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MSHA REGULATIONS AND BOM RESEARCH PROGRAM ON MULTIPLE SHORT-DELAY BLASTING OF COAL

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ABSTRACT

As the first stage in the rulemaking process, MSHA prepared requirements for the approval and use of permissible explosives and blasting items in underground coal mines. These draft requirements known as "preproposals" were announced in the Federal Register in mid-1984. The draft requirements on the use of explosives were written as a revision to Title 30, Code of Federal Regulations, Part 75, Subpart:N. The draft requirements for approval of permissible explosives including sheathed explosives for unconfined applications, approval of water stemming bags, approval of detonators and approval of blasting machines were prepared as Parts 15, 16, 17 and 25 respectively.

During the development and preparation of the preproposals, it was determined that field research on delay blasting of coal would be needed before the draft approval and use requirements could be finalized. In order to conduct the field research, an experimental site was acquired by the Bureau of Mines. The Bureau of Mines under a contract, obtained a surface coal mine site in Ohio to conduct field research on the delay blasting of coal. The major objective of the research program was to study total elapsed delay time for blasting bituminous coal and determine if it could be safely expanded beyond the present 500 millisecond limitations without igniting a methane or methane/coal dust atmosphere. The preliminary results from the work completed to date indicate that the increase of total delay from 500 to 1000 milliseconds has no detectable effect on safety relative to incendivity as long as permissible practices are observed in all other aspects.

Further testing and assessment of the data are needed to validate the observations and conclusions reported in this paper and to establish a firm basis for regulatory changes. The research program discussed in this paper is continuing.

INTRODUCTION

For the purpose of improving regulations, MSHA has made a comprehensive review of the blasting and explosives standards for underground coal mines which are contained in Part 75, Title 30, Code of Federal Regulations. A concurrent review was also made of the approval requirements contained in Title 30 for permissible explosives, blasting machines and related blasting items. From these reviews, MSHA completed development of preproposal safety standards for the use of explosives in underground coal mines and related requirements for the approval of permissible explosives and blasting items. The preproposals are the first stage in the MSHA rulemaking process whereby public comments are solicited for consideration, review and evaluation prior to an MSHA proposed rule. The current\approval standards, which contain use requirements for explosives, were reorganized and the use requirements were consolidated into a revised Part 75. The revised Part 75 contains sections on the use of explosives in bituminous, lignite and anthracite mines and a section on compressed air blasting; The preproposed approval standards cover approval requirements for permissible explosives including newly prepared requirements for sheathed explosives for use in unconfined applications, approval requirements for water stemming bags, new approval requirements for detonators and also requirements for approval of blasting machines. These preproposed explosive use and approval requirements were announced in mid-1984 in the Federal Register with a request for public comments.

During development of the preproposed explosive use and approval standards, MSHA requested the Bureau of Mines, U.S. Department of the Interior to conduct experimental research on multiple short-delay blasting of coal with permissible explosives. The type of research work requested had not been performed since the work done in the Bureau's Experimental Coal Mine at Bruceton, Pennsylvania over 30 years ago. Accordingly, the Bureau with the assistance of MSHA sought a mine site to conduct the experimental research on the delay blasting of coal with permissible explosives. A site was found for the experimental work and officially acquired in early August, 1984. The site, known as Consolidation Coal Company's Dark Hollow Mine, is located between St. Clairsville and Cadiz, Ohio. It is a surface coal mine site covering several acres of bituminous coal, from part of which the overburden has been removed, and a nearby 50 foot highwall. The exposed coal seam (Pittsburgh No. 8) and the seam in the base of the highwall are about 5 feet thick (see Figures 1 and 2).

The main objective of the Bureau's experimental research at the acquired site was to study and determine if the total elapsed delay time for multiple short-delay blasting of bituminous coal could be safely expanded beyond 500 milliseconds without igniting a methane or methane/coal dust atmosphere. MSHA presently limits the total elapsed time to 500 milliseconds. The experimental arrangements, tests performed and conclusions made are described herein.

EXPERIMENTAL PROGRAM

The first series of shots at the Dark Hollow Mine was conducted in a pit in which the overburden had been stripped from the S-foot thick coal seam. The resulting-exposed coal block was approximately 250 feet long by 100 feet wide. This test area provided ideal research conditions since shooting could be conducted in an actual coal seam while avoiding many of the difficulties that would be encountered in an underground coal mine. For each of the shots, steel ingot 8 were placed on top of the coal to provide burden and minimize the tendency of the coal to relieve in the upward direction. Preliminary shots indicated that 100 tons of steel ingots placed over an area measuring 20 by 10 feet was sufficient for this purpose. Placement of the steel ingots is shown in Figure 3.

The delay blasting research began with a series of two- and three-hole shots to provide information necessary for the design of appropriate test blast patterns. The initial shots showed that when 2 fully stemmed, 90-inch deep, l-3/4-inch diameter holes, each loaded with 3 pounds of permissible explosive, were rear primed and fired at a 24-inch horizontal spacing with a 75-msec delay, partial misfires (failure to propagate detonation throughout the explosive column) were consistently observed. Examination of the muck pile showed the misfires to be the result of cut-off holes; the misfired cartridges of the second hole were no longer in a column but were shifted up to 12 inches to either side of the original column location. These misfires were avoided if the holes were p-laced 24 inches apart vertically or diagonally, spaced 30 inches apart horizontally, or the explosive load was lowered to 1.5 to 2 pounds per hole. Considering this information, the blasting pattern illustrated in figures 4 and 5 was developed. This pattern, known as an "off-the-solid" slab round is commonly used for conventional mining of coal in Appalachia. Two-inch diameter holes made by a hand-held drill were used in this phase of the research. In some of the earlier work, l-3/4-inch holes made with a drilling rig were used. However, the drilling rig was not available throughout the test program. The slab round pattern permitted the research work to be conducted with total elapsed delay times up to 5500 msec. Emphasis in the test work was placed on experiments using the slab pattern with a total elapsed delay time of 1000 msec. In the experimental work, the explosive columns were rear primed, file loaded and clay was used for stemmed shots. Later in the research, agreement was made with Consolidation Coal to use another pit which had a 5-foot high coal seam in a 50-foot highwall. At this location shot holes were loaded to 3 pounds but the length of the coal face available permitted only a limited number of test shots. The type of permissible explosive used, the explosive loading per hole, and delay timing were varied to determine the effect of these parameters on safety relative to incendivity. In the test work an attempt was made to use a sequential blasting machine to control the firing times for each of the holes in the shot pattern. This technique proved unsatisfactory because the multiple firing lines needed were frequently broken. Therefore, all but two of the shots were fired using commercial electric delay detonators connected in a single series to a 20-shot permissible blasting machine.

For this research, a gassy mine atmosphere was simulated by the positioning of a 20- by 20- by 6-foot steel gallery against the coal face. Care had to be taken to provide a good seal between the open front of the gallery and the coal face. To accomplish this, a cutting machine was used to prepare a fairly

smooth coal face prior to positioning of the gallery. The front opening of the gallery had pieces of rubber affixed to it to obtain a tight fit against the face. Once the face had been loaded, the open sides of the gallery were covered with 4-mil polyethylene. The gallery is shown in Figure 6. In preparation for a shot, methane was introduced into the gallery through a one-inch plastic tube connected to compressed gas cylinders in an instrumentation truck 200 feet away. The gallery atmosphere was constantly mixed by a squirrel-cage fan connected to two corners of the gallery by 8-inch reinforced-plastic flexible duct. The composition of the gas mixture was continuously monitored by a LIRA[5] infrared analyzer; gas samples were also taken for lab analysis to verify the analyzer's calibration. When the gallery atmosphere had stabilized at 9 pct methane, the mixing fan and analyzer were shut down and the test shot was fired. All of the shots were recorded on video tape by cameras located in an area overlooking the pit. An ignition in the gallery could be identified by the associated bright orange fireball which was totally absent for nonignitions. The area of the face with the broken coal resulting from the firing of a slab round is shown in Figure 7. Figure 8 illustrates the fireball produced by a planned ignition of the gallery.

DISCUSSION AND CONCLUSION

As shown in Table 1, no ignitions were obtained for any of the shots of 12-hole patterns of stemmed holes fired as off-the-solid slab rounds with. total delays of 1000, 2000, and 5500 msec. Some characteristics of the permissible explosives used in the research are listed in Table II. The research thus far indicates that increasing the total delay from 500 to 1000 msec has no effect on safety relative to incendivity so long as permissible practices are utilized for all other aspects of the shot. Although a few shots were performed with total elapsed delay times of 2000 and 5500 milliseconds, the data were too limited to suggest trends or conclusions relative to these long delays. Concerning the aspect of misfires, 3 were observed in test shots DB-36, DB-44 and DB-54. The misfire in DB-36 is not significant because the shot was fired using a sequential blasting machine and involved the failure of holes 10, 11 and 12 to fire due to the cutting of the firing line connected to these holes, Three firing lines were used in shots DE-36 and DB-44: one firing line to holes 1 through 6, one to holes 7 through 9 and one to holes 10 through 12. Shot 44 was also fired using a sequential blasting machine but the misfire in this case was different; the explosive column and intact detonator appeared to have been ejected from one hole. In this case the two other holes connected in series with the misfired hole, as well as all the other holes in the pattern, fired properly so the misfire was not attributed to a broken firing line; the actual cause of the misfire is not known. The misfire in the case of shot DB-54 consisted of half a cartridge of a permissible water gel explosive found in the muckpile and may possibly be attributed to cutoff of an explosive column.

Although the test work thus far did not result in ignitions for a total elapsed delay time of 1000 msec, additional tests and analysis of the data are needed to substantiate the overall validity of the conclusions reported and to establish a firm basis for regulatory changes. Experimental work is planned to investigate other shot patterns, larger amounts of explosive per

[5]Reference to specific products does not imply endorsement by the Bureau of Mines or the Mine Safety and Health Administration.

hole, minimum burden required, effects of hole spacing, water bag stemming and the phenomena of "dead pressing" and deflagration.

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Table 1. Summary of 12-hole gallery shots stemmed with 2 feet of clay and rear primed. (All cartridges were 1-l/4-inch diameter, file loaded)

Shot No.	Permissible Explosive	Lb/Hole	Hole Depth, inches	Hole Diam., inches	Shot Type	Delay msec	Misfire	Ignition
DB-23	Granular A	1.6	60	2	Slab	1000	No	No
DB-24	Granular B	1.65	60	2	Slab	1000	No	No
DB-25	Granular B	1.65	60	2	Slab	1000	No	No
DB-26	Granular B	1.65	60	2	Slab	1000	No	No
DB-27	Water Gel	1.54	60	2	Slab	1000	No	No
DB-28	Gelatinous	2.0	60	2	Slab	1000	No	No
DB-29	Granular A	1.4	60	2	Slab	1000	No	No
DB-30	Emulsion	1.74	60	2	Slab	1000	No	No
DE-36	Granular B	1.65	60	2	Slab	2000	Yes	No
DB-44	Emulsion	1.74	60	2	Slab	2000	Yes	No
DB-45	Water Gel	1.5	56	2	Slab	1000	No	No
DB-50	Emulsion	1.74	60	2	Slab	1000	No	No
DB-51	Emulsion	1.74	60	2	Slab	1000	No	No
DB-52	Water Gel	1.5	60	2	Slab	1000	No	No
DB-53	Water Gel	3.0	88	2	Slab	1000	No	No
DB-54	Water Gel	1.5	60	2	Slab	5500	Yes	No
DB-55	Water Gel	3.0	84	2	Slab	5500	No	No
DB-60[1]	Emulsion	3.0	96	2	Slab	5500	No	No
DB-63	Emulsion	2.9	84	2	Slab	1000	No	No
DB-65	Water Gel	3.0	84	2	Slab	1000	No	No
DB-67	Gelatinous	3.0	72	2	Slab	1000	No	No
DB-68	Water Gel	3.0	84	2	Slab	1000	No	No

[1]Shots DB-60 through DB-68 were fired in the highwall. DE-23 through DB-55 were fired in the uncovered coal.

TABLE 2. Permissible Explosives Used in Delay Blasting Research

Permissible Explosive	Cartridge Diam., Length inches	Cartridge Weight, grams	Average Detonation Rate, ft/sec
Granular A	1 l/4, 8	187	8,200
Granular B	1 l/4, 8	189	9,840
Gelatinous	1 l/4, 8	226	18,440
Water Gel	1 l/4, 15	350	11,650
Emulsion	1 l/4, 12	264	16,540

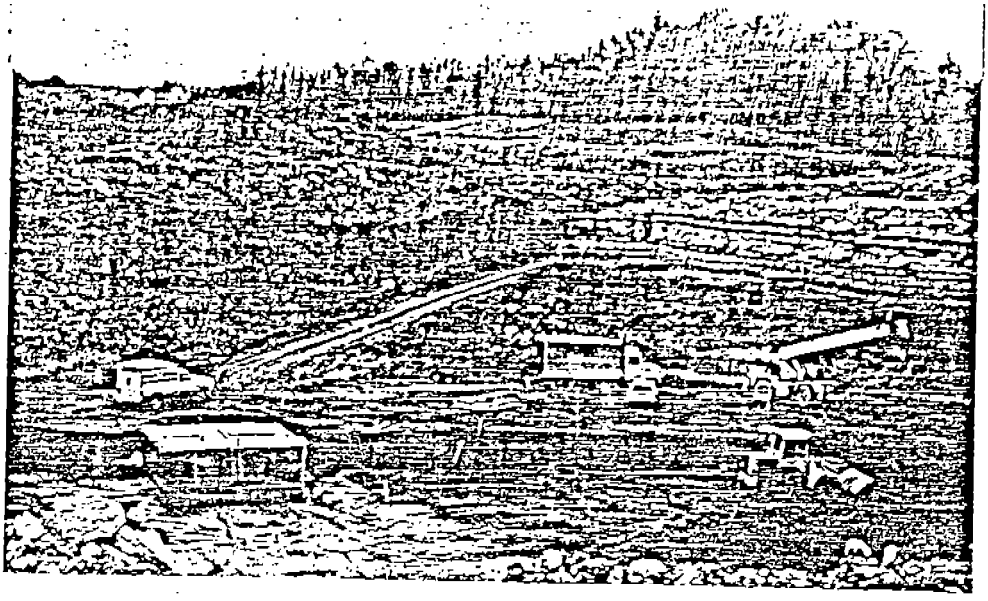

Figure 1. Uncovered coal seam in which initial research was conducted.

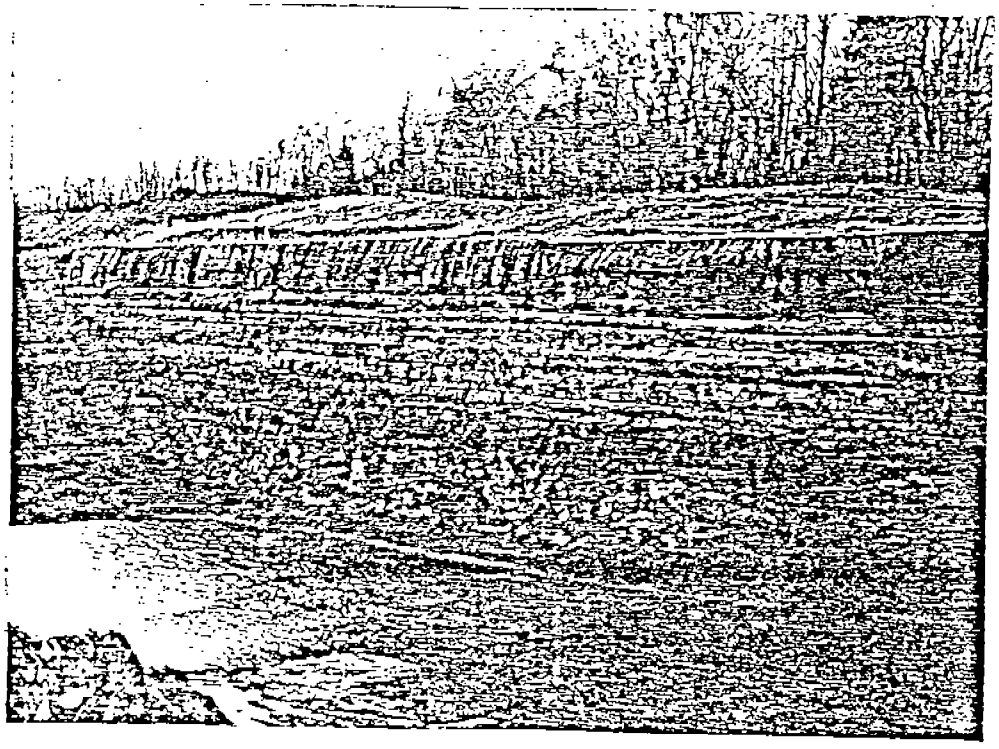

Figure 2. Highwall in which later research was conducted.

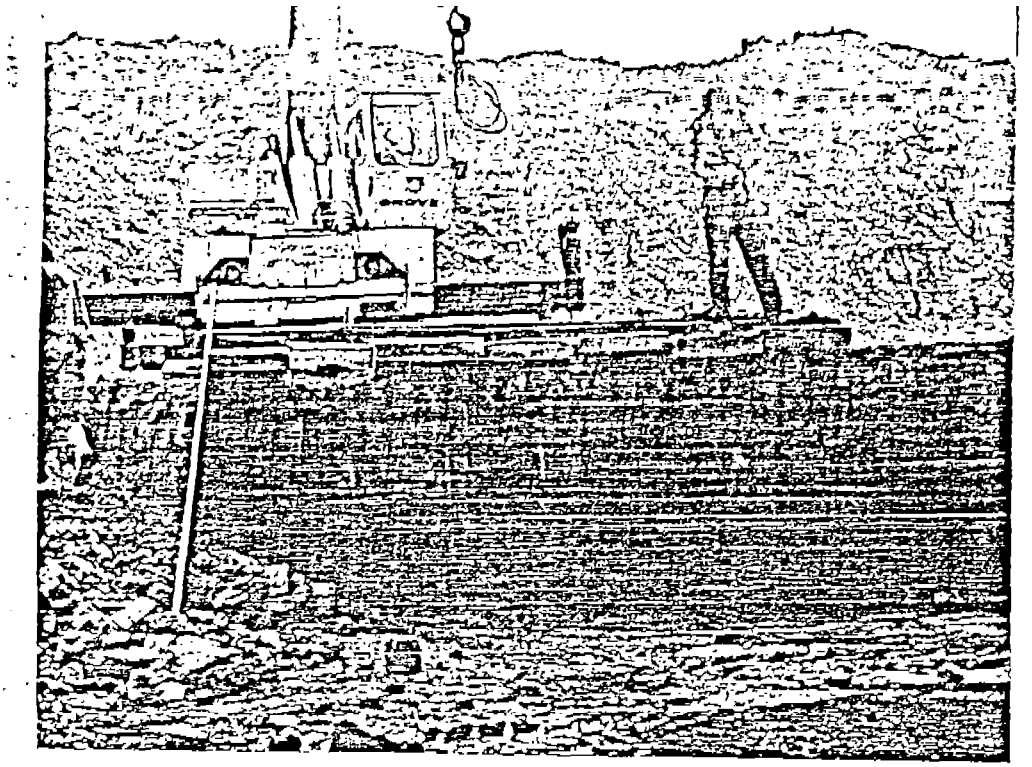

Figure 3. Steel ingots placed atop the coal to serve as burden.

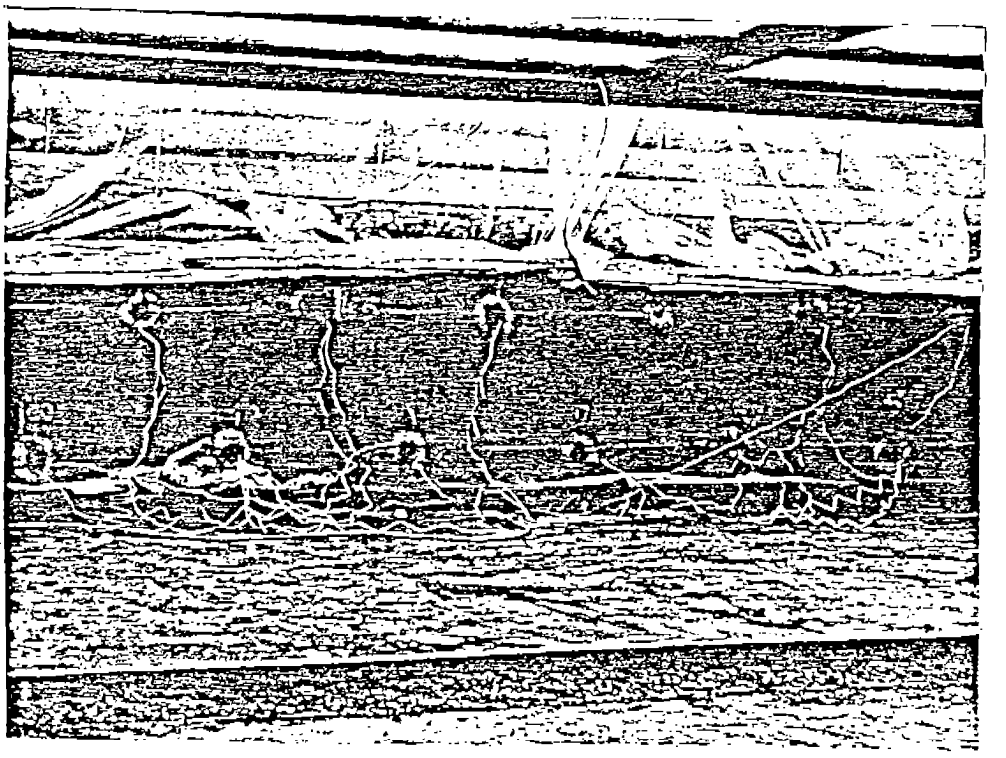

Figure 4. A typical 12-hole, slab-round, shot pattern.

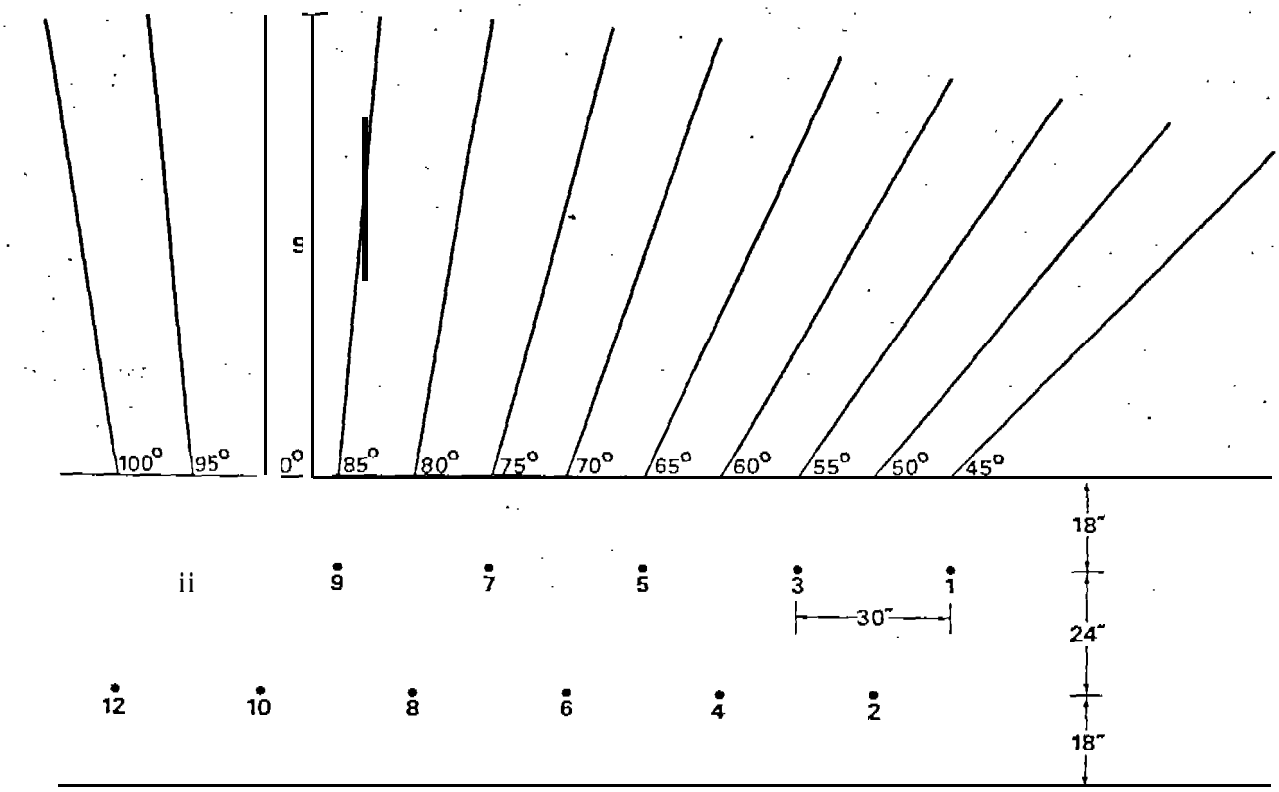

Figure 5. Layout of the 12-hole, slab-round, shot pattern.

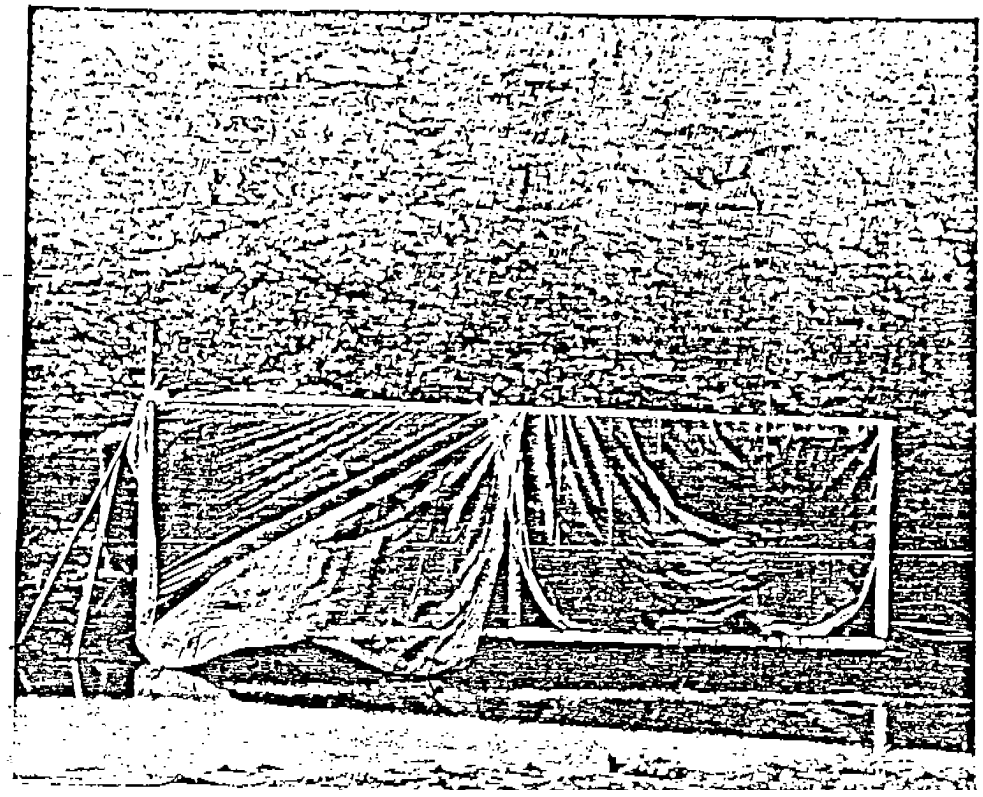

Figure 6. The steel and plastic incendivity test gallery in place against the highwall face. The gallery has not yet been sealed for firing.

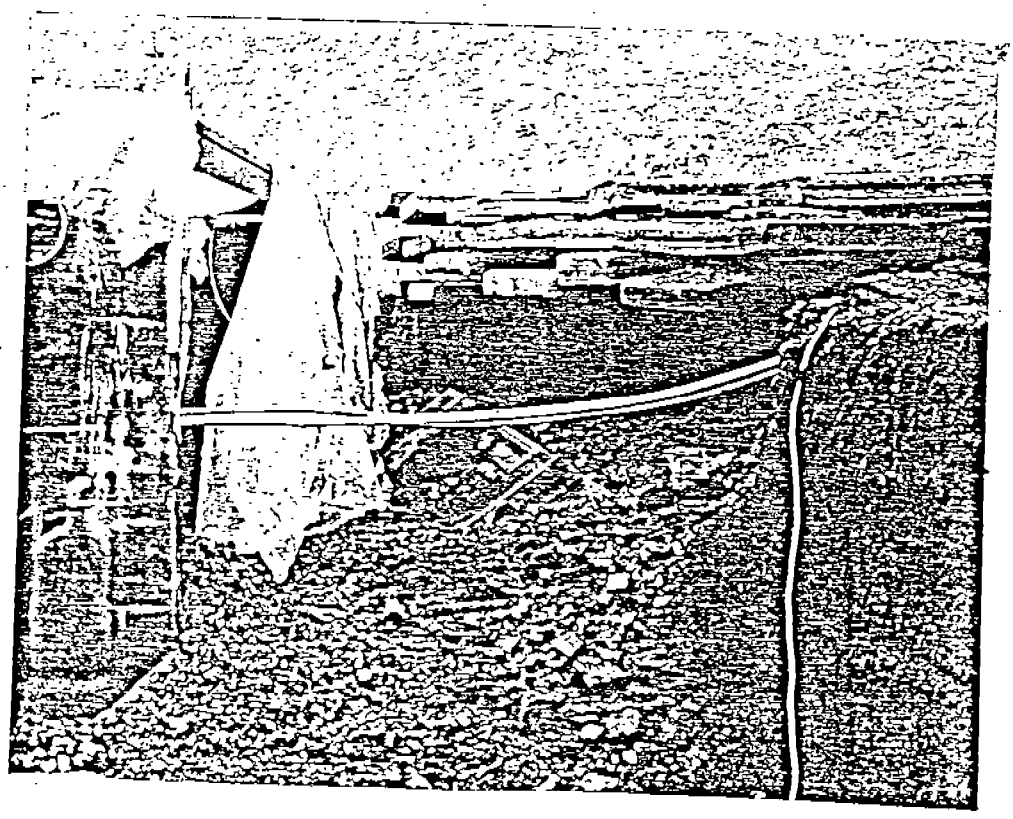

Figure 7. Photograph of the coal broken by a 12-hole, slab-round shot.

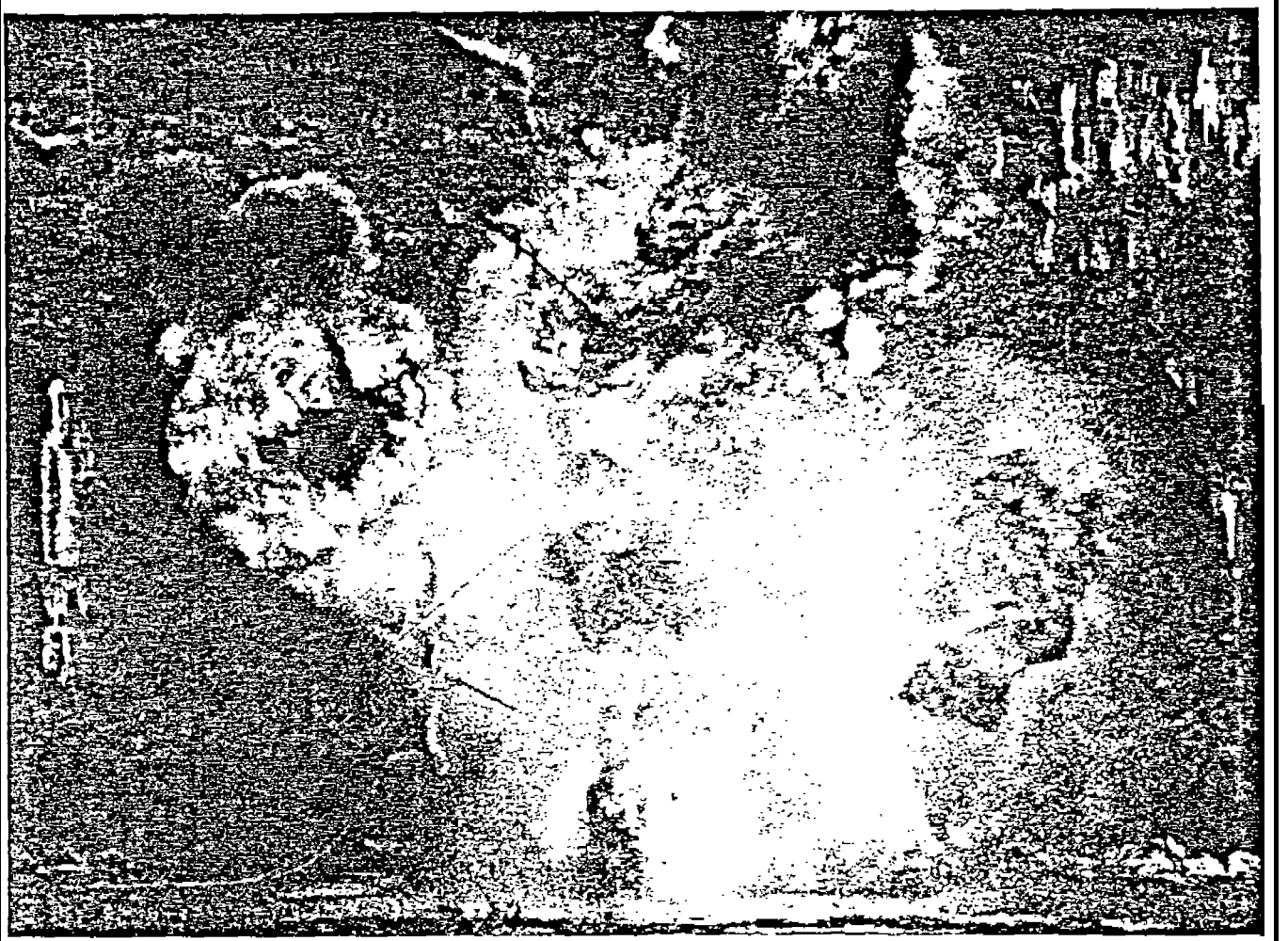

Figure 8. Fireball produced by a planned ignition of the gallery.