours later black smoke issued from the air shaft. Both shafts were sealed immediately.

Nineteen days later an air lock was built above the manway compartment of the air shaft and apparatus men entered the mine to curtain off the first, second, and third west C south entries and all north workings, as the explosion had blown down the curtains previously erected. During this work one man wearing apparatus lost his life. Men who were with him said that the pneumatic cushion of his helmet apparatus was so inflated that it made his jaws ache, and he opened the valve of the cushion for relief. If he did so, gases could have entered the helmet. There was some doubt, however, in regard to his previous physical condition. He was said to have been under the doctor's care for heart trouble.

SECOND EXPLOSION

Ten days later the fan was started as an exhaust, thus making the hoisting shaft a downcast. Men entered the hoisting shaft and built board and plaster stoppings across the north side of the shaft bottom and across the west air course immediately north of the first southwest crosscut; they also hung a curtain on the C entry just north of the same crosscut, deflecting the air south on the C entry. On the next day, two hours after this curtain was hung, three men who had advanced down the C entry to the first west C south claimed they saw fire ignite gas ahead of them on the C entry. The explosion killed three men at the shaft bottom, but the three men who said they saw the fire reached the surface, as did five men who were on the C entry at the first southwest crosscut and three men who were plastering the stopping on the west air course. The same afternoon both shafts were sealed again.

RECOVERY WORK

After 15 months another attempt at recovery was successful in 46 days without accident. Three shifts, each with eight men and a boss, did the work. At the company's invitation, two engineers of the technologic branch of the United States Geological Survey, later the Bureau of Mines, arrived with rescue equipment.
Experience after the first explosion had shown that if the mine bottom could be ventilated and all the falls loaded out complete recovery of the mine would be assured. The following detailed account of the recovery of the 23 acres forming the mine bottom is divided into four periods, for the sake of clearness:

*First period, 26 days.*—The seal over the hoisting shaft was removed, and a 5-foot small temporary fan was installed and connected with the air lock over the manway compartment of the shaft by a wooden conduit. The fan was started as a blower on the second day. Men working on top of the manway cage built a partition from the surface to the shaft bottom, which carried the air down the manway compartment and returned it up the skipways.

![Diagram](image)

**Figure 23.—Plan of north bottom at hoisting shaft, first period of recovery, fire 25**

A heavy fall of top coal and rock, beginning 50 feet north of the shaft, completely blocked the entry; a board and plaster stopping marked 1 in Figure 23 was built in front of it.

As these falls blocked progress north and south of the main bottom, to bring in fresh air a wooden tunnel (6 feet high, 4 feet wide, and 230 feet long) was built south from the shaft along the west side of the main bottom to the first crosscut leading west and through this crosscut to the west air course. The sides and top of this tunnel were 1 by 6 inch pine flooring, covered with wood-fiber plaster on the inside. Board-and-plaster stopping 4 was built in the west air course. A temporary brattice was hung from the end of the tunnel to the C entry to permit board-and-plaster stopping 5 being built on the C entry.

The south leg of this tunnel was then joined to the northwest rib at the intersection of the west air course and the first southwest crosscut. The intake air went north along the west air course, and
the return went through the C entry to and through the southwest crosscut, on the outside of the wooden tunnel to the shaft bottom, and thence out the skipways.

Board-and-plaster stoppings 15 and 20 were built as shown in Figure 23, then stopping I was removed and the fall immediately north of the shaft was cleared up. This fall contained 490 tons of roof coal and rock, which was hoisted in the skips and loaded into railroad cars under the tipple.

Second period, 18 days.—Stoppings 2 and 13 were removed, a curtain brattice was hung across the entrance to the wooden tunnel, and board-and-plaster stopping 21 (fig. 24) was built. This arrangement changed the ventilation; the fresh air passed directly north from the manway compartment of the hoisting shaft to the east side of the mine, and returned through the first southeast crosscut. Under this arrangement stoppings 22 to 55 were successfully built.

A body of water along the A south entry near stoppings 35 to 41 (fig. 25) was removed in three days by three 2-inch siphons; a second near stopping 52 was removed in 39 hours by a compressed-air pump with 4-inch suction and 3-inch discharge.

Removal of the methane proved difficult. The temporary ventilating machinery did not furnish more than 5,000 cubic feet of air per minute, and as the cross sections of the entries were 100 to 150 square feet the velocity of the air was low. Each afternoon when the barometer fell the gas tended to back on the men and often prevented their advance unless they wore oxygen breathing apparatus. On the fifteenth day of this second period the pump was taken down the hoisting shaft and installed 20 feet west of stopping 51, Figure 25.

Apparatus men inspected the bottom of the air shaft before stopping 31 was erected, hung curtain brattices on the A south entries so that plaster stoppings 49 and 50 could be built, and did other work impossible without apparatus.
Figure 25.—Sketch of fire zone, showing stoppings and conditions, fire 25
Six out of the eight sets of apparatus bought by the company 16 months prior to the fire could not be used because of deterioration. The reader should remember, however, that the older (helmet) apparatus then in use was not up to the mark of modern apparatus, and the helmet type of apparatus has been discarded.

Third period, 2 days.—An old stopping in the crosscut between board-and-plaster stoppings 26 and 27 was made tight with a canvas curtain, two old doors on the northeast crosscut were closed, the curtain closing the entrance to the wooden tunnel was taken down, and half of stopping 6 was removed. (See fig. 25.) This arrangement took the air directly to the C entry and returned it through the southwest crosscut on the outside of the wooden tunnel to the skip ways. Stopping 5 was then removed, and a canvas brattice was built through the center of the C entry beginning at the northeast rib of the intersection of the southwest crosscut and the C entry, and extending south as far as the third west C south entry. This permitted the building of board-and-plaster stoppings 56, 57, and 58. Figure 25 shows that these stoppings, 58 in all, completely separated an area at the shaft bottom from the inside workings of the mine.

The two old doors in the northeast crosscut were opened, the canvas brattice closing the crosscut between stoppings 26 and 27 was torn down, stopping 6 was repaired, stopping 21 was removed, part of the wooden tunnel was torn down, and a board-and-plaster stopping was built across the southwest crosscut between B entry and the west air course; stopping 2 was closed, and a regulator was made in stopping 4. Then the 18-foot diameter fan at the air shaft was started as an exhaust, furnishing 27,000 cubic feet of air per minute on the west split in the mine and 45,000 cubic feet on the east split. The next day the men began to clean up the area thus ventilated.

COMPOSITION OF MINE ATMOSPHERE

Table 6 shows the composition of the atmosphere in the air shaft during the recovery of the mine bottom. The samples were taken through a short pipe provided with a gate valve and were analyzed with a portable Orsat apparatus having a combustion pipette for the determination of methane.

Table 6.—Analyses of atmosphere in air shaft during 46 days

<table>
<thead>
<tr>
<th>Number</th>
<th>Day</th>
<th>CO₂</th>
<th>O₂</th>
<th>CO</th>
<th>CH₄</th>
<th>N₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Per cent</td>
<td>Per cent</td>
<td>Per cent</td>
<td>Per cent</td>
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</tr>
<tr>
<td>1</td>
<td>1</td>
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<td>75.8</td>
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<tr>
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<td>9</td>
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<td>0.2</td>
<td>18.0</td>
<td>75.0</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>3.5</td>
<td>3.5</td>
<td>0.1</td>
<td>16.9</td>
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</tr>
<tr>
<td>4</td>
<td>11</td>
<td>3.8</td>
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<td>0.1</td>
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</tr>
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<td>5</td>
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<td>59.3</td>
</tr>
<tr>
<td>6</td>
<td>28</td>
<td>3.3</td>
<td>8.5</td>
<td>0.2</td>
<td>8.5</td>
<td>75.9</td>
</tr>
<tr>
<td>7</td>
<td>45</td>
<td>3.4</td>
<td>6.2</td>
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<td>13.0</td>
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<tr>
<td>Normal fresh air</td>
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<td>0</td>
<td>21.0</td>
<td>0</td>
<td>0</td>
<td>79.0</td>
</tr>
</tbody>
</table>
Sample 1, taken before the seal of the hoisting shaft was broken, contained not a trace of oxygen, which indicates that any oxygen that may have remained after the explosions was consumed by the fire or absorbed by the coal. Sample 7 was taken just before the air shaft seal was broken in making ready to start the large fan. It is noteworthy that the atmosphere in the air shaft during the 45 days of recovery work at the shaft bottom contained too much methane to be explosive.

USE OF SAFETY LAMPS IN RECOVERY WORK

With all the development work about the shaft bottoms inclosed and ventilated the recovery of the remainder of the mine proceeded systematically and cautiously; the original fire had died out. This recovery work was done before the Bureau of Mines had been established—at a time when there was no official testing of safety lamps and miners' electric lamps.

To be able to test for gas the boss of each shift carried an oil-burning and also a naphtha safety lamp. His eight men carried incandescent electric lamps, with tungsten filaments, which gave more light; they were fitted for attachment to a miner’s cap and were connected by a two-wire insulated cable with a battery carried in the hip pocket. The makers claimed that the lamps could be used in the presence of explosive gases with absolute safety. Nevertheless, because it was feared that a spark that would ignite methane might be caused by making or breaking the circuit, all miners were forbidden to turn an electric light off or on while in the mine.

REMARKS

All electric wiring should be installed properly and inspected frequently.

Oxygen breathing apparatus should be tested often enough to insure its being in perfect condition when needed. Rubber tubes deteriorate, and the potash absorbent is liable to cake.

Electric current should not be switched onto wires leading into a mine in which gas is standing.

System is essential in all recovery and rescue work.

FIRES CAUSED BY OPEN FLAMES IGNITING GAS

The three fires cited under this heading show the danger of open-flame lamps in gassy mines. In two of the mines the ignition of gas merely set fire to the coal, but in the third it caused a serious explosion. Falls of roof forced the gas onto the open flames.
The accounts of two of the fires emphasize the difficulty and danger of fighting fire in gassy mines and show the necessity of providing breathing apparatus and training men in its use.

Open lights should not be permitted in old workings or where gas is known to be present, and the Bureau of Mines recommends that only permissible electric lamps be used for illumination and permissible flame lamps for testing in all coal mines.

26. APPARATUS MEN KILLED

In a coal mine an undercutting machine at 2.30 p. m. one day cut a gas feeder in room 13 off No. 8 right butt entry (fig. 26), and the open lights of the two machine men ignited the gas. There was no explosion, but the coal was set on fire.

![Figure 26.—Details of fire area, fire 26](image)

SEALING THE FIRE

The fire was fought promptly, but there was no water line near it; however, by 5 p. m. the men could approach within 10 or 15 feet of the fire, which had gained a little headway. Sealing off the fire started at 8 p. m., after some delay caused by the cement and water having to be brought a considerable distance. The bulkheads were erected in the order indicated in Figure 26. At 2 p. m. the following day a fall of roof in room 13 forced smoke as far as room 5.

This fall alarmed the management, and it asked the Bureau of Mines to assist. Four bureau engineers with seven sets of apparatus arrived at the mine in about two hours. The fifth bulkhead had been completed just before their arrival. The bulkheads were built of brick and set in a 1 to 3 cement-sand mixture. For sampling purposes and for the escape of gases as pressure developed inside two 2-inch pipes fitted with flap-top valves were set in No. 5 bulkhead, near the middle, one 1 foot below the roof and the other 2 feet above
the floor. Emergency and air-regulating doors 6, 7, and 8, and stopping 9 with sliding doors were also erected. The sealing was thoroughly done; all seals were tight and remained so for 66 days. Analyses of samples of the atmosphere inside the bulkheads were as follows:

*Analyses of air behind bulkheads*

<table>
<thead>
<tr>
<th>Days after sealing</th>
<th>CO₂</th>
<th>O₂</th>
<th>CO</th>
<th>CH₄</th>
<th>N₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per cent</td>
<td>Per cent</td>
<td>Per cent</td>
<td>Per cent</td>
<td>Per cent</td>
</tr>
<tr>
<td>6</td>
<td>5.87</td>
<td>1.43</td>
<td>1.42</td>
<td>22.27</td>
<td>69.01</td>
</tr>
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<td>3.9</td>
<td>1.9</td>
<td>.2</td>
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</tr>
</tbody>
</table>

The table shows that the content of CO was persistently high for the first 12 days and that the content of CH₄ gradually increased.

**Opening the Sealed Area**

On the sixty-sixth day the Bureau of Mines, by request, assisted in reopening the mine, as no trained men were employed there. The fire occurred before the rescue organization of the bureau had been established. An opening large enough to admit a man wearing apparatus was made in No. 5 stopping. The leader of the party and one other man entered through the brick wall at 11:55 a.m. to advance 215 feet to the room in which the fire originated. The leader directed that if the two did not return in 35 minutes the men on the outside should send in help. After they had been in five minutes the assistant wished to return to fresh air, and the leader said that he would return with him. The assistant started in advance at a fast walk and ran the latter part of the way to the hole in the stopping. Two of the other engineers entered to find the leader, but were partly overcome while searching and had to retreat. (At the time of this fire self-contained breathing apparatus had not reached their present efficiency.)

Three more engineers with apparatus arrived at 5 p.m. It was suggested that the stoppings be opened to direct the fresh air by the shortest possible route to where the leader was supposed to be lost. Before this was done a safety lamp showed the presence of methane which might be carried to the fire, so the gas was being removed by ventilation.

The three engineers, with some of the mine officials, went into the mine at about 1 a.m. and broke through the stopping. A close watch was kept on the return air from this area to control the gas, as it moved out and diffused, within safe proportions. At about 4 a.m. the fire boss started in with the intake air current; he was accom-
panied by two or three other men without breathing apparatus and two engineers with breathing apparatus. The first party found the leader’s body at the place indicated in Figure 26, and it was taken out about 5.10 a.m.; his apparatus, the cooler of which was cracked, was sent to the surface for examination.

**CAUSE OF DEATH OF APPARATUS MAN**

The leader had carried two electric lamps, one a flash lamp. It would seem that the leader may have lost sight of his assistant, who returned in the dark, and thought that he had got lost in one of the rooms. It was reported that shortly after the assistant reached fresh air three taps were heard on the electric wire inside the stopping. These taps may have indicated that the leader was signaling distress; he evidently walked to the end of room 6, a distance of 200 feet from the entry, where there was a loaded mine car and at one side of it a wall of gob. To pass through the space between the car and the wall would have been hard for a man wearing apparatus; and some obstruction probably caught the apparatus, opening the circulating system and admitting the mine air.

This man had been thoroughly trained in the use of breathing apparatus, had had much experience in exploring mines after explosions, and was familiar with the rules and regulations concerning explorations in atmospheres containing noxious gases. If the apparatus he wore had the same defect at the time the assistant left him as it had when found on him, he could not have walked to where his body was found. He had no cause to explore room 6, except to look for the assistant.

Before the leader entered the noxious gases he had familiarized himself with the plan of that part of the mine and had explained that the first exploration would be to go to room 13, 215 feet from the brick wall, to see if the fire was out.

At the inquest, the coroner’s jury found that the leader died from asphyxiation by gas, that the accident was due to his failing to obey instructions given by the Bureau of Mines, and that the apparatus was defective. The jury recommended that the air cells (air cooler) be so placed on the apparatus that the apparatus would not become defective from a jar or blow; and that no person not thoroughly instructed be permitted to wear apparatus in dangerous gases.

**CONDITION OF APPARATUS USED**

Investigation of the apparatus worn by the leader showed that the top seam of the cooler had opened, admitting mine gases into the circulating system. When the crack was repaired, the apparatus was worn without danger. The assistant was overcome so soon because
the tube leading from the breathing bag to the reducing valve was not screwed tight near the valve and oxygen escaped.

REMARKS

Every mine should have rescue apparatus and at least 10 men trained in its use and able to render first aid, or else have a joint rescue station within ready reach.

Instructions on the use and care of breathing apparatus and on the organization of rescue and recovery work are given in handbooks issued by the Bureau of Mines.

This accident caused the Bureau of Mines to effect improvements in oxygen breathing apparatus and to make recommendations for the organization of rescue and fire-fighting crews using apparatus.

27. FALL OF COAL FORCES GAS ON OPEN LIGHTS

ORIGIN OF FIRE

A heavy fall of roof at 9 o'clock one night forced some gas onto the open lights of some miners who were drawing pillars. The ignited gas burned 2 of the miners severely, but 36 others escaped unhurt. Several hours later in that part of the mine the foreman found a hot fire which the men were unable to control. A crew of six apparatus men, called from a mine about 30 miles distant, arrived two days later with three oxygen breathing apparatus (helmet type of 1907) and a fresh-air apparatus. They bratticed off the section of the mine in which the fire was burning and spent that day and half of the next in the work.

At 1.30 p. m. on the third day after the fire started, when almost the entire fire area had been bratticed and 21 men were inside the mine, an explosion partly destroyed many of the newly erected brattices and threw many of the men about. All, however, escaped to the shaft bottom and were hoisted to the surface. As some of the men were slow in reaching the top, the Bureau of Mines was requested by telephone to send a rescue crew at once. A corps of four arrived by autotruck at 4.05 p. m. Meanwhile, after all the men were out of the mine, a second violent explosion occurred. The management decided to run no further risk, but to seal the mine at the top of the shaft and allow it to remain sealed for one year.

TESTS OF INCLOSED AIR

In order to determine from time to time the composition of the mine atmosphere the company put down a borehole close to where the fire had started, and kept the top of this hole plugged except
when air samples were collected for analysis. Preparations were made to reopen the mine when the samples analyzed by the company's chemist during the tenth month showed that there was virtually no oxygen in the atmosphere surrounding the fire area. The Bureau of Mines then was requested to take air samples at the borehole to check the company analyses, as the management wished to reopen the shafts. Two samples taken that day contained 3.16 and 3.31 per cent carbon dioxide, 1.69 and 0.03 per cent oxygen, 0.16 per cent and a trace of carbon monoxide, and 21.14 and 21.42 per cent methane, respectively; they indicated that there was probably no fire in that section of the mine. Samples obtained a month later underground, inside the fire area, checked closely with the samples obtained on the surface at the borehole.

REOPENING THE MINE

The hoisting shaft and fan shaft were unsealed just 11 months after the fire had started. Twenty feet of water in the hoisting shaft (210 feet deep) was removed by means of water boxes on both cages and by the mine pump. This water had effectively prevented any air entering the mine through the hoisting shaft.

The fan was started slowly as an exhaust, making the hoisting shaft the intake. The main entry was cleaned up for 900 feet, the fire area was sealed by double brattices, and the air current was short-circuiting from one shaft to the other.

Twenty-six days later the management asked the bureau to assist again in exploring the fire area. A crew of seven men, including a gas analyst, went to the mine by autotruck, carrying 12 oxygen breathing apparatus, a portable Orsat gas-analysis apparatus, canaries, and safety lamps. The foreman and another man were given apparatus and acted as reserves. Then the party, with apparatus on, was lowered into the mine and advanced 900 feet to a double-door air lock, which was the fresh-air base outside the fire area. Three men wearing apparatus advanced through the air lock and 1,000 feet to a turn in the haulage road, while three others, also wearing apparatus, remained at the fresh-air base. No heat, smoke, or fire was detected.

Although a canary had not shown any distress, a flame safety lamp was extinguished. Two samples of the atmosphere gave the following analyses: Carbon dioxide, 2.6 and 2.5 per cent; carbon monoxide, traces; oxygen, 7.4 and 6 per cent; and methane, 14.6 and 16.6 per cent.

It was then decided to explore to the origin of the fire, which was 2,600 feet from the fresh-air base. Three apparatus men remained as a reserve, and four apparatus men went through the air lock and
over the same route as before. When they turned up the room to the right off the haulage road a change in the atmosphere was indicated by the canary falling from its perch. The men carried the canary back to the entry in the hope it would revive, then advanced up the room on the haulage road and into the parallel entry for a total distance of 1,000 feet from where the canary had been overcome; there they found water 18 inches deep and a wooden door across the entry. This door had been undisturbed by the explosion a year before. The air and water both seemed cool and no smoke was detected. A short distance beyond the door, which was pushed open after some effort, the party found heavy falls, and further advance was not deemed wise.

The crew now returned to and entered room 4 as the fire had started in room 11 on the same entry. The absence of all heat or smoke was almost certain evidence that no fire existed. Two samples of air were taken in room 4, and the men returned the 1,000 feet to where they had left the canary. They found it had revived considerably. The men then returned to the fresh-air base. They had been gone 35 minutes and had traveled a total distance of 4,000 feet in an asphyxiating atmosphere. The coal was 6 feet high.

The two samples taken in room 4 showed 3.3 and 2.5 per cent carbon dioxide, 2 and 6.8 per cent oxygen, traces of carbon monoxide, and 20.2 and 14.6 per cent methane.

**REMARKS**

A fire area may be examined successfully by men wearing apparatus.

A flame safety lamp should always be carried to check the oxygen content of the mine air.

A portable gas-analysis apparatus is invaluable in explorations after a fire.

To put down a borehole to a fire area often allows valuable information to be obtained.

All sealed fires should be kept sealed until conditions or analyses indicate that they are out or active combustion has ceased; even then a bed of hot coals may still be glowing, so reopening should be done with care.

**28. THREE EXPLOSIONS DURING THE SEALING OF A FIRE**

**MINING CONDITIONS**

The coal bed in this mine was 7 feet thick and lay between a roof of light-colored shale containing many “niggerheads” and a floor of carbonaceous shale underlain by hard clay. The two-compartment
shaft was 420 feet deep. Development was by a modified panel, room-and-pillar system. (Fig. 27.) The mine as a whole was dusty. Coal was undercut by shortwall machines. All haulage was by electric trolley locomotives. The coal was shot with permissible explosives set off by fuse and No. 6 detonators. Shots were fired by the miners just before they left for the day.

Various parts of the mine gave off gas freely, yet the miners used carbide lamps. Fire bosses carried flame safety lamps. The shaft bottom and main haulage roads were electrically lighted. An old-type fan, reversible but running as a blower and moving 60,000 cubic feet of air per minute, was in use, but a new fan with a capacity of 200,000 cubic feet had been purchased at the time of the disaster. No special fire-fighting equipment was maintained underground, although pipe lines laid in the east and west sections for pumping could be utilized.

Although the company had maintained a first-aid team at the mine, it had no rescue apparatus, so none was available until a State rescue crew and a Bureau of Mines rescue car arrived.

EXPLOSION AND FIRE—SEALING THE MINE

Heavy falls of roof in rooms 4, 5, and 6, third main south, pushed out an accumulation of gas which was ignited by two men with open lights when they passed room 6. The resulting explosion killed 4 men and burned 22 others. At the instant of the explosion the flame shot to the right up the main east entry, to the left down the main west entry, and straight ahead to the main north and the shaft bottom; catching 26 men in its path. All rescue work was completed within six hours.

About 20 hours after the explosion fire was discovered in room 4 at the point $\times$, and gas was found at the edge of falls in rooms 4, 5, 6, 7, and 8. (Fig. 27.) It was decided to seal off the fire area at the points $A$, $B$, $C$, and $D$. This was done about 18 hours later. About 17 hours afterwards a second explosion blew down brattices, including those between the main and air shafts.

The shafts were sealed 33 hours after the second explosion, but 56½ hours afterwards a third explosion blew off part of the seal at the main shaft. This seal was repaired within the next two days. A borehole drilled to flood the fire area became so clogged in a few days that it was not of much value.

REOPENING THE MINE

The mine remained sealed for 27 days. During this time and for several days afterwards the air within was sampled and analyzed regularly. Figure 28 shows the results of analyses. Meanwhile
preparations were made to carry on recovery as quickly as possible with due regard to safety. Crews were trained in the use of breathing apparatus and in building stoppings under mine conditions. It was planned to close off the fire area in the main south before restoring ventilation.

On the twenty-seventh day the seals at the shafts were removed and a crew entered the mine. On the next day, as smoke showed near the original fire, both shafts were sealed for another 10 days.
Because of caves in the fire area the exact position of the fire could not be determined, and control of ventilation was impossible because any movement of the air would carry explosive gases over the fire. It was important not to interrupt the ventilation until the area could be closed, although there was practically no ventilation directly past the fire, except that naturally induced by the fire. An explosive mixture of air and gas was known to exist near the fire 16 hours before the first sealing was done.

Additional trained men were procured from another State rescue team and from two other districts, and through their efforts within six days the fire was successfully resealed at A, B, C, and D, and the ventilation restored in other parts of the mine.

REMARKS

Open lights should not be permitted in the vicinity of old workings that contain gas, and only approved flame and electric safety lamps should be carried.

When men are allowed to return to work after a fire area has been sealed, the danger of an explosion should be considered until analyses of the atmosphere behind the seals show so low a content of oxygen that there is no danger of an explosive mixture forming.

The recovery work at this mine demonstrated the great value of breathing apparatus for explorations and for erecting stoppages ahead of ventilation. In fact the work could not have been done without apparatus. Well-trained rescue crews are an asset at any coal mine.

FIRES CAUSED BY OPEN-FLAME LAMPS IGNITING INFLAMMABLE STRUCTURES

Conflagrations started by open lights igniting inflammable material need little introductory comment. Experience has shown that the penalties of carelessness may be terrible. Use of approved lights eliminates many dangers.

29. SEALING AN INACCESSIBLE FIRE

Water from a hose played on a fire in a large anthracite mine extinguished the flames, but a heavy fall of roof that filled the entry kept the fire from being put out completely. The fire gained headway and soon filled the workings with smoke strongly charged with sulphur fumes that probably came from burning roof coal. Water for the hose was supplied by an underground pump. Oxygen breath-
ing apparatus were worn by the men while starting the pump, during the sealing of the fire, and in the subsequent investigation.

FIRE-FIGHTING METHODS

The fire is supposed to have started in a driver’s shanty in a slant crosscut near rooms 29 and 30, second east gangway. Water was played on it in the main left and in rooms 28, 29, and 30. About 28 hours after the fire started examination showed the fire was burning strongly at 130 feet up the room. As strenuous efforts had been made to fight the fire in dense smoke, the mine officials decided to seal the area with stoppings.

Stoppings 1, 2, 4, and 5 were of brick and 3 was of wood; stopping 1 was completed and 2 was almost completed when smoke drove out the men. Evidently a fall kept the air from returning through room 32. The fourth left entry filled with smoke, the fan stopped when a crank pin became loose, and consequently the men had to leave the mine. The door of the main slope below the fourth left was opened, which prevented the smoke from following down the slope. After the fan had started the smoke kept the men from getting into the fourth left entry. After the fan was stopped and started again, small explosions were heard in quick succession. It was then decided to close off all of the left side of the main slope from the fourth left to the head of the slope. Wooden brattices were placed at 13 different points, and brick stoppings were erected on the outside of these brattices. During the work on these stoppings the gases in the smoke overcame four men, who soon recovered when taken to fresh air.

GAS SAMPLES AND TEMPERATURE READINGS

A 2½-inch pipe with a gate valve on the outside was put through the brick stopping on the fourth left to permit sampling of the air within and determination of temperature. Between the valve and the brick stopping a pipe was inserted that extended into a barrel containing water and made a water seal which permitted the release of pressure from the inside and prevented the inflow of fresh air. For taking air samples and determining temperatures a maximum-and-minimum thermometer, put on the end of a glass tube 5 feet long, was inserted through the pipe, which was closed with a rubber gasket. Gases were drawn into the glass tube by means of an aspirator on the projecting end, then a small tube filled with water was connected to the aspirator and a sample of the atmosphere was obtained by displacement. Below are some temperature readings.

50769°—27—7
### Temperatures in the sealed area

<table>
<thead>
<tr>
<th>Days after sealing</th>
<th>Inside, °F.</th>
<th>Outside, °F.</th>
<th>Days after sealing</th>
<th>Inside, °F.</th>
<th>Outside, °F.</th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>65</td>
<td>45</td>
<td>10.</td>
<td>57</td>
<td>46</td>
</tr>
<tr>
<td>2.</td>
<td>61</td>
<td>43</td>
<td>11.</td>
<td>57</td>
<td>46</td>
</tr>
<tr>
<td>3.</td>
<td>58</td>
<td>43</td>
<td>12.</td>
<td>58</td>
<td>44</td>
</tr>
<tr>
<td>4.</td>
<td>56</td>
<td>43</td>
<td>13.</td>
<td>59</td>
<td>50</td>
</tr>
<tr>
<td>5.</td>
<td>56</td>
<td>45</td>
<td>14.</td>
<td>56</td>
<td>48</td>
</tr>
<tr>
<td>8.</td>
<td>55</td>
<td>48</td>
<td>15.</td>
<td>55</td>
<td>51</td>
</tr>
</tbody>
</table>

Samples of air on the fourteenth and fifteenth days showed carbon dioxide, 2.7 and 2.6 per cent; carbon monoxide, 0.2 and 2.1 per cent; oxygen, 1.4 and 8.2 per cent; and methane, 2.2 and 1.6 per cent, respectively.

While air locks were being constructed for the purpose of investigating the fire area, air entered the workings, and on the seventeenth day the oxygen content of the mine atmosphere had risen to 12.3 per cent, the carbon dioxide content was 1.7 per cent, and the methane content 1.3 per cent.

Ten months later men wearing breathing apparatus entered the sealed area and found the fire out.

### 30. Sealing and Smothering a Fire

**Origin of Fire**

A fire in an anthracite mine was not discovered for 24 hours because the fire boss on a Sunday morning failed to inspect four working places in a certain section. (Fig. 29.) An open light is supposed to have ignited timber while men were "tracking" a derailed mine car on Saturday evening. The mine was gassy, but open lights were used in that section and locked safety lamps elsewhere. At the point of derailment, and for a long distance inside, the gangway was heavily timbered with double timbers placed virtually skin to skin. This part of the gangway was very dry. As the timbers had been in place a long time they probably were dry and easily ignited.

The coal of this bed is hard and tough. In most places the roof consists of 4 to 8 feet of fire clay, overlain with hard sandstone. Such roof requires much timbering. The mine had been developed by the usual gangway and companion airway which were driven at intervals of 200 to 600 feet. Black blasting powder and dynamite were chiefly used, also some permissible explosive.

The mine made 1,500 to 10,000 gallons of water a minute, the amount varying with the season. Two-inch fire-fighting water lines connected directly with the surface mains and also with the pump columns at the foot of the shaft. These lines extended along all
main haulage roads and had hose connections at frequent intervals. A liberal supply of fire hose was kept in permanent underground stations and at the surface.

As soon as the fire was reported the company immediately laid two more 2-inch water lines and discharged the water from them upon the caved material under which the fire was burning. Later, a 5-inch line was laid through No. 3 tunnel from a sump, and six additional hose with 3/4-inch nozzles were directed on the fire from the intake side. The airway was the return from that section, and out by the fire it was so filled with smoke that the fire could not be attacked from that side.

**Figure 29.—Part of mine sealed off, fire 30**

**EXPLORING AND SEALING THE FIRE AREA**

The mining company did not have breathing apparatus, but after the fire had been fought several days another company sent its rescue foreman with some trained miners to the colliery to assist. They tried to explore the fire area through the return, but on account of smoke and the heat could do little more than ascertain that the fire had spread to the return air course.

Three fans—one 35-foot, one 24-foot, and one 20-foot—ordinarily supplied in all 164,000 cubic feet per minute to the whole mine, but in the region of the fire the current had been reduced to 21,000 cubic
FIGURE 30.—Profile of mine, showing position of seals, fire 30
feet per minute so that there might be the least possible draft for the fire. Gas, which was sure to have been accumulating, kept men from getting around the fire to note its extent and to determine the condition of the atmosphere on the inside. After 6 days of direct fighting it was decided to seal off the entire workings in this bed; this sealing was done 13 days after the fire started. As nearly as could be determined the fire had extended in by with the air current about 300 feet along the gangway, through a crosscut, and into the return air course. The old chambers north and south had been caved and filled several years prior to the fire.

The seals (fig. 30) were of concrete, 10 to 18 inches thick; the sides, top, and bottom were hitched about 10 inches deep into the coal and rock. Openings, 4 by 5 feet, had been left during construction to permit the circulation of air until after the walls of the seal were completed. When all the seals had been built, these openings were simultaneously closed with doors made of 1-inch hardwood boards covered with 1-inch flooring, and securely plastered to insure their being air-tight. Two-inch pipes with gate valves on the outside were placed in the seals to take air samples. In the No. 2 tunnel seal (fig. 30), which was at the lowest elevation, an 8-inch pipe water trap was constructed in the form of an elongated U placed vertically in the drainage ditch, the vertical legs being about 15 inches in height. This prevented any in-leakage of air.

COMPOSITION OF ATMOSPHERE IN FIRE AREA

Samples were subsequently taken in duplicate at the accessible seals; the seal in No. 3 tunnel was inaccessible on account of water and silt that had accumulated after its construction. Because of the shortness of the sampling pipes and the great difficulty of obtaining samples the results perhaps did not indicate the actual character of the atmosphere inside the seals. The operating company collected samples at approximately six-day intervals, and after careful study of the analyses shown in the accompanying table decided, after 135 days, that the fire had been smothered.

Analyses of atmosphere in fire area during 130 days

<table>
<thead>
<tr>
<th>Days after sealing</th>
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<th>No. 3 tunnel</th>
<th>Air shaft</th>
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<td>O₂</td>
<td>CH₄</td>
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<td>16</td>
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<td>------</td>
</tr>
<tr>
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<td>2</td>
<td>18.4</td>
<td>------</td>
</tr>
<tr>
<td>23</td>
<td>2.0</td>
<td>11.4</td>
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</table>

1 No sample.
### Analyses of atmosphere in fire area during 130 days—Continued

<table>
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<tr>
<th>Days after sealing</th>
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<th>No. 3 tunnel</th>
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<td>(?)</td>
<td>(?)</td>
<td>2.0</td>
<td>4.5</td>
<td>34.4</td>
</tr>
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</table>

¹ No sample.
² Sample taken at top of air shaft about 2 hours after the opening of seals in air shaft and No. 2 tunnel

No CO was detected in any of the samples. This fact is surprising and may indicate that the fire was extinguished earlier than was expected.

**OPENING THE AREA**

The seals at the air shaft and at No. 2 tunnel were opened, and on the following day the seal in No. 3 tunnel. Men wearing oxygen breathing apparatus opened the seal in the air shaft, but the other seals were opened without the use of apparatus. The crews securely braced the doors and then removed the spikes. At a set time, by compared watches, the braces were pulled down and the men were quickly hoisted to the surface.

The accumulation of gas in the workings was allowed to drain for 24 hours before an inspection was made; then it was decided not to change the conditions for several days. Daily examinations were made, and as no more heat was observed the officials opened the cave on the gangway enough to allow men to pass and to reestablish the ventilation in order to remove the gas in the workings.

**REMARKS**

Where open lamps are used, a night fire boss or a fire runner should examine all working places, traveling ways, and haulage ways for fires or deranged ventilation to check the work of the day fire boss and to guard against fires getting beyond control.

To lessen the danger of a fire or explosion being caused by open lights, the Bureau of Mines recommends that only approved locked flame safety lamps and approved electric lamps should be permitted
in all coal mines, whether rated as gassy or nongassy. Mixing open and closed lights is hazardous.

The possibility of sealing pitching workings in an anthracite mine and the effectiveness of producing a deficiency of oxygen in order to smother a mine fire were demonstrated. The company had successfully fought a number of mine fires by this method.

The value of systematic sampling and analysis of the atmosphere in a fire area was again demonstrated.

The use, so far as practicable, of steel or other incombustible material for roof supports on main haulage roads is recommended.

31. VALUE OF AIR SAMPLING DURING SEALING AND FLOODING

In a large anthracite mine an open-flame oil lamp stuck in the leg of a set of timber ignited it and started a fire. Use of the open lamp was in violation of an order to the men, who were cleaning up a fall in an airway, to use safety lamps only. Ordinarily in this mine both open and safety lamps were used. The fire could easily have been put out when first discovered by the fire bosses if breathing apparatus and men trained in its use had been available, but the fire gained headway, and fighting it was much hindered by falls of roof.

MINING CONDITIONS

This mine was opened by a 600-foot shaft, north and south tunnels, and east and west gangways, and was equipped to produce 2,500 tons daily. The coal bed had a roof of shale and a floor of sandstone; bed, roof, and floor all emitted a little methane. As the mine was moist from the water that exuded from the coal and roof, there was no dust (anthracite dust is not dangerous). Black powder, permittibles, and dynamite were used to shoot the coal and dynamite to brush the roof or floor; charges were fired with squibs, fuze, and triple-strength electric detonators. Drill cuttings and pieces of rock were used for stemming and were tamped with copper-tipped steel tampering bars.

FIRE-FIGHTING METHODS

After the fire was beyond control—largely because of falls of roof and interrupted ventilation—the stoppings, pipe lines, and exhaust-air conduits shown in Figure 31 were constructed. It was then decided to flood the fire area. Figure 32 gives details of the dams. A 3/4-inch hole was bored through the seals in chutes Nos. 18, 20, and 22, and a rubber tube inserted to sample the atmosphere behind the "dams" or seals.
COMPOSITION OF ATMOSPHERE IN FIRE AREA

The atmosphere behind the seals was sampled daily for more than a month. Some of the analyses were made at the colliery with portable apparatus.

The accompanying table gives analyses of 33 samples of air taken from behind the seal in chute 22 during a period of 36 days, starting 18 days after the fire broke out but when the area below it was being flooded.

Table 12.—Analyses of air in fire area behind “dam” No. 22

<table>
<thead>
<tr>
<th>Day</th>
<th>Time</th>
<th>Carbon dioxide (CO₂)</th>
<th>Oxygen (O₂)</th>
<th>Methane (CH₄)</th>
<th>Nitrogen (N₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Per cent</td>
<td>Per cent</td>
<td>Per cent</td>
<td>Per cent</td>
</tr>
<tr>
<td>First</td>
<td>5.30 p.m.</td>
<td>2.6</td>
<td>9.6</td>
<td>12.2</td>
<td>75.6</td>
</tr>
<tr>
<td>Second</td>
<td>12.05 a.m.</td>
<td>2.4</td>
<td>12.0</td>
<td>12.0</td>
<td>73.6</td>
</tr>
<tr>
<td>Do</td>
<td>3.30 p.m.</td>
<td>2.4</td>
<td>13.6</td>
<td>13.6</td>
<td>70.4</td>
</tr>
<tr>
<td>Third</td>
<td>11.00 a.m.</td>
<td>2.4</td>
<td>13.4</td>
<td>14.0</td>
<td>70.2</td>
</tr>
<tr>
<td>Do</td>
<td>5 p.m.</td>
<td>1.6</td>
<td>16.0</td>
<td>12.8</td>
<td>79.6</td>
</tr>
<tr>
<td>Fourth</td>
<td>6 p.m.</td>
<td>2.2</td>
<td>12.0</td>
<td>14.0</td>
<td>68.8</td>
</tr>
<tr>
<td>Fifth</td>
<td>6.30 a.m.</td>
<td>2.3</td>
<td>14.6</td>
<td>38.1</td>
<td>65.9</td>
</tr>
<tr>
<td>Sixth</td>
<td>4 p.m.</td>
<td>2.6</td>
<td>6.2</td>
<td>34.2</td>
<td>67.0</td>
</tr>
<tr>
<td>Do</td>
<td>9.45 a.m.</td>
<td>2.9</td>
<td>5.7</td>
<td>29.3</td>
<td>62.1</td>
</tr>
<tr>
<td>Do</td>
<td>4 p.m.</td>
<td>2.4</td>
<td>6.2</td>
<td>30.1</td>
<td>61.3</td>
</tr>
<tr>
<td>Seventh</td>
<td>6.30 a.m.</td>
<td>2.8</td>
<td>4.1</td>
<td>34.9</td>
<td>58.2</td>
</tr>
<tr>
<td>Do</td>
<td>6.35 a.m.</td>
<td>2.6</td>
<td>4.1</td>
<td>36.2</td>
<td>57.1</td>
</tr>
<tr>
<td>Do</td>
<td>4 p.m.</td>
<td>2.4</td>
<td>6.1</td>
<td>37.5</td>
<td>54.0</td>
</tr>
<tr>
<td>Eighth</td>
<td>12.05 p.m.</td>
<td>2.5</td>
<td>6.5</td>
<td>38.0</td>
<td>53.0</td>
</tr>
<tr>
<td>Ninth</td>
<td>2.1</td>
<td>6.8</td>
<td></td>
<td>41.0</td>
<td>50.1</td>
</tr>
<tr>
<td>Tenth</td>
<td>do</td>
<td>2.6</td>
<td>3.0</td>
<td>53.0</td>
<td>41.4</td>
</tr>
<tr>
<td>Twelfth</td>
<td>do</td>
<td>1.8</td>
<td>8.8</td>
<td>40.2</td>
<td>49.2</td>
</tr>
<tr>
<td>Thirteenth</td>
<td>do</td>
<td>1.3</td>
<td>9.5</td>
<td>41.6</td>
<td>47.6</td>
</tr>
<tr>
<td>Fourteenth</td>
<td>1.30 p.m.</td>
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<td>9.2</td>
<td>43.4</td>
<td>46.0</td>
</tr>
<tr>
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<td>9.0</td>
<td>46.2</td>
<td>45.3</td>
</tr>
<tr>
<td>Sixteenth</td>
<td>do</td>
<td>1.9</td>
<td>8.5</td>
<td>48.1</td>
<td>41.5</td>
</tr>
<tr>
<td>Seventeenth</td>
<td>do</td>
<td>1.8</td>
<td>9.5</td>
<td>45.2</td>
<td>43.7</td>
</tr>
<tr>
<td>Eighteenth</td>
<td>2.0</td>
<td>10.1</td>
<td>39.3</td>
<td>48.6</td>
<td></td>
</tr>
<tr>
<td>Nineteenth</td>
<td>12 m.</td>
<td>1.6</td>
<td>12.5</td>
<td>37.6</td>
<td>8.3</td>
</tr>
<tr>
<td>Twentieth</td>
<td>12.05 m.</td>
<td>1.8</td>
<td>10.6</td>
<td>39.0</td>
<td>48.6</td>
</tr>
<tr>
<td>Twenty-first</td>
<td>do</td>
<td>2.1</td>
<td>9.8</td>
<td>41.0</td>
<td>47.1</td>
</tr>
<tr>
<td>Twenty-second</td>
<td>do</td>
<td>2.0</td>
<td>9.6</td>
<td>39.8</td>
<td>48.0</td>
</tr>
<tr>
<td>Twenty-third</td>
<td>2.0</td>
<td>9.2</td>
<td>40.0</td>
<td>48.8</td>
<td></td>
</tr>
<tr>
<td>Twenty-sixth</td>
<td>do</td>
<td>1.2</td>
<td>15.6</td>
<td>21.2</td>
<td>62.0</td>
</tr>
<tr>
<td>Thirtieth</td>
<td>12 m.</td>
<td>.8</td>
<td>18.9</td>
<td>6.4</td>
<td>73.9</td>
</tr>
<tr>
<td>Thirty-fourth</td>
<td>do</td>
<td>.15</td>
<td>20.4</td>
<td>.4</td>
<td>78.7</td>
</tr>
<tr>
<td>Thirty-fifth</td>
<td>do</td>
<td>.20</td>
<td>20.6</td>
<td>.2</td>
<td>78.0</td>
</tr>
<tr>
<td>Thirty-sixth</td>
<td>12.05 m.</td>
<td>.10</td>
<td>20.8</td>
<td>.1</td>
<td>79.9</td>
</tr>
</tbody>
</table>

1 The analyses on the twenty-sixth day, and later days, indicated either that seal or “dam” No. 22 had been opened or that the barometric pressure was high, the area was intaking, and air was leaking through or around the seal.
No carbon monoxide was detected in any samples.

OPENING THE AREA

About 35 days after it was sealed the fire area was reopened by driving the east and west proving or exploration places, shown in Figure 31, to the top slates over the airway. These places were ventilated by a pipe line and a brattice from No. 20 chute. Within 10 feet of the airway much heat and some gas were encountered in the west place, so a stopping was built and water turned in for several days.
This procedure was effective. Within 90 days of the outbreak the work of recovery was virtually finished.

**Remarks**

Some miners will disobey orders—in this instance the order not to use open lights—hence supervision should be close and inspection frequent.

Mine rescue apparatus should be available and men trained in its use should be ready to act in emergencies.

In every mine that liberates gas or requires much timbering there should be special water lines along the gangway, with connections for hose or other pipe lines at intervals not exceeding 200 feet. Fire-fighting crews should be organized and should be given fire drills in the mine.

All coal mines should be equipped with water lines and hose and should always be able to draw on an ample supply of water.

Close inspection should be maintained for fires.

When a fire has been sealed analyses of samples of the atmosphere of the sealed area indicate, if the samples are properly taken and due
Fifty-nine Coal-Mine Fires

regard is given to changes of barometric pressure, whether the seals are tight and whether the fire is subsiding. Fires in inclosed areas retain heat a long time, and a small leakage of air will permit slow combustion; opening a sealed area too soon may be disastrous. In mines that give off methane it is important to know the methane and oxygen contents of the atmosphere of a sealed fire area before the area is opened, in order that by suitable control of the ventilating air the hazard of an explosion may be avoided.

![Diagram of Stoppings and Brattices](image)

**Figure 32.---Types of stoppings ("dams") used, fire 31**

**Fires Caused by Ignition of Oil**

Any kind of oil, even an oil of high flash point, should be carefully guarded from open flames and other possible sources of ignition. The three mine fires cited here were started through careless use of open-flame lamps.

32. **Carelessness and Poor System of Handling Oil**

**Origin of Fire**

Burning drops of oil from the lard and kerosene lamp of an oiler fell into the drip tub, which contained 15 gallons of mine-car oil. (Fig. 33.) The burning oil set fire to the timbers and the fire spread 100 feet north and 35 feet south of a downcast hoisting shaft. Eventually the fire was extinguished by playing water on it and loading out the falls.
Smoke and noxious gases filled virtually all workings north of the point of origin. When the fire started, 200 men and 24 mules were in the mine, but 190 men escaped up a stairway in an air shaft. Apparatus men from a Bureau of Mines safety station arrived within five hours. Nine men were found dead; one man who was found unconscious was revived. Sixteen mules died.

**MINING CONDITIONS**

The bed of bituminous coal being worked averages 4½ feet in thickness. The immediate roof is a hard "shelly" band, 12 to 18 inches thick, overlain by shale. The floor is a smooth, hard fire clay, which becomes soft and swells and is taken up to make height for the mules.

The double-entry, room-and-pillar system of mining was employed. All coal was shot off the solid, with FF black blasting powder. The mine made no gas. Open-flame oil and carbide lamps were used. Haulage roads were sprinkled about once a month, but the mine was dry. A 12 by 5½ foot exhaust fan at 90 revolutions per minute supplied 25,000 cubic feet of air per minute, and another 8-foot exhaust fan, at another shaft, gave 35,000 cubic feet. A 2-inch water pipe ran from the surface to the foot of the hoisting shaft.
The lubricating oil used was stored in a 300-gallon tank on the surface, and each day 35 to 40 gallons was drawn into a barrel which was lowered to the bottom of the 201-foot shaft. In winter the temperature in the shaft (downcast) was so low that the oil would not flow unless heated, so a steam coil was used to heat the oil. Drips were caught in the tub below the spigot. The mine cars were oiled in a runaround at the foot of this shaft; the oil can, shown in Figure 33, was used instead of the squirt gun used elsewhere.

REMARKS

Where car oiling is done underground, any heating apparatus required should be so arranged that if the oil ignites the fire can be easily confined within some fireproof room or chamber.

Oilers and others who carry open lights should be warned against approaching a place where oil is exposed.

33. BURNING OIL IGNITES MINE TIMBERS

An open light held about 12 inches above lubricating oil in an open tub (half of an oil barrel) ignited the oil, which was dumped onto the floor by a man who apparently lost his wits. The mine fan was stopped. The fire spread to the timbers supporting the roof. Twenty-nine men who tried to reach the hoisting shaft through the smoke were suffocated, although the return airway might have provided a means of escape.

The mine was opened by two slopes from the outcrop and by a shaft 320 feet deep. The room-and-pillar system of mining was used. A 10-foot exhaust fan produced up to 34,000 cubic feet of air per minute.

Little damage was done to the mine, except for one fall in the main east entry near the bottom of the shaft where the fire originated. This fall, which was 80 feet long, 12 feet wide, and from 4 to 6 feet thick, checked the fire, partly smothering the flames and preventing their spreading. The shaft was sealed for a time, then it was reopened and water was turned on the fire. All bodies were recovered within 24 hours.

REMARKS

This fire was due to carelessness. The oil was not expected to ignite so easily; the open light was held about 12 inches above the oil; a flash followed, and the oil ignited.
Extreme care should be used in handling all inflammable material. No open lights should be used in the vicinity of inflammable material.

Oil should be transported in steel containers, and then in the smallest quantity practicable.

Oil and other inflammable substances should be stored in fireproof rooms with steel or concrete doors, and the rooms should be so placed that in event of fire the passageway to the shaft or escape way will not be made impassable.

Fire-fighting crews should be organized and facilities for fire fighting should be provided underground.

Where it is possible, the lubrication of mine cars should be done outside of the mine.

34. OIL FROM A BROKEN PIPE LINE ENTERS A MINE AND IS IGNITED

ORIGIN OF FIRE

A surface cave-in broke a 4-inch pipe line carrying oil. The oil flowed into the mine, where vapor from the oil was ignited by an open-flame lamp.

About 20 men were in the mine at the time and were partly overcome, but the foreman’s prompt reversal of the fan (normally run exhausting) allowed them to escape.

In fighting the fire at first some of the oil and charred material was loaded out, but when the fire spread and got beyond control the Bureau of Mines was asked to assist. As the cover was only about 40 feet thick and breaks extended to the surface, effectual sealing to exclude air was impossible. Three days after the fire started the fan was stopped and four bureau men put up five temporary canvas stoppings. They wore oxygen breathing apparatus and gas masks while building three of the stoppings. The company then built seals of brick and cement and flooded the area, about 5 acres.

FIRES CAUSED BY OPEN-FLAME LAMPS IGNITING HAY

Underground stables constitute a fire hazard because of the hay and other feed kept there. Moving hay from the shafts to the stables is hazardous if open lights are carried, as is shown by the Cherry mine disaster (1909) in Illinois, which killed 259 men. In the stable itself fire may start from open lights, matches, pipes, or electric sparks or arcs.

35. OIL LAMP IGNITES HAY

Section 72 (a) of the coal-mine operating regulations issued by the Secretary of the Interior under the terms of the leasing act of February, 1920, reads:
Hay, straw, or similar highly inflammable material taken into a mine shall be compressed into bales or covered with tarpaulin or in a closed car and shall not be handled when unbale in the presence of open lights.

This clause doubtless was inserted because those who drafted the regulations had in mind the terrible disaster described below, which killed 259 men. A bale of hay was ignited by an open oil lamp; the fire spread to the mine timbers and the mine shaft. The two senior authors of this bulletin, together with other mining engineers of the United States Geological Survey (the Bureau of Mines had not been established), assisted in the recovery work.

![Diagram of the mine layout](image)

**Figure 34.—Vertical section (theoretical) through shafts, fire 35**

**MINING CONDITIONS**

Figure 34 gives a vertical section of the mine, and Figure 35 a plan of the entries in the middle bed in which the fire took place. The first bed, being thin and irregular and cut out in many places, was unminable under existing conditions. The second bed is somewhat irregular in thickness; it had been opened four or five years before the fire, and the workings covered an area of about 240 acres. The farthest workings were about three-fourths of a mile from the shaft. Development was by the room-and-pillar system. Many of the rooms started had to be stopped on account of bad roof or the
irregularities of the bed. Probably two-thirds of the area covered by the mine was blocked off permanently after more or less of the pillar coal had been extracted. In this bed 303 men were employed on the day shift.

Mining on the third bed had begun about a year before the fire. Entries had been driven around a large block surrounding the shafts and longwall workings had been started, as Figure 36 shows. There were about 90 working places, but as work was being pushed 181 men were employed in this bed on the day shift.

The mine had two entrances, a large hoisting shaft and a combined air and escape shaft, as the figures show. Coal from the third bed was hoisted to the second bed by a single cage in one compartment of the air shaft. The loads were shoved off on the south side of the shaft, the empties were back-switched to the north side and put on the cage from that side. The loaded cars were hauled around to the hoisting shaft, sometimes to the north bottom and sometimes to the south bottom. The coal was caged with the coal from the second bed and was hoisted on large cages, on which the 2-ton cars
were placed tandem. These arrangements were regarded as temporary and were to be changed when the workings in the third bed were further developed.

A stairway in one compartment of the air shaft ran from the third bed up through the second bed to the surface. In addition to this method of escape from the third bed to the second a single cage in the compartment of the hoisting shaft could be fastened to the floor of the main cage by a rope, which ordinarily hung from the cage seat at the second bed.

A fan with steel-plate casing provided ventilation. It was reversible, but ordinarily was used as a pressure fan. The hoisting shaft was the upcast. At the second bed the intake air was split; most of it went through the workings in this bed, the remainder went to the workings in the third bed.
All underground haulage was by mules, and there were stables in each bed. The stable in the second bed was about 60 feet from and parallel with the main bottom, as shown in Figure 37. A straight passageway from the south main bottom to the air shaft intersected an unused road opposite the entrance to the west end of the stable. A regulator door in the entrance of the stable admitted a split of fresh air for ventilation.

Figure 37.—Detail plan of entries in middle or second bed, near shafts, fire 35

The main bottoms, stable, and landing of the air shaft on the second bed had been lighted by electric lamps up to a month before the fire, but because of failure of the electric cable open kerosene torches, each made of a piece of 2-inch pipe, 16 inches long, plugged at one end and reduced at the other to hold a cotton wick, were in use. They were hung to the timbers by wires and sometimes dripped burning oil.

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Shortly after noon on the day of the fire, when 484 men were in the mine, a car containing six bales of hay for the lower bed was taken off at the second bed and run around to the air shaft, down which it was to be lowered. When near the air shaft the hay was ignited by one of the torches. After futile attempts had been made to extinguish the fire the car was dumped down the air shaft into the sump, where the water put out the fire in the hay. Before the car was dumped the flame from the hay had set fire to the timbers in the second bed. The fan was successively slowed, stopped, started, stopped again, and reversed.

Some of the men were warned, and 10 or 12 cage loads were hoisted in the main hoisting shaft to the surface. About three-fourths hour after the fan was reversed the wooden doors at the top of the air shaft were burned, making the fan useless. The fire spread rapidly to the hoisting shaft and 10 rescuers being lowered in that shaft were burned to death. At 4 o'clock it was decided to seal the main shaft, and water was turned on the air shaft until active flames were extinguished. The fire did not reach the third bed, but the smoke and gases did. Probably most of the men who were killed succumbed quickly, although notes they left indicated that some lived two days. The fire in the middle bed was limited to the immediate vicinity of the hoisting shaft, a pump room, the stable, and the entry leading to the air shaft. In this shaft the face of the linings and projecting timbers were burned from the middle bed to the surface, but except for 30 to 40 feet at the top and bottom the lining was not seriously damaged.

Two engineers of the technologic branch of the United States Geological Survey arrived with rescue apparatus next day, and one with a volunteer helper made three trips down the air shaft, which was sealed that night. The next day the hoisting shaft was opened, and State mine inspectors and others went down. In all of these trips, when apparatus was worn, the smoke made vision impossible; so the air shaft was uncovered, a steam jet was put in, and the repaired fan was restarted, making the hoisting shaft the upcast. As fire could be seen and heavy falls were taking place, it was decided to reseal the shafts. As the hoisting shaft was on fire at the second bed, a sprinkler discharging 80 gallons of water per minute was suspended in the shaft, but later a company of firemen with an engine arrived from Chicago and threw down the shaft a stream of 600 gallons per minute.

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8 This branch of the Geological Survey became later the nucleus of the Bureau of Mines.
The air shaft was examined the next day through an air lock. The engineers wore apparatus and used a wooden float or cage that had been constructed for the purpose. It was decided that the fire, whose active flame had been extinguished by the sealing, could be attacked from the hoisting shaft. The fan was then started upcasting. The cover over the hoisting shaft was removed and the fan was started exhausting, thus making the hoisting shaft a downcast. Water was played down the air shaft, the hose was gradually carried to the bottom, and the mine was entered on the south side. Firemen kept streams of water playing on smoldering coal and timber under falls on the north side of the shaft. The mine elsewhere was found to be cool but full of black damp, which was slowly cleared out, entry by entry, through suitable direction of the ventilating currents.

Meantime the fire near the shaft was under control but was too deep seated under the falls to be extinguished by direct means; so after the recovery operations the mine was sealed again. It remained sealed until the fire was out. During the recovery operations samples of the return air from the fire were regularly taken and analyzed to ascertain whether danger from explosive mixtures existed.

Although it was expected that all of the miners would be dead, 20 had barricaded themselves in the first and second west entries; after considerable difficulty they were rescued by apparatus men. They had been entombed for seven days.

**REMARKS**

The fire called attention to various dangers and the precautions to be taken, as follows:

The danger of lining shafts and passageways between them with combustible material. After this fire the State of Illinois enacted a law requiring the fireproofing of coal-mine shafts.

The hazard of open lights and torches in mines is no longer necessary with the advent of permissible closed lights.

The need of ample fire-fighting equipment and systematic drills with it. Water taps and hose should be not only at the foot of every shaft but throughout the main bottoms. Water mains laid throughout the mine would be still better.

The advisability of providing escape facilities in shafts—the escape ways to be isolated or separated from other compartments by fireproof partitions and to be ventilated by an intake split of fresh air from the outside.

The doubtful expediency of relying on stairways in deep mines, even if the stairway is in a separate compartment. Men partly overcome with smoke or gas are not in condition to climb 500 feet or so, aside from the long time needed to climb out and the corresponding
exposure to danger. It is advisable to supplant ladder ways and stairways in shafts more than 300 feet deep by hoisting arrangements ample for quick escape.

36. WELL-ORGANIZED RESCUE WORK

ORIGIN OF FIRE

Fire broke out in the stable just off the main slope and 1,600 feet from the main shaft, which was 400 feet deep. Miners used open lights and the main slope and stable were lighted by electricity. Open lights and smoking were not permitted in the stable. The cause of the fire is unknown but may have been some violation of the rules or possibly an electric short circuit.

RESCUE WORK

In the mine were 171 men, and the superintendent led 168 of these to safety by a way known only to him, in which there was an intake current. One man who was working on the main slope when he found he could not get to the shaft because of the smoke took refuge in the engine room, where the air was good, and telephoned to the surface. Some men went down the air shaft and brought him out. Two other men did not go with the 168 saved but, against the urgent protest of three men coming behind them, went through a door, entered the main slope which was filled with fumes from the fire, and were later found dead 50 to 75 feet from the door.

The fire started at 4 p. m., and by 1.30 a. m. two rescue cars, including one of the Bureau of Mines, and 22 trained apparatus men arrived. Crews of six men each had been organized on the way. Crew No. 1, provided with safety lamps, lifelines, and other equipment, went down the mine and brought up one of the dead men. Examination showed he had been dead several hours. As the other men could not possibly be alive and the fire seemed to be gaining headway (the smoke was so thick that a flash light could not be seen 3 feet away), it seemed advisable to abandon immediate efforts to find the other body and try to get the fire under control. One crew of apparatus men carried extinguishers to the fire and another crew extended the water pipe. By midnight of the next day the fire was under control; then the fan was started. An hour later the mine had so cleared of smoke that the other body could be removed.

All the work of fighting the fire and recovering the bodies was done with the aid of breathing apparatus. Each crew of six men was under a competent captain or leader whose order was obeyed implicitly, and each crew carried a life line. Before he entered the mine each man was given a number.
Although there were many falls in the mine while the fire was being fought, no accident happened to any of the apparatus men. The wooden cribbing of which the stable was built burned out and the ground caved badly, making the fire fighting difficult and dangerous and requiring the apparatus men to exercise great care and good judgment to avoid injury.

REMARKS

This fire calls attention to the wisdom of having stables fire-proofed, and also provided with steel fire doors for closing exits if an emergency develops. The work of the apparatus men shows the value of thorough organization and strict discipline in recovery operations.

FIRES CAUSED BY SHOTS OF DYNAMITE

The two fires discussed below call attention to the danger from using dynamite in coal mines. One of the fires was probably caused by dynamite igniting a pocket of gas; the other by dynamite that failed to explode in a shot hole but burned and ignited the coal.

37. DYNAMITE IGNITES POCKET OF GAS

The possibility of a fire starting in a loading chute of an anthracite mine is so remote that miners or officials are not likely to anticipate it, but in one mine two miners who were robbing pillars were suffocated by such a fire.

PROBABLE ORIGIN OF FIRE

The most plausible theory as to the origin of this fire is that a small charge of dynamite used to blast out a timber "battery" ignited a small pocket of gas behind the battery and in a narrow hole through a chain pillar. Company miners were to remove the battery. On account of the steep dip of the bed, approximately 70°, it was customary to blast out a battery when necessary. The miners presumably used ordinary dynamite instead of the permissible explosives prescribed by the mine rules; these explosives are less likely to ignite gas, although when fired unstemmed they are by no means safe to use in an explosive mixture. Because of the good ventilation in the lower breast and a crosscut near its face the miners evidently did not consider that testing for gas behind the battery before they fired the blast was necessary. The blast was fired at 10.30 a.m.

The fire in the chute kept the miners from retreating to the gangway below through the regular manway, and because of the steep
pitch they could not climb to a counterroad above, from which a rock-slope second opening, about 500 feet east, led to the water level or surface tunnel.

As soon as the mine officials learned that the two miners were still in the chute a rescue party went down the rock-slope second opening and by means of ropes lowered rescuers down the pitch about 150 feet, where the bodies were found. Breathing apparatus were taken in by the rescuers, but the fire had been extinguished by a fire-fighting crew and there was not enough smoke to necessitate using the apparatus. The men had been dead some time when their bodies were recovered. It was estimated that they could not have lived in the smoke more than 10 or 15 minutes. The bodies were recovered about 4:30 p.m.

REMARKS

The bureau's representative in the anthracite region recommended that—

In mines where different kinds of explosives are used special effort should be made to designate the character of the explosive to be used in each kind of work. The miners should be trained to follow the judgment of the mine foreman or his assistant in this respect.

Robbing operations in steeply pitching beds should, where practicable, have two manways, one on the intake and one on the return air. The outside, or return, manway should lead from the next outside chute, provided with suitable trapdoors, through the "monkey," and should be maintained to the working face. The inside manway could be constructed in the customary manner.

Possibly a disastrous mine fire was prevented by use of the regulation fire-fighting water line on the gangway. Frequent and convenient fire-hose connections had been provided.

38. SEALING OFF A BURNING PILE OF COAL

ORIGIN OF FIRE

A hole charged with six sticks of 35 per cent dynamite failed to explode but burned and set fire to a pile of coal in a mine. A miner is said to have seen the fire but did not report it, and about 20 hours later it was reported by others to the superintendent. Bureau of Mines engineers arrived within two hours and men and apparatus four hours later. A crew of five men from another mine had just finished their training but were able to wear the apparatus and assist for nearly 24 hours without rest. No lives were in danger during the fire fighting.
FIRE-FIGHTING METHODS

Neither water nor fire extinguishers were available. About three hours after the apparatus arrived seven men entered the mine. It was decided to build a temporary bulkhead of brattice cloth and then erect a more substantial bulkhead of boards. Because of a breakthrough between two rooms about 35 feet from the face of the first room the men had to construct the brattice and the bulkhead about 33 feet from the burning face of the other room.

On account of the heat and the outward pressure of the fumes the men could not seal the temporary bulkhead tightly enough to permit the erection of the permanent bulkhead without the use of breathing apparatus. The permanent bulkhead was made of two thicknesses of heavy lumber. A pipe and valve were inserted for sampling the air behind it. Two days later the bulkhead was holding tight and the surroundings were cooler.

On the fourth day a 1,700-foot water line was completed to the outside of the bulkhead. On the fifth day the bulkhead was opened and the fire area explored by two apparatus men. Considerable carbon dioxide was present, but the fire was apparently out. Water was turned into the room to make sure the fire had been extinguished and to cool the coal.

FIRES CAUSED BY ELECTRIC MOTOR OF UNDERGROUND FAN

Auxiliary, or booster, motor-driven fans underground have been responsible for a number of fires and explosions. The two fires cited here were traceable to the motors or their connections.

39. LACK OF BARRIER PILLARS NECESSITATES SEALING A LARGE AREA

The character of the fire and the use of few, if any, panel or barrier pillars caused 90 acres of coal to be sealed for six months. The company was anxious to have the fire checked promptly, as coal in a mine near by had been burning for 25 years, despite many efforts to extinguish it.

MINING CONDITIONS

The mine, one of the largest in the State, had produced as much as 4,800 tons in 10 hours, but when the fire broke out was yielding 1,500 tons in 8 hours. Mining was by the room-and-pillar system. With adjoining and connected mines the workings covered about 6 square miles. The bed is 6 feet thick, lies virtually horizontal, is dry, and has a strong sandstone roof. As the mine made gas only flame safety lamps were permitted. Ventilation at the time was by an underground fan at or near where the fire was supposed to be burning, and some persons thought the electric connections of the fan
motor were responsible for the fire. With the chief source of ventilation cut off, smoke and gases backed up near the main entry. Several fans, working in tandem, were installed to remedy this condition. A blowing fan at the main pit mouth delivered 40,000 cubic feet of air per minute, and an exhaust fan that delivered 10,000 cubic feet was placed at a shaft mouth more than 2 miles away on the other side of the mine workings. Two other smaller fans were put in suitable places in the mine. Engineers of the technologic branch of the United States Geological Survey were notified. When they assisted in the subsequent operations they used breathing apparatus.

SEALING THE FIRE AREA

On the tenth day after the fire started its exact position was determined; it could be seen burning into the roof shale over the coal. The fire, which had gained access to an air course by means of a breakthrough from the main north (see fig. 38), was fought with water supplied through 450 feet of hose by an electric pump.

![Figure 38](image)

**Figure 38.—Sketch of workings explored, fire 39**

On the eleventh day it was decided to erect stoppings in the air course and main north and water from a 2-inch hose was played on the fire all night.

On the twelfth day a stopping of 8 inches of brick was built in the air course, and another attempt was made to reach the fire in the main north before the air course was entirely sealed. Men used the hose to clear away the smoke up to within 20 feet of the fire and played water on the fire for three hours. At the end of the day, in spite of their efforts, the fire was burning fiercely.

After various efforts for eight days more it was decided to seal the fire. Thirty stoppings were necessary. They were made of brick, 9 inches thick, faced with cement, and well tied to the ribs, roofs, and floor. One was 20 feet high, but the others averaged 7 feet. Two of them, 1,200 feet apart, had pipes provided with valves inserted through them for sampling.

Samples of the atmosphere behind one of these stoppings 90 days later averaged 7.72 per cent carbon dioxide, 0.78 per cent oxygen, 0.70 per cent methane, and 90.80 per cent nitrogen. The low con-
tent of oxygen indicated that combustion could no longer be sustained.

REOPENING THE AREA

On the one hundred and seventieth day after the start of the fire it was decided to reopen the fire area. An inspection of the 30 stoppings took three and one-half hours. At this time ventilation by two fans in tandem gave 58,000 cubic feet of air per minute. Air locks had been constructed outside of two stoppings close to the fire.

Two days later apparatus men entered the fire area. Finding several large falls but no evidence of fire, they allowed fresh air to enter the workings. Then the same men without apparatus went in to investigate further.

The next day more air was allowed to pass over the site of the fire. Enough black damp drifted out to preclude the carrying of flame safety lamps farther than the wooden stopping in the "dark" entry, as shown in Figure 38.

The area was closed until plans were completed to take care of the gases without danger. Then the entries were cleared, the fire walls torn down, and the haulage ways opened.

40. NEED OF PERSISTENCE IN FIGHTING A FIRE

PROGRESS OF FIRE

In one mine a fire broke out that asphyxiated 20 men. Their bodies were recovered two days later. Apparently efforts to extinguish the fire relaxed somewhat, and the fire gained headway. Water was pumped on it for 70 hours, and attempts were made to load out or mine the burning material. Conditions, however, became such that the whole mine had to be sealed at the collars of the two shafts. Large falls of roof prevented local sealing, which would have been comparatively simple two days after the fire started. Bureau of Mines engineers assisted in fighting this fire. Apparatus was worn intermittently during the first 31 hours while rescue work was under way.

A large fan at No. 1 shaft provided ventilation for two connected mines, but these were two motor-driven booster fans underground, one near the foot of No. 2 shaft and the other about 700 feet from it. The two shafts, both downcasts, were half a mile apart. Either overheating of the bearings or arcing of the electric motor was thought to have caused the fire. The motor and fan were destroyed.

ANALYSES OF MINE AIR

Both shafts were sealed about 10 days after the bodies of the men had been recovered. A 3-inch pipe with a gate valve was fixed in
each of the seals for sampling the mine air. Analyses of samples taken from the two shafts are given below.

**Analyses of air from sealed shafts**

<table>
<thead>
<tr>
<th>Gases</th>
<th>20 days after sealing</th>
<th>34 days after sealing</th>
<th>47 days after sealing</th>
<th>54 days after sealing</th>
<th>82 days after sealing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. 1</td>
<td>No. 2</td>
<td>No. 1</td>
<td>No. 2</td>
<td>No. 1</td>
</tr>
<tr>
<td>Oxygen</td>
<td>18.69</td>
<td>13.14</td>
<td>14.41</td>
<td>9.10</td>
<td>8.9</td>
</tr>
<tr>
<td>Methane</td>
<td>1.13</td>
<td>3.37</td>
<td>3.20</td>
<td>7.24</td>
<td>7.7</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>0.57</td>
<td>2.29</td>
<td>0.77</td>
<td>3.76</td>
<td>1.2</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>0.00</td>
<td>0.07</td>
<td>0.00</td>
<td>0.19</td>
<td>0.0</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>79.62</td>
<td>81.13</td>
<td>81.62</td>
<td>79.71</td>
<td>82.0</td>
</tr>
</tbody>
</table>

The following conclusions were based on these analyses: After 20 days the percentage of oxygen and the trace of carbon monoxide at No. 2 shaft indicated that the fire was smoldering.

The analyses at the end of 34 days indicated that the fire was nearly out, but as some CO was present there probably were hot coals to rekindle the fire and possibly cause a gas explosion if air were turned in. At 47 days after sealing the samples showed no CO, and the oxygen had dropped to a point that could not sustain a fire. At 54 days the air pressure was inward. On the eighty-second day after sealing the analysis showed conditions practically the same as on the forty-seventh day, and reopening the mine was deemed safe. The mine was reopened 19 days later, or 101 days after sealing.

**REMARKS**

Here is another example of the value of careful sampling and analysis of mine air as a guide to conditions in a fire area.

The use of underground booster fans is fraught with much danger. They are needed only under the most exceptional conditions. Large main fans on the surface should be employed, and adequate airways, kept free from obstructions, should be provided.

**FIRE CAUSED BY GASOLINE ENGINE**

A gasoline engine, pump, or locomotive is a hazard in a mine. All produce noxious fumes and may cause a fire or explosion. Their use underground is now forbidden by the mine-inspection departments of many States.

**41. GASOLINE FAN ENGINE SETS FIRE TO COAL**

A gasoline-engine plant driving a fan far inside the mine set fire to the coal in the air course. The workings filled with smoke, and 13 men were suffocated.
MINING CONDITIONS

The bed worked is high-grade cannel coal 42 inches thick. The mine, a drift opening with a main entry and air course, is developed by the room-and-pillar system. Gas had never been detected, and open lights were used exclusively.

A 5-foot blower fan, belt-driven by a gasoline engine and surrounded by woodwork, was about 500 feet in by the drift mouth. The exact cause of the fire was not determined, but it is believed that the engine took fire from overheating or the gasoline tank exploded.

Early in the rescue work a temporary fan driven by a gasoline engine was installed at the drift mouth, and most of the mine was explored without oxygen breathing apparatus. The bodies of four men were soon found, but the bodies of the other nine were not recovered for about 42 hours. The nine men had tried to erect a barricade but were overcome by fumes before they completed it.

REMARKS

To place a main ventilating fan underground is bad practice; it inevitably causes recirculation of air and the accumulation of impurities therein. Furthermore, if a fire or explosion occurs even partial ventilation usually becomes impossible. In this case, driving the underground fan by a gasoline engine constituted an additional and serious hazard.

FIRE CAUSED BY GAS OR DUST EXPLOSIONS IGNITING COAL

42. VIOLENT EXPLOSIONS AND A PERSISTENT FIRE

Sealing a mine does not always extinguish a fire if openings to the surface admit air to the fire area, nor does flooding unless the water reaches the fire or effects an air-tight seal in the fire zone. When it is practicable, flooding the fire zone has the advantage that the water cools the hot coal and there is less danger of the fire rekindling when the area is opened to restore ventilation. At the mine described here, four men were killed by the initial explosion. The mine was sealed for nine months and flooded in part for six months.

MINING CONDITIONS

A 9½-foot bed was being mined at a depth of 500 feet. Two feet of the coal was left in the roof. Certain parts of the mine gave off much methane; seven places were marked "gas" on each of the nine shifts preceding the explosion, and 136 places were marked "O. K." A 12-foot force fan offset 20 feet from the air shaft, which
was also the escape shaft; gave 93,000 cubic feet of air per minute. The current was split at the foot of the shaft to ventilate the north and south halves of the mine. Over the air shaft were explosion relief doors.

In the rooms, which were 25 feet wide, the coal was shot from the solid. In the entries compressed-air puncher machines undercut the coal to a depth of 6 feet and a width of 9 feet, then it was shot with two holes near the roof, one hole on each rib. Room necks were turned in advance of the last crosscut. A 2½-inch auger bit was used. The usual charge of F black blasting powder was 22 to 30 inches, and coal dust was generally used as stemming. It is estimated that over 550 pounds of powder were in the mine at the time of the explosion, as 5,500 pounds were used during nine shifts in one month, or an average of 24.4 kegs to produce 1,000 tons of coal per shift.

Two shot firers entered the mine each day at 2 p.m. to examine the length, size, and position of each hole before it was charged. They remained in the mine until all the men ascended, and then began shooting, starting in the south entries about 4:30 p.m. Two fire runners, or fire hunters, entered the mine as shooting began and examined each place or shot after the charge had exploded; they began their inspection after the shot firers had shot a block of rooms and advanced to the next. As a rule, all four men (two shot firers and two fire hunters) carried open lamps. The company kept five safety lamps at the shaft bottom for use in emergency.

DETAILS OF EXPLOSIONS

One afternoon, about 35 minutes after shot firing started, an explosion took place which threw clouds of dust and débris from both shafts far higher than the sheave wheels, 78 feet above the surface. The damage to the tipple was slight, for the headframe was well built of steel. The fan house and fan were uninjured, as the explosion doors opened at the instant of the explosion.

Two hours later 20 men descended the air shaft to 60 or 70 feet from the bottom, where the lower ladders had been blown out. The fan was then slowed down. Two men who were lowered by ropes to the bottom found that the mine was on fire. All returned to the surface, the fan was stopped, and five minutes later a second explosion took place, which was said to be more violent than the first which set fire to the mine. For 15 minutes the flame is reported to have reached 75 feet above the sheave wheels on the tipple and to have set fire to some woodwork in the cupola. The shaft emitted flame for more than two hours. When the flame died down, smoke continued to come up. An hour later some blazing wood from the
cupola fell down the shaft, igniting gases and causing a third explosion. Flames continued for one and one-half hours. Three hours later, after another slight explosion, fire blazed from the shaft for five and one-half hours. Then the shaft was sealed.

As the fan housing was leaking much smoke and gas, apparatus men erected a stopping with an air lock in the conduit leading from the fan to the air shaft. The stopping was built of portable sections that had been put together outside. Later a sample of air taken at the stopping showed 3.6 per cent carbon dioxide, 10.7 per cent oxygen, 0.3 per cent carbon monoxide, 7.4 per cent methane, and 78 per cent nitrogen.

ATTEMPTS TO REOPEN MINE

An attempt was made to reopen the mine 110 days later. A sample of air at the air shaft (upcast) gave 7.9 per cent carbon dioxide and 4.3 per cent oxygen. Two engineers of the technologic branch of the United States Geological Survey, who wore the helmet type of oxygen breathing apparatus with telephone attachment, were lowered in a bucket through a trapdoor into the air shaft, the telephone line being lashed to the hoisting cable. They found water had risen until it was 6 or 7 feet deep and was within 2 or 3 feet of the roof of the entries. The temperatures were low; the atmosphere 6 feet above the water contained 6.3 per cent carbon dioxide, 4.9 per cent oxygen, and 0.1 per cent carbon monoxide. A trapdoor was then constructed in the hoisting shaft. When the engineers were on the point of being lowered again in a bucket, gases that were probably admitted during the construction work ignited at the fire and caused an explosion which blew open the trapdoor at the main shaft, cracked the air-shaft seal, opened the doors of the fan housing, and blew down the stopping in the air conduit of the fan.

The mine management thought this explosion might have been caused by a big fall of roof and started the fan. In a few minutes dense clouds of smoke which became blacker were forced out of the hoisting shaft. The seals over the shafts were replaced.

On the following day the oxygen content in the air shaft had increased to 10.8 per cent, but the carbon dioxide content was 5.2 per cent. During the next 27 hours various tests were made, such as partly and fully opening the 3 by 4 foot doors at both shafts, but smoke continued to pour out; so the shafts were sealed again.

FLOODING THE MINE

The management decided to flood the mine. Ditches were dug to bring water from swamp land near the shafts and served to conduct into the mine the water from a heavy rainstorm. Another
explosion occurred during this storm; it blew off a concrete seal over the main shaft.

It was decided to increase the depth of the water in the shafts. Water was pumped into the mine for six days until there was a depth of 76 feet in the shafts, or enough, it was calculated, to flood the highest workings. Then unwatering was started. A self-dumping water cage bailed considerably more water in a day than the pumps sent into the mine in the 6 days; yet, after 24 days of bailing, the water level was lowered only 20 feet. It was supposed that the imprisoned air and the gas given off by the coal were of such volume and under such pressure that it held up the water level in the shafts. (See fig. 39.)

From time to time as the water level was lowered the compressed gases would depress the water level in the mine below the roof level at the shafts and permit some of the imprisoned gases and air to escape; then the water columns in the shafts would drop again and act as a seal.

About six months later the mine was reopened. Men wearing breathing apparatus explored the workings before the fan was started. Fire was found in a raise working, but it was extinguished by direct attack.

**Remarks**

Evidently the mine air and gases prevented the water reaching the seat of the fire. A borehole or holes from the surface would have allowed the gases to escape and the water to reach the hot coals. The method has been used successfully in fighting underground fires in the Pennsylvania anthracite region.
FIRE CAUSED BY BURNING MATERIAL FROM SURFACE STRUCTURES

43. DIFFICULT RECOVERY WORK SKILFULLY DONE

A wooden conduit on the surface, which led from a fan located at the outcrop of a lower bed to workings in a higher coal bed, caught fire and the fire spread into the mine.

MINING CONDITIONS

The three mines of this company employed 200 men and produced 600 tons of coal daily. They are near the summit of a mountain 1,360 feet high. The topography is rugged and irregular. Two coal beds, 58 feet apart vertically, outcrop near the summit of the mountain.

No. 1 mine, in which the fire occurred, worked the upper bed, which is 4\(\frac{1}{2}\) feet thick and lies between a floor of shale and a roof of hard gray shale overlain by a bluish-gray sandstone. The No. 2 mine worked the lower bed, which is 3\(\frac{1}{2}\) to 5\(\frac{1}{2}\) feet thick and fairly clean. No. 1 mine produced 150 tons daily.

Figure 40 shows the relative positions of these two mines. No. 1 mine was opened on the upper bed by a 600-foot drift through the top of the mountain. No. 2 mine was opened by drifts. In No. 1 the system of working was double-entry, room and pillar. The first left entry had been driven within 20 feet of the surface. The coal was undercut by electric chain machines and shot with black powder. Haulage entries were lighted by electricity, and the miners used open lamps. Electric motors hauled the mine cars.

VENTILATING SYSTEM

A steel fan, 44 inches in diameter, stood inside a frame building near the mouth of the air course of the lower mine, and a frame conduit, 6 by 6 by 115 feet, extended up the hillside to the mouth of the air course of No. 1 mine. (Fig. 41.) The fan, which was running as a blower at the time of the fire, was belt-driven by a 30-horsepower electric motor. When the fire started the fan was said to be forcing about 15,000 cubic feet of air per minute into No. 1 mine; the fan also furnished a split of air for the lower mine. This split was controlled by a regulator. As no men had been working in that mine for some months the split had been reduced to a few thousand cubic feet of air per minute. At \(E\) (fig. 40) was a motor-driven fan which furnished ventilation for another part of No. 2 mine.

No. 1 mine was ventilated by a continuous air current with no splits. The main air course served as the intake and the main haul-
age way as the return. Wooden brattices in the crosscuts between the parallel entries and wooden doors between the butt entries directed the air current, as Figure 40 shows. As far as could be ascertained, no fire-fighting apparatus was at the fan house or near by.

**ORIGIN OF FIRE**

On the night of the fire three men were working in room 5 and two were running a mining machine in room 6 of the upper mine (No. 1). At about 11.50 p. m. the night boss glanced out of the window of the mine foreman's office and saw flames issuing from the fan house. He
and another man immediately ran to the fan house to stop the fan, at $A$, Figure 40, at the entrance of No. 2 mine, but the fire had gained such headway that they could not enter the building. Then they tried to break the connection of the wire to the fan motor at the point
where it joined the trolley wire but failed. The fan continued to run and carried the flames up the wooden air conduit, causing it to burn fiercely, and sending the smoke and fumes directly into No. 1 mine. Fearing for the safety of the five men inside, the night boss and his companion ran up to the mouth of the haulage way of No. 1 mine and found hot smoke and gases issuing from it. Twice they tried to reach the mouth of the first left entry, 100 feet in, but the smoke was so hot and noxious that they could not proceed more than 40 feet. Then they ran to the foreman’s office and telephoned to town for assistance. Meanwhile the flames had enveloped almost the entire air conduit, 115 feet long, and even after the fan stopped because of the burning of the belt or motor, the updraft continued to force the smoke and flame into the main air course of No. 1 mine. A small fire was also started in No. 2 mine in which no men were working. The cause of the fan house getting on fire was not ascertained.

**ATTEMPTS AT RESCUE**

The district mine inspector arrived at 2:50 a.m., three hours after the fire started. He found the fan house and air chute burned to the ground, fires burning fiercely in both the air course and haulageway of No. 1 mine, and also in the air course of No. 2 mine below. All attempts to enter No. 1 mine had failed.

Meanwhile another electric fan had been hauled around the mountainside from the No. 4 mine opening at $E$, and the inspector had this fan set up at the mouth of the main haulageway at $C$ and run as an exhaust fan. The mouth of the normal intake airway at $B$ had been bratticed up with sheet-iron plates and earth, and as the door at the entrance to the main haulage opening $D$ on the other side of the mountain had been opened, that entrance became the intake. Then the inspector led a rescue party into the mine through the main entrance $D$, going in with the intake air current for 350 feet to $F$. Further progress was impeded by a fierce fire 60 feet ahead at the mouth of the first left entries. In these entries the five entombed men had last been seen. The party returned and closed the door at the entrance $D$ to stop the air current going to the fire.

It was then decided to drive a manway from the outcrop of the coal bed into the face $H$ of the first left air course. Accordingly, the company’s engineer, using lamps for sighting, extended a survey line around the thickly wooded mountainside from pit mouth $C$ to a point opposite the face $H$ of the first left air course. Excavating began at 4 a.m. and was completed in nine hours. Many miners volunteered, and the work was pushed as rapidly as possible in one-hour shifts. The manway when completed was 27 feet long, 4 feet wide, and 5 feet high.
This opening at $H$ (fig. 40) became an intake, as the newly installed fan was exhausting at opening $C$, and all other openings were closed. The inspector, after a preliminary examination with safety lamps, formed a rescue party to enter the first left entry through the manway. Before entering, the men erected a tight canvas brattice across the first left air course at a point marked $K$ to carry the intake air from the new opening through the last breakthrough and eastward along the first left entry. It was thought that the five entombed men would be found somewhere near rooms 5 and 6 off the first left entry, where they had last been seen by the night boss and a visitor.

**RECOVERY WORK**

After a wait of 30 minutes to permit the fresh air to force out the dense smoke and the gases from the first left entry, the inspector led in a party of six men. The entry was still somewhat warm and smoky as the party advanced 300 feet to the mouth of room 6. Several safety lamps were extinguished, but carbide lamps remained alight. A hasty advance was then made 100 feet to the face of room 6, where two bodies were found beside the cutting machine. Neither was burned; both men seemed to have fallen in their working positions, so quickly had they been overcome.

Room 5 was next explored through the crosscut from room 6 and the three other bodies were found. None of them were burned, and evidently no one had made any move to escape; the gases had apparently asphyxiated the men while they were at work. By 2:30 p.m. all the bodies had been recovered.

**EXTINGUISHING THE FIRE**

The mouth of the newly made manway was again closed and the fan at mine mouth $C$ (fig. 40) was reversed and run as a force fan. The work of fighting the fire began at $C$ with the intake air. A large electric pump from another company had arrived by rail. It was hauled up the mountainside and set up within and near the lower mine entrance. An accumulation of water in No. 2 mine was made available for fire fighting. As the fire in the lower mine had been extinguished with hand pumps and water buckets, all attention was given to fighting the fire, very hot and stubborn, in the upper or No. 1 mine.

From all indications the fire extended more than 150 feet into the main haulage way and main air course of No. 1 mine. The wooden door and brattice were destroyed in the first two crosscuts, as were the two doors between the first left and first right entries. On the second morning the fire-fighting crew had reached the first crosscut on the main haulage way and was directing the water from its hose
line through this crosscut into the main airway. A canvas brattice had been erected across the main haulage way inby this crosscut. The atmosphere inside the canvas brattice was very smoky and hot, indicating an active fire inby on the haulage way.

The fire was finally extinguished on the seventh day.

**REMARKS**

All fan houses and air conduits should be made of incombustible material.

All mine fans, where the hazard of fire exists, should be examined by a competent man every half hour or oftener.

Efficient fire-fighting appliances should be kept ready for immediate use near the mouth of a mine. Fire fighting and rescue crews should be organized and should have practice drills at regular intervals at least once a month.

Stopping should be of incombustible material.

A telephone system should be installed in every mine.

**FIRE CAUSED BY IGNITION OF NATURAL GAS FROM A WELL**

Gas wells in coal fields constitute a hazard which calls for special planning. If the position of a well is not known, the hole may be cut at any time and the gas may escape into the workings. An open light is liable to ignite this gas and set fire to the coal. The position of all known oil and gas wells should be shown on mine maps so that proper pillar reservations as well as mine ventilation plans can be made.

**44. AN UNCHARTED GAS WELL**

**ORIGIN OF FIRE**

In one mine a machine undercutting at the face of room 11 off the nineteenth left heading (fig. 42) cut into an old gas well which had been drilled some time before the opening of the mine. The gas was ignited by the machine man’s open light and set fire to the coal. The immediate ignition of the gas prevented its diffusion through the mine and perhaps prevented an explosion, as open lights were used. Fortunately, nobody was killed or injured by the fire.

The company had no information as to the position of the well. Precautions had been taken to find all gas and oil wells and have them recorded on the mine maps. A well found about 300 feet from the one cut into was shown on the mine map, and although it was a water well, the company allowed coal to stand around it as a safeguard. No information could be obtained concerning any other wells until this gas well was encountered underground. Then a search on the surface was started and the location of the well was determined.
MINING CONDITIONS

The mine, a drift opening, was working a bed of bituminous coal 3½ feet thick, with shale roof and floor, and was classed as non-gassy. Feeders had been detected, although none had emitted a large quantity of gas. Open lights were used. A 16-foot fan supplied 34,000 cubic feet of air per minute.

EXTINGUISHING THE FIRE

The fire broke out at 11 a.m. At 4 p.m., after attempts to recover the mining machine and to get to the fire had failed, a 4-inch brick stopping was started at the mouth of the nineteenth left entry and an 8-inch brick stopping at the mouth of the twentieth left. As smoke was filling that part of the mine, air was conducted to the bricklayers by canvas pipe. The stoppings were completed by 11 p.m., but were made 16 inches thick the next day.

It was decided to open the gas well at the surface and try to extinguish the fire by pouring water down, but the hole made in the casing by the machine became choked and the water did not reach the fire. As the fire was sealed off, it was allowed to smother itself.

About a month later men entered the room and built a strong stopping against the coal next to the gas well to prevent further trouble.

REMARKS

Encountering the gas well could not be anticipated, but in any coal field in which gas or oil wells have been drilled it would be wise to equip all mines with permissible lights and permissible electric machinery.

When gas or oil wells are abandoned in coal fields they should be filled from bottom to top.
FIRES OF UNDETERMINED ORIGIN

The causes of the fires mentioned in this section were not determined, but the reader may be able to reach some conclusions after a study of the details. The descriptions are given because of the firefighting methods adopted, the results obtained, and the lessons taught.

45. AN UNUSUALLY STUBBORN FIRE

When a fire has gained much headway, to play water from hose on it is often of no avail and complete sealing or flooding is the only remedy. Here is a typical example.

MINING CONDITIONS

The bed being worked was 6 feet thick and under a cover of 200 to 300 feet. The roof was sandy gray shale, which required careful timbering. The coal ignited easily. A foot above the bed was about 8 inches of "wild" coal.

Development (figs. 43 and 44) was by a drift on the hillside. All power was electric, including that for undercutting machines and locomotives. Black blasting powder was used to shoot the coal. Ventilation was by a motor-driven 8-foot disk fan, exhausting. As the motor was a constant-speed motor, the speed of the fan could not be changed. This fact caused trouble when the fire occurred, for the fan supplied too much air to the fire area. However, this situation might have been met by obstructing the air current or by-passing it.

FIGHTING WITH HOSE

Fire broke out in closely timbered cribbing in the main entry and caused the roof shale to fall; it eventually spread to the solid coal and to the "wild" coal in the roof. To fight the fire, 2,700 feet of 2-inch pipe was laid within 24 hours from a valley below the mine. The fire gained great headway before enough water was available. Water was played on the fire by a ¾-inch wire-bound air hose. The nozzle was not suitable, but the fire was fought for about 36 hours with this hose, and the crew succeeded in driving the fire back in three entries almost to the positions shown by the dotted line in Figure 43, which represents the limit of the fire zone.

The fire probably gained while being fought, as it spread inby, fed by a strong air current, faster than its outby end was extinguished by the small stream of water. Finally it became so hot that the men had to come out. A 4-inch pipe line was next laid. It burst at several points, was repaired, and finally delivered a good supply of water. Figure 45 shows steam drawn out of the mine by the fan, and Figure 46 shows smoke issuing from the main entry.
In response to a call, a third engineer (two were already there) of the technologic branch of the United States Geological Survey arrived with apparatus about 12 days after the outbreak. In spite of falls the fire was fought with water. Four days later two 50-foot lengths of 2-inch pipe were pushed over a large fall in the air course near the crosscut; they were connected to the 4-inch main and played water on the fire. Then the air course was shut tightly about 30 feet from the mouth by a double board stopping filled with well-rammed wet clay. A similar stopping was built 60 feet in by the main entry. Both stoppings were fitted with 2-inch pipes and valves for sampling air.

The fire smothered itself in about 25 days. A new main entry was completed about 2 weeks later.
The new main entry, driven 120 feet to the coal, was about 300 feet from the old one and beyond the fire. The fire area was then surrounded by stoppings. Figure 43 shows where the seals were placed.

46. FIRE STARTING IN A MOTOR ROOM

Fire of unknown origin started in a motor room near the main shaft and soon spread to the shaft, burned out the timbers to the top, and destroyed the headframe and surface buildings. Ten men were suffocated by smoke and gases.

MINING CONDITIONS

The mine, which produced 1,000 tons daily, was opened by two 700-foot shafts. A fan of 60,000 to 75,000 cubic feet capacity was at No. 1 shaft, the uptake. No. 2 shaft was the downtake, and the air was split at the bottom, half going to the north and half to the south of the mine. The coal, classed as subbituminous, was 6 1/2 feet thick. Methane had never been found, but as soon as the fire-clay floor became damp it heaved and emitted considerable carbon dioxide; to sweep this from the workings required a large volume of air. The mine was naturally dry and was sprinkled once a week by cars and hose. Electric and compressed-air machines undercut the coal. Miners used open lights. Black blasting powder was used in shooting the coal, and 40 per cent nitroglycerin dynamite in shooting rock. Shots were stemmed with coal dust; since then clay has been used.

FIRE-FIGHTING METHODS

The fire started at 8.30 p.m. As soon as the pit boss saw smoke issuing from the fan he and three other men went down No. 2 shaft, sent out five men working on the north side, and tried to extinguish the fire with a hose. Meanwhile somebody on the surface reversed the fan, hoping thereby to save 10 men working on the south side, and the fire fighters barely escaped with their lives. Then the fire gained headway and burned out the main shaft, which caved tight, and the whole mine was filled with black damp.

A Bureau of Mines rescue car was notified early the next day, and 13 hours later arrived at the mine; it brought rescue crews from two other mines. Two hours later four apparatus men went down the air shaft and repaired the partition between the two compartments to reestablish circulation. When men without apparatus could safely go to the bottom brattice crews were organized; the apparatus men went ahead to put up props and nail on boards, and the other men came behind with the brattice cloth. That night four bodies were found near the door at the parting at the junction
Figure 44.—View of mine mouth and surroundings, fire 45
Figure 45.—Steam in return air from mine, fire 45

Figure 46.—Smoke issuing from drift mouth, fire 45
of the fifth southwest and A entries. Three nights later three bodies were found between the fourth and fifth southwest and one body in the second southwest. By the ninth night all of the south side of the mine had been explored, but the two other bodies had not been found.

The air was then cut off from the south side and carried to the north side, which was fully explored, but no trace of the missing men could be found. The south side was again explored, and on the morning of the fourteenth day the two men were found in room 3 off L entry, where they had been overlooked during the first exploration. The failure to find these two men on the first trip caused 10 days of hard and dangerous work.

**REMARKS**

It is not safe to have a motor room or transformer station too near a shaft. Such a room should always be fireproofed and have steel or concrete doors which can be quickly closed.

Systematic installation of fire doors which can be closed, at the order of mine officials, when men have been withdrawn, is a valuable precaution.

Fans should not be reversed except by order of the official in responsible charge underground, and then only when the effects have been carefully considered.

**47. VALUE OF MINE-AIR ANALYSES**

Here is an excellent example of the value of sampling and analyzing the atmosphere of a sealed fire area.

**MINING CONDITIONS**

The mine was working, on the room-and-pillar system, a 6-foot bed that lies nearly flat. The shaft is 71 feet deep. The fan was underground and 60 feet from the shaft bottom. Fire of unknown origin broke out about 5 p. m. one day but was not discovered until 4 a. m. next day, when it was burning fiercely. No men were in the mine. Both shafts were sealed by 8 a. m.

**FIRE-FIGHTING METHODS**

A Bureau of Mines rescue car came by request two weeks later to assist in recovering the mine. With the aid of a maximum-and-minimum temperature thermometer and a gas-analysis apparatus, the following data were obtained:
Temperatures of mine air and water

Mine air 10 feet below seal over hoisting shaft.......................... 69°F
Mine air 20 feet below seal over hoisting shaft.......................... 74°F
Mine air 65 feet below seal over hoisting shaft, or 5 feet above water
at foot of shaft.............................................. 76°F
Water at foot of hoisting shaft.................................................. 78°F

Three samples of the mine air were taken through a 2-inch pipe
that reached 15 feet below the seal over the hoisting shaft; they
had the composition shown below:

Chemical composition of the mine air

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide (CO₂)</td>
<td>3.85</td>
<td>3.8</td>
<td>3.4</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td>8.03</td>
<td>8.5</td>
<td>8.7</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Methane (CH₄)</td>
<td>0.6</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Nitrogen (N₂)</td>
<td>85.9</td>
<td>86.9</td>
<td>87.05</td>
</tr>
</tbody>
</table>

The handicaps to fire fighting were (1) no water lines or other
means of getting water with which to fight the fire underground,
(2) no brattice cloth with which to erect temporary stoppings, (3) the
fan was in the fire zone and considered unrecoverable, yet the com-
pany was not disposed to get a new fan, and (4) no props for secur-
ing treacherous roof.

As both cages were in the hoisting shaft below the seal, it was de-
cided to remove temporarily the seal over the east hoisting compart-
ment to allow the cage in that compartment to be hoisted out of the
shaft. This was done, and the shaft compartment was resealed as
quickly as possible, permitting only the minimum amount of fresh
air to enter the mine. The cage was placed on the wings of the
tipple, and the rope for it was removed from the hoisting drum. A
horizontal 2 by 4 foot trapdoor was then constructed in the seal over
the west compartment to permit men to get on the hood of the cage
when it should be hoisted up to the seal. As men wearing breath-
ing apparatus had trouble in climbing up and down from the
hood to the floor of the cage these trapdoors were later discarded, and
a wooden air lock large enough to accommodate the cage was built
over the hoisting compartment at the ground landing.

Inspection of the mine by apparatus men revealed (1) the roof at
the shaft bottom was dangerous, (2) the fire was still burning, (3)
this fire was buried under exceedingly heavy falls, and (4) the extent
of these falls could not be determined as the air course led more
than 2,000 feet through old workings and was impassable because of
water and falls of roof.
Oxygen breathing apparatus, therefore, had to be used by the men while building a stopping across the main entry 50 feet north of the shaft in order to seal off the fire zone. This stopping was a canvas curtain reinforced by a brattice of tongued-and-grooved boards. It was 14 feet wide by 6 feet high. An analysis of a sample of air taken just prior to its completion showed: Carbon dioxide, 5 per cent; oxygen, 4.8 per cent; methane, 0.2 per cent; and nitrogen, 90 per cent. No carbon monoxide was found, an unusual condition where a fire is burning.

A certain amount of ventilation was then established by breaking an air pipe at the foot of the shaft and starting the compressor. This supplied enough fresh air to permit men to enter the mine, clean up the smaller falls, and retimber the shaft bottom.

This method of recovering a mine sealed on account of fire allowed but little fresh air to enter the mine until the stopping was built.

**Remarks**

Here again is demonstrated the value of breathing apparatus and trained men in reopening a sealed mine and the importance of a systematic method of attack.

**48. Value of Known Escapeways and Signboards**

**Origin of Fire in an Anthracite Mine**

In a mine that produced daily more than 2,000 tons of coal were two underground steam-driven slope engines and one tail-rope engine. One man tended both slope engines, as they were used only one and two hours, respectively, a day. One engine room had a timber frame for engine foundations, a plank floor, and a wooden cupboard for oil and supplies; 12 sets of 8 by 10 inch yellow pine and plank served for a boardwalk from the engine-room floor through a crosscut to a passing branch (a roadway); and several props in the crosscut supported the roof and held up steam and water pipes leading to the engine room. The room itself was lighted with a kerosene lamp. During the absence of the engineman (while he was at the other slope engine, about 800 feet distant by a short route) fire broke out in the first engine room and spread 300 feet into the branch roadway. The smoke and gases carried by an air current of 450 feet per minute filled about 25 acres of workings in half an hour and suffocated 72 men. Of the 84 men in the mine only 12 escaped.
MINING CONDITIONS

The mine was opened by two shafts, main hoisting and supply, sunk through a number of coal beds to a depth of 600 feet. The lowest bed (anthracite) had three splits, the bottom one with 4° pitch being opened from the No. 2 split by a rock slope about 700 feet northeast of the foot of the main shaft from the shaft-level gangway and also by a tunnel on the shaft level about 1,200 feet northeast of the foot of the main shaft. (Fig. 47.) The main haulage roads of the east slope and tunnel were served by a tail-rope engine, marked A in Figure 48, about 400 feet east of the foot of the main shaft.

The north-slope engine room, marked B, which was destroyed by fire, was in a heading parallel to the shaft-level gangway in the No. 2 split of the bed and 800 feet east of the foot of the main shaft. The engine hauled the coal from the north slope in the No. 2 split from the north basin to the shaft level. The new north-slope engine, marked C, was in the bottom split, about 800 feet by way of shaft D—1 east of the north-slope engine room; it hauled the coal from the north dip in the bottom split to the foot of the east-slope level.

This mine was ventilated by three exhaust fans, one 35 feet in diameter with single intake and two 20 feet in diameter with double intake, that furnished a total of 370,000 cubic feet of air per minute. The first was on the east side of the main hoisting shaft and the second on the west side, each exhausting from separate compartments; the two fan conduits were connected by a cross-drift on the south side of the shaft. The third fan was at the east end of the colliery yard. The bottom split of the lowest seam was ventilated by two main air currents, which were divided into six splits.

FIRE-FIGHTING METHODS

Smoke from the fire was first noticed at 8 a.m. at a point 500 feet east of the north-slope engine room by men who spread the alarm by telephone and by running to different places. Some of the men connected a hose to the water pipe and turned water on the fire from the north-slope side, all within 10 minutes. Another hose was attached soon after, and the fire in the engine room was under control, but timbers and many mine cars in the passing branch were on fire. The town fire department was notified, a hose line was run down the
supply shaft, and by means of a twin coupling two additional streams of water, making four in all, were thrown on the fire in the branch.

Between 12 and 1 o'clock noon the rescue departments of the district railroad and the Bureau of Mines were notified. The car of the former arrived at 3 p.m. with 13 men; it was followed immediately by 5 bureau men who came by train and street car and one hour later by a bureau car with 8 men, a total of 26 trained men and apparatus.

Meanwhile 12 men escaped; they reached the bottom of the main shaft two and one-half hours after they had been warned of the fire.

The rescue parties entered the mine, found that a regulator had been closed, explored some of the workings, and found three dead men. As it was considered impossible for anybody to be alive in this section it was decided to open the regulator and drain the area of afterdamp and black damp with which it was heavily charged. During this exploration one of the rescue men was overcome. He had been exposed to the gases from the fire for several hours before he donned the breathing apparatus. Efforts to revive him proved of no avail, although they were kept up five and one-half hours.

The fire was virtually extinguished by this time. Another exploring party entered the mine and found many dead bodies. A special crew was then selected to examine the mine and bring out the victims. By 2 p.m. the next day, or 30 hours after the fire started, all of the 72 bodies had been recovered.

REMARKS

An investigation of the fire area and workings led to these conclusions:

The fire was probably the result of carelessness—lighted matches, or the burning stub of a cigarette. It is possible, however, that the kerosene lamp was responsible, or the large amount of oily material in the engine room was ignited by an open light.

The water service for fires had been installed in the wrong place; it should have been on the intake instead of the return side of the engine room.

When the fire started no official was in its vicinity. The foreman and superintendent had been ill. All the colliery organization, however, worked incessantly and heroically.

The men fighting the fire seem to have lost sight of the fact that men on the inside were endangered by the fumes and smoke. If temporary stoppings had been constructed in the heading off the north slope leading into the engine room and on the main branch at the head of the north slope at N and O, respectively, the air current entering the tunnel would have gone down the east slope and through shaft D-1 (fig. 48) into the tunnel, and would have been entirely free from fumes.
The positions of the dead bodies indicated that the men lacked knowledge of the emergency exits. The men on the west side of the tunnel or straight road were found facing the return side of the air current, those on the straight road were facing the intake, and those on the east side were either undecided or bewildered, as their bodies were in different positions, except those of three men on the branch $K$, who were facing the leakage from the intake. One body was found at the door $M$ leading into the intake; the door was partly opened and the body was facing the intake. In the mine the emergency exits were ample, but the men evidently were not familiar with them.

RECOMMENDATIONS

The recommendations made by the bureau engineer after this disaster were as follows:

1. All rooms in which steam or electric machines for hoisting and pumping purposes are installed, and all stables, tool storages, fire-boss stations, and emergency hospitals, especially if their installation is intended to be permanent, should be constructed as far as possible of incombustible material, such as concrete, brick, or steel; close inspection of such rooms should be enforced by the colliery officials.

Use of all wooden cupboards, boxes, benches, and other inflammable receptacles should be prohibited. Wherever practicable, the use of timber should be discouraged in the construction of entrances of all kinds, such as tunnels, shaft lining, and shaft brattices.

2. All mines should be equipped with enough rescue and resuscitating apparatus for emergencies.

3. A selected corps of not less than six, preferably more, competent men at each colliery should be thoroughly trained in the use of the rescue apparatus.

4. A rescue, first-aid, and fire-fighting crew should be organized at each colliery. If rescue apparatus and trained company men had been available at the time the fire was discovered, the entire area affected could have been traveled by apparatus men to change the ventilation or to notify and rescue men.

5. A systematic campaign of instruction pertaining to the safety of life and property should also be arranged at each colliery.

6. As far as possible, all traveling ways or means of egress should be marked with fingerboards or signs, painted "This way out," and all employees should be drilled at certain intervals in escaping from the mines through these exits. All other unused roads not leading in the direction of the escape shafts or openings should be securely fenced off and properly marked "DANGER," with the proper way of exit plainly indicated.

The number of casualties might have been greatly reduced if more ready means than old workings had been provided for a regular
or emergency traveling way and if the miners had known of this means of escape. If the men had been properly warned and led by persons thoroughly familiar with the mine, they could have walked from the farthest face of the workings to a place of safety in only 10 minutes by going through the door M.

7. No better means of warning the men can be recommended than telephones installed on the main haulage roads, passing branches, hoist rooms, slope engine rooms, and pump rooms. However, telephones that have not a constant attendant should be equipped with a loud-sounding gong to attract attention.

8. As far as possible connecting doors should be placed between all main intake and return airways near the foot of the main upcast, and at the entrance to each split, so that the air currents in emergencies can be short-circuited.

9. In every underground stable made of combustible material a door of sufficient area should be left at the back or return end of the stable, this door to be operated from the stable entrance by a connecting chain, wire rope, or some other contrivance, so that the volume of smoke from a fire in the stable can be sent immediately to the main return and will not be carried into the interior part of the workings.

10. All main ventilating doors and timbers on main haulage roads should be given a coat of whitewash at stated intervals. All loose bark and decayed parts of timber should be carefully removed before whitewash is applied. This treatment will make the timber more resistant to fire.

11. All fire-service lines, fire pumps, and other fire-fighting equipment at collieries should be kept in good condition. All engine and pump rooms and stables should be equipped with water-line connections and enough hose and with chemical fire extinguishers kept in a fireproof room and available for immediate service in case of fire. Each mine foreman should be directed to report in writing to his superintendent at least once every month the result of tests made under his personal supervision, and to note the conditions of this equipment. All fire-fighting appliances should be installed on the intake side of the entrance to the room and stables.

12. Material such as asbestos should be substituted for the present use of wooden blocks on brake bands, which, owing to friction heating, give off smoke and fumes that are readily mistaken as coming from a wood fire. Portable kerosene blast furnaces with crucibles should be used to melt lead for reconing inside ropes; this would eliminate the smoke fumes caused by heating the lead over a wood fire.4

4The Bureau of Mines does not consider it safe to employ open lights or fires in any coal mine, according to recent recommendations.
If the men killed had realized the impending danger as soon as they detected the fumes, more of them would have escaped. Undoubtedly they mistook the first fumes noticed, thinking the fumes came from the tail-rope brake band and lagging, which often become heated and gave off much smoke.

49. CAVING A SLOPE MOUTH AND FLOODING TO EXTINGUISH A FIRE

A fire starting in the timbering of the upper part of a slope—near the surface—may, under favorable conditions, be smothered by caving tight the mouth of the slope; explosives may be used for the purpose. This was done at an anthracite mine where a fire (cause unknown) started in the timber lining of a slope manway (25° pitch) that extended from the surface into the mine. No water lines were available at the time. A number of men who were warned by the fumes escaped, but the fumes killed five.

The fan was stopped and the top of the slope was caved about 15 hours after the fire started; but although the mouth of the manway was sealed, the fire had extended into the mine. At this time the main intake air traveled westward along the water-level road for 1,000 feet to an inside plane, and after passing down the plane for 600 feet it was deflected east and west to ventilate four working lifts. The east lifts extended 600 feet west of the plane and the west lifts between 800 and 1,000 feet west of it. Men in any of the lifts would be exposed to the fumes from the fire.

The Bureau of Mines was asked to assist in the recovery. Three engineers and two volunteers from another company arrived with apparatus within 40 minutes after the call. Additional men and apparatus and a Bureau of Mines rescue car arrived shortly after. Part of the exploration was done with breathing apparatus and part without.

50. LACK OF ENOUGH BREATHING APPARATUS WHEN FIRE STARTED

Open carbide lights and black blasting powder were used and the coal was shot off the solid, but no shots had been fired on the day the fire started. An entry was making gas from small feeders in the floor and face. An open light may have ignited one of the feeders or the brattice cloth.

FIRE-FIGHTING METHODS

During the early stages of this fire two apparatus men managed, by regulating the ventilation, to drive back the smoke some distance, but the heat was intense, and they could only work a few minutes at a time. By turning more air into a crosscut that was connected
with the back entry in which the fire was burning the two men got within 130 feet of the fire and could play some water on it. The temperature was high and the steam was so dense that they had to wrap themselves in wet blankets, and the working periods were very short. While the oxygen cylinders of the breathing apparatus were being refilled men without apparatus tried to pour water on the fire, but were driven back. When the apparatus men were again ready the fire had gained such headway that decision was made to flood the workings. About 17 hours after the fire-fighting crew first entered flooding the mine was started; 20 hours later 1,000,000 gallons of water had been pumped in and the fire extinguished. Apparatus men who watched the progress of the flooding reported, among other things, that the water from the area was very hot. Mining was resumed two days later. It was the opinion of the company officials that if at the beginning they had had four or five sets of apparatus instead of two the fire could have been extinguished with the hose. The company had been urged to procure more apparatus, and after the fire did so, not only at this mine but at four other mines.

REMARKS

The superintendent of the mine made these excellent recommendations to the general management:

Use safety lamps throughout the entire mine.
Discontinue shooting off the solid and undercut all coal.
Replace black blasting powder with permissible explosives.
Discontinue unsystematic shooting by miners and install an electric shot-firing system similar to that used at other mines of the company.

51. EXPLOSION DURING THE SEALING OF A FIRE

MINING CONDITIONS

A 6-foot bed of bituminous coal with shale roof and floor was opened by a slope driven down the pitch (9°) and was mined by the double-entry room-and-pillar system. In the panel where the fire started most of the pillars had been removed. The right side of the mine was making gas and safety lamps were used there, but as no gas had been detected in the vicinity of the fire zone black blasting powder and permissible explosives were used, set off by shot firers and electric batteries in the section rated as gassy and by miners in the area rated as nongassy. A reversible fan supplied ventilation. The mine was generally moist.

50769°—27—10
Fire was discovered in the seventh left flat air course at about 11 p.m. The fire was apparently extinguished with water from a hose, but a local explosion two days later showed that the fire was still smoldering. (See fig. 49.)

It was then decided to seal off the fire area, and the work was started on the afternoon of the third day and continued until the sixth day. During the progress of this work hourly examinations were made for any gas generated by the fire, and reports were made by telephone to the office outside. All reports gave conditions as safe. When the last brattice was nearly completed and only a few minutes more were needed to finish the work, an explosion killed 1 and overcame 2 of the 7 men in the mine. The four men that were not affected brought the others to the surface. The explosion was confined to a small section on No. 7 left flat.

A pipe had been inserted in stopping 15 (fig. 50), and the fire area was flooded soon after. Samples of air taken about 100 days after the fire was sealed showed 48 per cent methane in the main return at the foot of the air shaft, 14 per cent in No. 3 butt air course off the
eightieth flat, 22 per cent in the seventh flat air course at the first breakthrough from the last room on No. 2 butt off the eighth flat, and 25 per cent in the seventh flat air course at the second breakthrough from the last room on No. 2 butt off the eighth flat.

When the water was pumped out, many difficulties arose, including rapid corrosion of the discharge pipes by the acid mine water. The mine was finally pumped out, but gas that had accumulated in the various entries had to be removed carefully. The third right entry was estimated to contain about 1,000,000 cubic feet of gas.

**REMARKS**

The fire and subsequent explosion demonstrated that although a fire may seem to be extinguished, yet in the adjacent gob there may

![Diagram](image)

**Figure 30.—Details of fire zone, fire 51**

be smoldering coals hot enough to ignite an explosive mixture. The area surrounding the falls in some of the rooms did not give any evidence of fire near by. The result shows the need of most careful inspection for fire, and that sealing, if necessary, should be done as quickly as possible and the men withdrawn from the mine.

**52. FLUSHING IN SOIL WITH CREEK WATER**

The following methods of extinguishing a fire were used at a bituminous mine that employed 45 inside men and produced about 160 tons of coal daily. Above the 8-foot bed of coal were 6 to 8 inches of draw slate, 24 inches of black carbonaceous shale, and 3 inches of “rooster” coal.
The cover was less than 50 feet thick. A 12 by 2\(\frac{1}{4}\) foot force fan supplied 42,600 cubic feet of air per minute. The air shaft was 30 feet deep and had an escape compartment with stairways.

Smoke was discovered issuing from the surface above a caved section of the mine from which the pillars had been extracted (see fig. 51) except for some stumps left to support a creek. The cover there was about 20 feet. Caves had come to the surface on either side of the creek, most of which had been filled in and seemed to be water-tight. The creek flow was about 200 gallons of water per minute.

To extinguish the fire about fifteen 6-inch holes had been put down with a churn drill. These holes had then been charged with 40 per cent dynamite and fired, and the creek turned into the cavity. Men then shoveled the soil into the mine. Hot gases, smoke, and steam from the fire were escaping from a number of these holes under the pressure created by the fan, which was a blower. On account of the caved ground the fire was not accessible from within the mine, but it was reported that gases from the fire had not entered any of the workings.
Figure 52.—Surface above fire area, fire 52

Figure 53.—Creek above fire area, fire 52
Fires of Undetermined Origin

When a Bureau of Mines engineer visited the mine, three holes, marked 1, 2, and 3 in Figure 51, had been drilled into the shale above the coal. Holes 1 and 2 did not penetrate the mine, but 3 did. It was sealed at the bottom by dropping in a post and shoveling in muck and sod; a hole about 12 feet deep was left that would hold water. In each of the three holes a charge of 75 pounds of 40 per cent dynamite was to be fired simultaneously, to be followed by the flushing in of surface dirt. The company officers thought that in this way a barrier could be made with the material flushed, and this barrier would prevent the fire from encroaching on the workings of the mine. The coal dips about 7 per cent, or enough for the water, after depositing the sand and dirt, to run into the mine from the fire area.

A study of the mine map indicated that the fire area could be separated from the other workings by making 10 or 15 stoppings, probably the most logical method of attack. Between this mine and the adjoining property, about 400 feet from the fire area (fig. 51), was a thin barrier pillar with an opening.

Recovery Work

Ten days after flushing, the surface immediately over the fire area was examined. The holes and craters previously visible had been closed with loose soil, and pools of water were standing in several of the depressions. Hot smoke and gas were escaping from a surface crack near the water-line trench about 20 feet west of the county road. The smoke and gas had the strong odor of a coal fire. A sample of the gas contained 4.82 per cent carbon dioxide, 14.37 per cent oxygen, 0.56 per cent methane, and 80.25 per cent nitrogen. The northeast corner of the bridge over the creek had subsided noticeably. Figures 52 and 53 show the surface above the fire area.

Underground, the main haulage way to the fire area showed smoke or heat, the pillar workings were well filled from caves, and mud from previous flushing from the surface was to be seen. Miners were removing stumps near two rooms.

A sample of air from a cross section at an opening that led to a cave to the surface contained 0.63 per cent carbon dioxide, 20.16 per cent oxygen, 0.09 per cent methane, and 79.12 per cent nitrogen. Another sample taken 20 feet out by No. 2, 10 inches from the floor, where a safety lamp had been extinguished three different times, contained 7.83 per cent carbon dioxide, 10.69 per cent oxygen, 0.89 per cent methane, and 80.59 per cent nitrogen. The volume of air was 11,100 cubic feet. The return air from the south side of the mine,
which included that from the fire area, contained only 0.06 per cent methane.

53. A MINE EASILY SEALED

Figure 54 shows how a fire was sealed in a drift mine that produced 300 tons of coal daily from a 9-foot bed. About 30 feet of cover overlay the fire area. The first stoppings leaked badly, so they were doubled and were filled between with clay. This sealing was successful.

54. WATER PIPE THRUST INTO BURNING COAL—SEALING NECESSARY

Thrusting the end of a water line into burning coal was tried at one small mine. The fire, which was 600 feet inside, had been burning about 40 days. Sealing and partial flooding had been tried, but the fire had extended above a point that could be reached by flooding. A pipe that had been laid in the mine was extended. A wooden X frame supported the last two lengths of pipe in the position desired. The fan was kept running while apparatus men thrust the end of the pipe into the burning coal and retreated before the water was turned on. All openings were closed, the fan was stopped, and water was allowed to flow all night. The trial was not successful, however, and the method usually fails unless enough water is put in to flood the burning coal or material.

Effective sealing was found necessary to extinguish this fire.

55. WELL-PLANNED SEALING AND RECOVERY WORK

This fire is supposed to have been started by a shot that "blew the stemming." Coal was shot off the solid with black powder. A shot firer was employed. The coal bed is 5 feet thick and lies under a cover of 320 feet. The immediate roof is a dark blue shale from a
few inches to 16 feet thick, above which is sandstone. A peculiarity of the roof slate is the many sulphur concretions which project into the coal; they make blasting difficult and cause blown-out shots, which often result in fires.

Figure 55.—Sketch showing how fire was sealed, fire 55

FIRE-FIGHTING METHODS

The fire had probably been burning two hours before smoke was seen; then the area was hastily surrounded with brattices 1, 2, 3, 4, 5, and 6 (fig. 55). The first four were built of inch boards made airtight with clay. Stopping 5 was formed by caving the roof.

When a Bureau of Mines car arrived two days later, it was decided to construct an air lock by building another brattice 5 feet outside of brattice 3. Through this air lock the apparatus men could get into the fire area without allowing fresh air to enter. The first work with apparatus was to tighten brattice 6, which had been hard to build and was leaking. By this time, 85 hours after the sealing of the area, it was expected that the smoke would have settled, but the
men found the smoke and steam so thick that nothing could be seen. Electric storage-battery lamps were used.

The temperature was very high, the roof was "drummy," and there had been a fall of shale. A sample of the air within the sealed area showed, 5.5 per cent carbon dioxide and 13 per cent oxygen, but no carbon monoxide. Room 6 and two entries were sealed by cloth and board brattices A, B, and C, a difficult job. Fresh air was directed into the places where the stoppings were being erected.

To turn in the fresh air, curtain G was torn down so that as little air as possible would be blown over the fire when the air lock was opened. Brattice 6 was then torn out and a curtain hung at H, after which the air-lock door at J was opened and the smoke was cleared out of the second south immediately. Men wearing apparatus then completed the board stoppings at A, B, and C without trouble.

The smaller fire area was reopened 12 days after it was sealed, or 16 days after the fire started. Stopping C was torn down, and no smoke was evident, a fact showing the value of tight stoppings. A curtain frame, G, was erected between the first and second east entries on the second south, and a curtain was hung partly across the entry. Then the wood stopping at A was torn down and the curtain brattice G on the second south entry made tight, which sent the fresh air into room 6 and out the second east entry. The men then followed this air in by through room 6, through the right cross-cut into the first east entry, and thence to the point of origin of the fire at the face of the first east entry. Thorough inspection seemed to show that the fire was out.

Circulation of fresh air was allowed to continue, and the place was left to "air out" and cool down. Three hours later the fire boss, returning to inspect the place, found that the fire had revived. He quickly summoned help, returned with buckets, went to the face of the first south entry (this entry was driven to the dip and had water at its face), and there obtained enough water to quench the flames. He said that much smoke was coming from beneath a small fall caused by the fire, and that the hot coals rekindled very quickly and made a fire hard to extinguish.

**REMARKS**

The following features of recovery work were demonstrated at this fire:

Any brattice used to seal off a fire region should be made as air-tight as possible.

Never conclude that a fire is out until all falls near the fire have been cleaned up.

Only trained men should use breathing apparatus in fighting fires or in rescue work.
Apparatus men should test the apparatus in a surface smoke room immediately before entering a poisonous atmosphere in which they are to do work.

Always have an extra bottle of oxygen at the most advanced base. Never allow less than five men wearing apparatus to enter for rescue work, and have in reserve at least five men wearing their apparatus and ready to turn on the oxygen.

Rescue men while traveling in dense smoke in a strange mine should pay out a rope in order to have a sure and certain means of finding the way back.

56. BLACK DAMP EXTINGUISHES FIRE

Two years prior to the fire discussed above another one had broken out in the same mine, and engineers of the technologic branch of the United States Geological Survey, wearing breathing apparatus, had assisted in recovery work.

![Diagram](image)

**Figure 56.**—A, Sketch of fire area, showing direction of air; B, sketch showing position of stoppings, fire 56

At this fire heavy falls interfered with operations. The fire was fought back with a hose for four days, but as black damp was found in large quantities at the mouth of the fourth north, immediately inside the crossover switch from the third north, and most of the fire fighters were more or less affected by the black damp, it was decided to erect the stoppings shown in Figure 56, B. These prevented access of fresh air and allowed the black damp to smother the fire. A 2-inch pipe with cap was left in the stopping on the return side of the fire. Figure 56, A, shows the fire area and the direction of air currents before the stoppings were erected.

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*A gaseous mixture of carbon dioxide and nitrogen in varying proportions, frequently accompanied by carbon monoxide.*
At this mine the coal lies at a depth of 140 feet. The seat of the fire was approximately 2,000 feet from the air shaft and 2,600 feet from the main shaft. (Fig. 57.) There were 300 men in the mine when the fire was discovered; all except seven escaped.

In spite of prompt attempts to fight the fire, it soon got beyond control. Crews from two State mine rescue stations had entered the mine and found the fire and signs of where the seven entrapped miners had gone. They also encountered explosive mixtures of gas near the fire, and gave the opinion that further efforts to rescue the men might result in more loss of life. Accordingly the mine was sealed, within 12 hours after the fire started. Bureau of Mines engineers, who were detained by an explosion at another mine, arrived after the mine was sealed.

It was decided to drill a hole through 140 feet of cover into that part of the third north entry where the seven men would probably bulkhead themselves off. To drill the hole took about 100 hours. When first drilled through the hole "drew air," but a sample of air taken from it about 16 hours later showed 7.4 per cent carbon dioxide,
3.1 per cent oxygen, 4.4 per cent methane, 0.3 per cent carbon monoxide, and 84.8 per cent nitrogen—a deadly atmosphere. Soundings were taken with the geophone on the first day of drilling, or three days after the outbreak of fire, and later on, but there were no sounds to indicate that the men were alive.

**RECOVERY WORK**

The mine was left under seal for 22 days. Meanwhile the State had supervised construction of an air lock over the air shaft. Two State rescue cars and one Federal rescue car and crews arrived to assist in reopening the mine. The seal over the air shaft was opened, and men wearing breathing apparatus entered. Seals were constructed near the bottom of the shaft and a fresh-air base established. By means of seals and air locks the men advanced to the fire area, which did not extend across the mouths of the third and fourth north entries. There had been heavy falls in the main west entries.

**FAILURE OF BARRICADE FROM EXPLOSION INSIDE**

The bodies of the seven entombed men were found 19 days later in a parting which was being driven off the third north entry, the place where it was expected the men would retreat, and where the hole was drilled. The men had erected a board barricade 40 feet from the face of the parting. Then they had started to build another in by the first one, but not having enough lumber to complete it they used their clothing. Evidently there had been a gas explosion within the barricaded area, as part of a barricade was blown down, and the men were suffocated by fumes from the fire or from the explosion. Open-flame carbide lamps were used in this mine, and doubtless an accumulation of gas in the sealed area was ignited by the lamp of one of the men. Had the mine been equipped with electric lights they might have been saved.

**58. FIGHTING A FIRE WITH ITS OWN GASES**

Either an open lamp or a short-circuited electric wire ignited timbers in No. 3 mine at the point marked “Fire” in Figure 58 and set fire to the coal. In spite of all efforts the fire had not been fully extinguished 17 months after it started. As fighting this fire involved unusual difficulties and great expense, the methods used should be of practical value at other coal mines.

**MINING CONDITIONS**

The mine works two beds of coking coal that dip about 5° and are separated by 3 to 5 feet of shaly sandstone. The lower bed, in which the fire occurred, is 10 to 12 feet thick; the upper bed is 5 to 5½ feet thick. The mine was rated as nongassy.
Figure 58.—Skeleton plan of mine, fire 58
Ventilation was by an exhaust fan at one opening, and there were intake openings as shown in Figure 58. The daily output was 1,200 to 1,400 tons. Shot firing was by electricity (500 volts, direct current) from outside of the mine.

SEALING THE MINE

The fire originated at a point where the men congregated while waiting for a man trip (motor haulage). The floor here was wet, and no inflammable material was lying about. The fire was fought with water hose for about 36 hours. (Fig. 59.) Then came a series of gas explosions and it was decided to seal the mine. Sealing was completed 30 hours later. The seals were at the portals and outcrop openings, and the sealed area comprised about 540 acres of active and abandoned workings in which were approximately 96,-000,000 cubic feet of excavation. As the mine normally gave off black damp (carbon dioxide and nitrogen), it was hoped the fire would be smothered by the mine gas and by the depletion of oxygen.

![Diagram](image)

**Figure 59.—Section of main slope, showing conditions while fire was being fought with hose, fire 58**

While the mine was sealed, samples of the air inside were taken daily. At the end of 21 days no carbon monoxide could be detected by the Orsat apparatus, and the oxygen content had fallen to 5 per cent. After 39 days an analysis of the atmosphere behind the stopping near the fan opening showed only 0.66 per cent oxygen, 4.65 per cent carbon dioxide, 0.05 per cent carbon monoxide, 0.89 per cent methane, and 93.85 per cent nitrogen. The temperature was 59° F.

BREAKING THE SEALS

The first seal near the fan opening was broken 39 days after the seals were completed, or 52 days after the fire broke out. A large crew of apparatus men advanced the fresh air circuit, by stages of 400 to 800 feet, to the seat of the fire within 23 days, but the fresh air was kept from the fire by air locks.

The hot caved workings contained an atmosphere of which the following analysis is typical: 2.41 per cent oxygen, 3.86 per cent carbon
dioxide, no carbon monoxide, and 0.66 per cent methane. It was found that if any air leaked into the workings the oxygen increased enough to make the coal give off considerable smoke. Once a blaze started while the fresh air circuit was being advanced. Note was made of the "breathing" of the mine gases under changes in barometric pressure. The fan was kept running during the advance.

After the fire area was reached (fig. 60) about 200 feet of new crossect had to be driven in order to get at the fire from more than one point. The farthest point reached by the fire was more than 1,500 feet from its origin. While this crossect was being driven,

apparatus men working in bad air loaded out some caved material; after the crossect was finished two unsuccessful attempts were made to load out hot material in fresh air. The mine gases had to be again directed on the fire to put out the flames that started. Ultimately the fire area was recovered after a long and difficult fight.

Apparatus men continued to load out hot material until 211 days after the seals were opened. These men could remain in a temperature of 190°F. for a few minutes, and at least one minute in a temperature over 220°F., were the air dry. The company had available 24 breathing apparatus, all of which gave good service. They were tested and cleaned regularly by experts. Between 50 and 60 appa-
ratus men were employed for more than six months, and they worked over 10,507 periods, in which they used 13,533 regenerator cans and 210,000 cubic feet of oxygen. A period was four hours long and on an average about two hours of it was actually given to work in the noxious atmosphere. The apparatus men cleaned up 3,835 feet of slope and entry, from which about 5,500 cars of caved coal and rock were removed. From one cave, 30 feet high and 30 feet wide, 40 cars of coal and rock were removed for each foot of advance.

REMARKS

Electric wiring in a coal mine should be properly installed to avoid the possibility of short circuits.

Fire extinguishers or hose should be readily available at points in the mine where men gather, and approved extinguishers for fires in electrical apparatus should be kept at all underground electric stations.

Open-flame lights should not be used in coal mines.

After a fire gains considerable headway, to shut down the fan or short circuit the air may be important, otherwise under such conditions the fire may spread rapidly in different directions.

One of the chief dangers to fire fighters when modern rescue apparatus is available is from falls of roof; these falls may be caused by the direct heat of the fire itself or by the hot gases rising from the fire.

After a fire has gained considerable headway it is usually better to keep just enough air passing over the fire to draw the smoke away; but at some fires an ample circuit of cool air may be carried to the fire fighters by a line brattice or by air pipes.

The drawing of inflammable gases over a fire must be avoided; careful control of the direction of air currents is essential.

A small hose is more easily handled than a large one, but a large hose giving a greater volume of water is necessary to wet smoldering coals under falls.

When a fire is sealed off great care must be taken to avoid an explosion. The air current should be controlled, if it can be, so as to keep inflammable gases away from the fire until the final seals are ready to be closed. Where conditions permit, the final seals should be closed by some automatic device after all the men have been withdrawn.

When a large area is sealed off, the absorption of oxygen by coal is an important factor in rapidly lowering the oxygen content of the atmosphere of the sealed area.

When gases are bottled up in a sealed area, the “breathing” through the seals or adjacent strata may be strong. This breathing
is caused by daily fluctuations in the pressure of the outside air and by the passage of storms.

It is difficult to approach a hot area surrounded by depleted air without admitting some fresh air to the fire, but admission of fresh air can be minimized by proper control of the ventilating currents.

Comparatively low temperatures close to a cave that contains glowing coals covered by falls may be very deceptive; consequently it is necessary to be continually on the watch for buried hot material.

Air containing not more than 5 or 6 per cent of oxygen will not support active combustion.

A hose stream of water is of no avail in fighting a fire unless it can be played directly on the hot material or unless the fire can be flooded. Water played on a large pile of caved and hot material will usually reach only a very small part of the material in the pile.

When water is used on a fire the steam makes the atmosphere unbearable for men unless they have special protection, such as movable shields, and air currents are carried to them by line brattices or air pipes. In constricted places air pipes are usually more practicable than line brattices.

59. FLOODING AND SEALING A PERSISTENT FIRE

In an anthracite mine a fire in abandoned and caved workings was fought by 12 men who wore breathing apparatus daily for five months and faced many hazardous conditions. No accidents happened and none of the men showed ill effects from prolonged wearing of the apparatus. During the five months 4,512 pounds of regenerative material and 9,000 cubic feet of oxygen were consumed in the breathing apparatus worn.

Figure 61 is a section of the property; it shows the coal bed worked, No. 2 shaft, and the fire area. The bed is 12 to 20 feet thick, and ranges from flat to vertical. The general method of mining is by room and pillar. Eight feet of the coal is taken in the first mining.

Men working on the rock slope complained of not feeling well. Samples of the air showed carbon monoxide in proportions that gradually became higher. This was evidence that there was a fire somewhere in the mine, and exploration was started to discover it. Approved gas masks and a carbon monoxide detector were used. Tests showed that the intakes to the slope workings carried no carbon monoxide, but the returns carried some; therefore the fire was in the old slope workings. Exploration was begun in that section, but the air became so bad that flame safety lamps would not burn, so eight sets of breathing apparatus were procured.
A Bureau of Mines engineer was detailed to supervise the work of the apparatus crews. The conditions were (1) a fire in abandoned and caved workings and not directly accessible was polluting the return air and threatening to interfere with the normal operation of the mine, and (2) extension of the fire into abandoned workings on the shaft level would make sealing difficult, if not impossible. It was finally decided to flood part of the area and seal the remainder, a total of about 20 acres. First the intakes were sealed; then the partial flooding was done; finally the returns were sealed. The work was difficult and hazardous, but was completed successfully.

**LESSONS FROM THE FIRES**

Throughout this volume, under the heading "Remarks" after the description of a fire, the authors have presented comment on the cause of the fire, the methods used by the fire fighters, and the precautions that should be taken to avoid fires of similar origin. In
addition, they have given recommendations made by the Bureau of Mines after several of the fires. Some of these comments and recommendations apply to all mine fires, some to fires of a certain class, and some to the particular fire.

By way of final summary the authors give these findings as the chief lessons that are taught by the 59 fires.

Coal mines shall be so laid out and worked that sealing a fire which gets too strong for direct attack will not necessitate inclosing a large area of the mine. Many mine fires originate in abandoned, unused, and, too often, uninspected old workings. Such places and all others that can not be inspected regularly should be sealed off with tight fireproof stoppings.

In coal fields where gob fires caused by spontaneous heating are common, room-and-pillar workings should be laid out in panels with only four or five openings, each opening provided with an emergency door. Where pillar drawing is practiced, it is advisable to draw pillars as soon as the working places have gone their full distance.

All structures on the surface that are at or near mine openings, especially intake airways, should be built of incombustible material.

Water lines, hose, and an ample storage of water should be provided on the surface. Water lines should extend throughout all active workings in the mine, taps should be provided at frequent and regular intervals, and hose should be easily accessible. This equipment should be marked on fire maps which should also show the normal direction of the ventilating currents and all overcasts, doors, and permanent stoppings. At a gassy mine the maps should indicate where gas is found frequently.

Little wood should be used in shafts. Downcast shafts and shaft bottoms or landings should be fireproofed or built of incombustible material; similar construction should be used for oil, pump, engine, and motor rooms and stables underground. These rooms should have iron fire doors, shutting from the outside. The upcast and downcast currents should never be placed in the same shaft and separated by a partition.

Open lights should not be used in coal mines.

Black blasting powder and dynamite, which have been responsible for many fires at the face, should be replaced by permissible explosives fired with electric detonators.

Shots should be fired by responsible mine officials.

A good underground telephone system is invaluable for fighting a mine fire.

At mines where the coal ignites easily, and at all bituminous mines where the coal is shot with black blasting powder or dynamite, firemen (fire runners) should inspect the faces after shot firing.
Electric lines and wires should be properly installed and regularly inspected. Ventilating currents at times of fires should never be reversed except by the written authority of the highest responsible mine official after he has received reports from the interior of the mine.

Breathing apparatus and apparatus men should be immediately available at all mines or at joint rescue stations not more than one-half hour distant from any mine.

At each mine the men should be organized to fight fire and should carry on a drill at least once a month.

Analyses of samples of the atmosphere of a sealed fire area are of much value in determining the progress of a fire and the tightness of the seals, but samples obtained when air is intaking through a particular stopping may be misleading unless that fact is noted.

Sealing or reopening a fire area in a gassy mine is a task that calls for sound judgment and great care. It is a disputed question whether the intake or the return air should be sealed first. Sometimes conditions compel one procedure or the other, but in general it is advisable to seal the intake first. The authors propose that the seals be built simultaneously and be provided with doors which may be shut by mechanical means or by timing agencies after the men have been withdrawn from the mine. In every bituminous and subbituminous mine the area near the seals should be thoroughly rock-dusted, if possible, before sealing.

Before a mine is unsealed analyses of samples of the mine atmosphere, systematically taken through pipes, should show no carbon monoxide and less and 5 or 6 per cent (maximum) of oxygen. Absence of carbon monoxide in a sample does not prove that the fire is out, but its presence even in fractions of 1 per cent invariably indicates, as experience has shown, that the fire is capable of reviving. This applies to coal-mine fires only, as carbon dioxide appears to be absorbed rapidly by coaly material. When a fire area is to be unsealed, and dangerous proportions of inflammable gas (2 per cent or more) are present in the area or its vicinity, the ventilation should be so planned that the gas will not be drawn over piles of gob that may conceal small smoldering fires.

Mine rescue crews, composed of experienced men who have obtained Bureau of Mines certificates and are equipped with permissible oxygen breathing apparatus and permissible gas masks, should be on hand to render assistance during the sealing or unsealing of fires.

All safety in mines rests fundamentally on foresight and discipline.
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