1950

Effects of higher speed explosives in drift rounds

Harve Preston Nelson

EFFECTS OF HIGHER SPEED EXPLOSIVES
IN DRIFT ROUNDS

BY

HARVE P. NELSON

****

A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

Degree of

MASTER OF SCIENCE IN MINING ENGINEERING

Rolla, Missouri

July 1950

****

Approved by J. D. Forrester
Professor of Mining Engineering

ACKNOWLEDGEMENTS

This study of the effect of higher speed explosives in drift rounds was conducted in connection with the testing of commercial and military explosives by Missouri School of Mines and Metallurgy for the Department of the Army. The author held the appointment of Research Fellow for the project. Sincere appreciation is hereby expressed for the aid thus provided.

The author is especially indebted to Dr. J. D. Forrester, Chairman, Department of Mining Engineering, for his assistance and guidance in every phase of the research.

Mr. Fred Brackeen, miner-driller, and his helper, Mr. Herman Stevenson, carried out the field work assisted by Mr. Elmer Packheiser, the mine Technician. Their aid and cooperation made this study possible.

Grateful acknowledgement is made to Professors Bruzewski and Latvala for their helpful suggestions in the preparation of this report and the entire staff, technicians and students of the Mining Depa tment for their interest and assistance.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

There is much still to be learned of what takes place in the actual explosive zone of a rock blast. Many factors, both known and unknown, have individual and collective effects. A program is now in progress by the Mining Department of Missouri School of Mines and Metallurgy for developing and preserving information about some of the factors affecting the use of explosives. Some work has been done.[1, 2.] More is now being completed by Messrs.

1. Shaffer, L. E. and Noren, C. H., "The Influence of Cartridge Diameter on the Effectiveness of Dynamite", Bulletin, Missouri School of Mines and Mettalurgy, Technical Series, Vol. 19, No. 1, March 1948, pp. 1-48.

2. Ackermann, K. G., "The I fluence of Grade Strength on the Efficiency of Gelatin Dynamite", Thesis, Missouri School of Mines and Metallurgy, 1948, pp. 1-75.

R. J. Jones and J. B. H. Fitz-William. Present plans call for continuing the research and gathering data on this subject which is so important to the mining industry.

The study made and the report given herein were made possible through a contract between Missouri School of Mines and Metallurgy and the Department of the Army for the purpose of ascertaining some of the properties of military and commercial explosives. Much information and data which should be of value to the School's program of explosive experimentation has been taken from the reports made to the Engineer Research and Development Laboratories. No important conclusions can be drawn from the data in this report. It is presented as a contribution to the assembled data of the overall project.

Explosives with very high rates of detonation are rarely used in underground work. As the velocity of detonation is probably the most important factor in blasting, it is considered a major factor in affecting the results of the tests. According to Bebie [3], the effectiveness of

3. Bebie, J., Explosives, Military Pyrotechnics, and Chemical Warfare Agents, 1943, pp. 6-7.

an explosive is primarily dependent upon the rate at which its energy is liberated; the rate of detonation of a high explosive is a measure of its brisance. The importance of this characteristic was also brought out by some of the earlier writers such as Brunswig and Bichel[4]. The latter,

4. Brunswig, translated by Monroe and Kibler, 1912, pp. 116-118.

as quoted by Brunswig, proposed the use of the product of one-half the mass of the products of explosion times the square of the velocity of detonation as an explosives' unit. Meyer [5] states that given the possession of the

5. Meyer, M., Explosives, An Introduction to Their Chemistry, Production, and Analysis, N. Y., Thomas Y. Crowell Co., 1943, p. 36.

other properties requisite for explosion, probably the most determining factor of total behavior is velocity of detonation.

MATERIALS AND EQUIPMENT

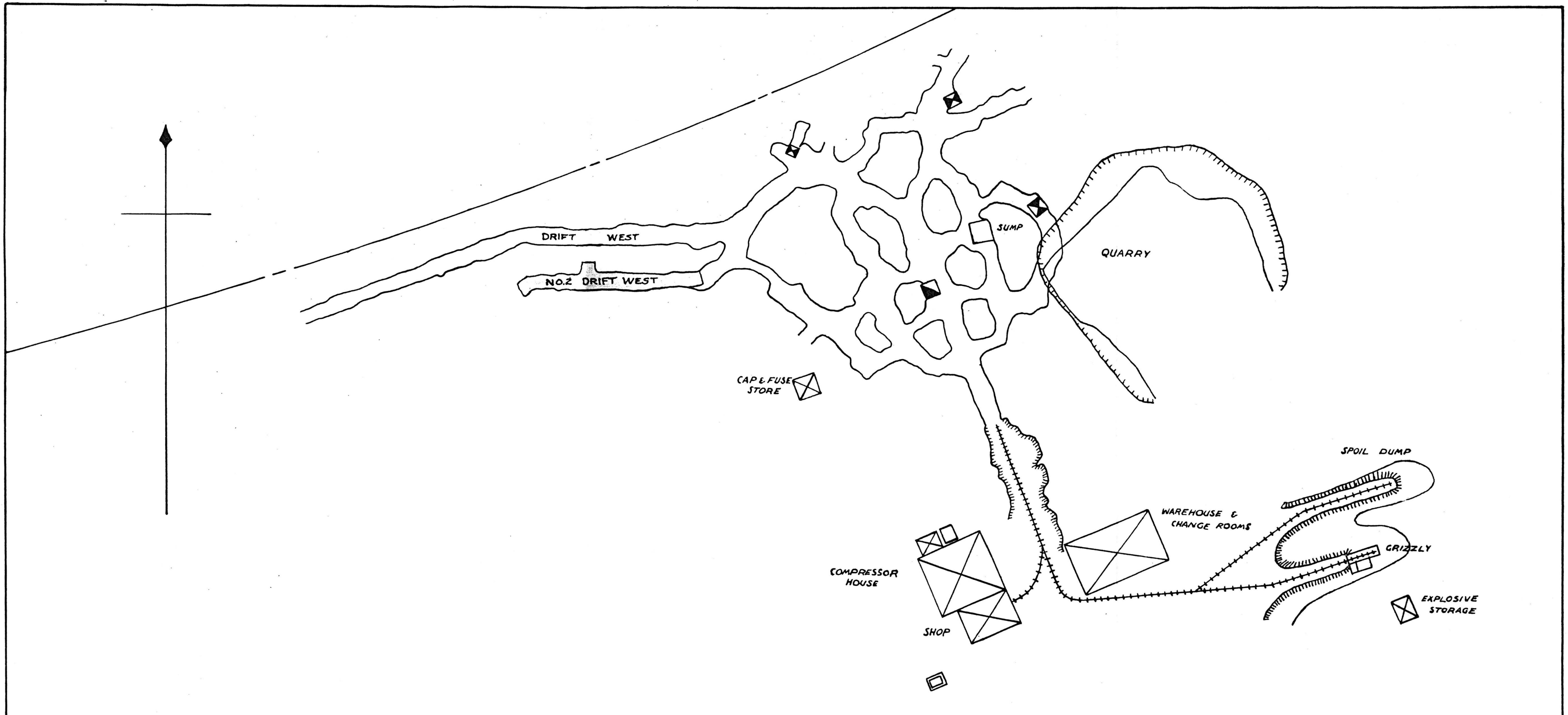
The experiments described herein were performed in the Experimental Mine of Missouri School of Mines and Metallurgy, which is located about one and one-half miles southwest of Rolla, Missouri. The mine workings consist of approximately 1000 feet of drifts and crosscuts served by an adit entrance into the hillside (Figure 1). The rock at the test site is a soft, gray, well-bedded, uniform dolomitic limestone of the Jefferson City series. It is described more fully by Shaffer and Noren [6].

6. Shaffer, L. E. and Noren, C. H., Op. cit., pp. 3-5.

Three vertical raises extend to the surface. Hinged covers were i stalled at the tops of these shafts in order to control the natural ventilation in the underground workings. In addition to this excellent natural ventilation, an electrically driven Coppus-Ventair blower with a 12-inch collapsible canvas tube was used after blasting to blow fresh air into the heading to force out the foul air. Its rating is 1200 cubic feet per minute through 300 feet of 1`-inch collapsible tubing.

Attention is called to the fact that the poisonous fumes given off by many of the test explosives are very dangerous in confined places [7]. This means that they would

7. War Department Technical Manual, FM 5-25, Explosives and Demolitions, May 1945, p. 3.



Plan of
MISSOURI SCHOOL OF MINES & METALLURGY
EXPERIMENTAL MINE
ROLLA, MISSOURI

SCALE: 1" = 40'

APRIL 1949

FIGURE 1.

not be safe for normal underground use in mining operations.

Mine track, 18-inch gauge, was already serving most of the mine and the dump. Track, air and water connections were extended to the test site. A switch and side track were added on the dump to handle the material going directly to waste.

Two sets of grizzly screens (Figure 2a and 2b) were constructed at the end of the existing track on the old mine dump (see Figure 1). The 12-inch grizzly is located immediately under the track. All material which passes through these bars drops a few feet to the second set of rails which are spaced 4 inches apart. This undersize falls directly to waste. The oversize remaining on each grizzly is removed by hand and weighed on a Fairbanks-Morse platform scale.

EQUIPMENT

Compressed air for the drilling and loading machines was furnished by an Ingersoll-Rand, two stage, air-cooled compressor, Model 210. The pressure at the compressor varied between 85 and 105 pounds per square inch.

All test rounds were drilled from a vertical column with the machine resting on a horizontal arm. A Cleveland Model D-24 drifter with a special 1 x 4¼ inch hexagonal chuck was used for 1½ inch holes. Holes of larger diameter were drilled by an Ingersoll-Rand DA-35 drifter with 1¼ inch round by 3 13/16 inch lugged shank chuck. Detachable

Figure 2-a. Grizzly and Weighing Scale

Figure 2-b. Screening Operation

Ingersoll-Rand jackbits were used.

The broken rock was loaded into 18.5 cubic feet steel mine cars by an Eimco Model 12-B Rocker shovel. A run of mine carload weighed 1997 pounds. This gave a car factor of 1.00 tons per car.

MATERIALS

All explosives that were used in the testing were classed as high explosives although their rates of detonation varied considerably as shown in the following list:

Explosive	Rate of Detonation in feet per second
Gelex #2	12,600[8]
40% Red Cross Extra Ammonia Dynamite	10,000[9]
40% Special Gelatin	13,000[9]
50% Special Gelatin	15,000[9]
50% Straight Dynamite	18,000[9]
60% Straight Dynamite	19,000[9]
Amatol	14,750[10]
TNT	20,400[10]
Pentolite	22,500[10]
Composition C-3	25,600[10]

8. E. I. du Pont de Nemours & Co., Blasters Handbook, 12th Edition, 1949, p. 64.

9. E. R. D. L., Ft. Belvoir, Virginia, Correspondence with J. D. Forrester, 7 July 1949.

10. E. R. D. L., Ft. Belvoir, Virginia, Correspondence with J. D. Forrester, 25 May 1949.

The commercial dynamites were standard 1¼ x 8 inch cartridges and the cartridges of military explosives were the same kind.

All charges were initiated by du Pont No. 6 regular delay electric blasting caps except those in Round D-16 in which safety fuse was used with Corps of Engineers Special Electric detonating caps and in D-15 in which du Pont No. 6 "MS" (millisecond) delay electric blasting caps were used. Primers which consisted of a half stick of 50 per cent straight dynamite with detonator were used with the military explosive except in D-16 where the large caps were used. The explosive in the primer was not included in the amount reported in the data. To secure the actual total quantity for each blast hole, using a military explosive, add 0.45 pounds (the weight of ½ cartridge) of 50 per cent straight dynamite per hole. The primer was placed in the center of all charges. Stemming was not used because its beneficial effects in this soft rock had been found to be insignificant by Shaffer and Noren[11].

11. Shaffer, L. E. and Noren, C. H., Op. cit., p. 21.

Electric blasting circuits were checked for faulty connections by galvanometer before firing. Rubber covered, 12 gauge lead wires were used. Trouble was caused in the early rounds by misfires. A new 30-cap push down type blasting machine was obtained to replace an older but larger machine of the same type. No one was permitted in the mine at the time of blasting. The blasting current was initiated outside the portal to avoid danger from concussion. This is particularly important when using high speed explosives such as composition C-3 or pentolite.

TEST PROCEDURES

At the outset of the project, efforts were made to develop a standard drift round which could be used with each explosive so that test conditions would be constant, thereby, allowing a direct comparison to be made between the results of the various tests. The search for a standard pattern failed. Then the problem turned toward developing rounds which could be broken successfully by the different explosives. In so doing interesting facts were uncovered which were apparently due to the inherent characteristics of the individual explosives used.

Test rounds were drilled in several patterns which are designated by the type of "cut", that is, the manner of applying the so-called cut-holes to obtain the initial cavity to which the remaining holes of the round break. Burn or burn-cut rounds (see Figures 3 and 4) rely upon several closely spaced horizontal parallel holes, wherein loaded holes break to uncharged ones. The adjacent first "relief" holes are aids in pulling the cut. A wedge or V-cut pattern (see Figure 5) is one in which at least two holes are drilled at an angle towards the center of the face. A center hole was drilled straight into the face between the two welle holes. The diamond-cut (Figure 6) consists of four holes a gled in towards the center, and in this case towards a center hole. In the barrel round (Figure 7), a hole was drilled at each intersection of the 8-inch sides of a hexagon. These holes flared out approximately 8 inches. A seventh hole was drilled at the center of the hexagon.

"Squaring up the face", i. e., making it as even and as perpendicular to the sides of the opening as practical, was done prior to drilling each test round. Average bootleg of the holes of a round may be determined by subtracting the advance shown in its data from the average hole length.

In case of misfires, additional explosives used in repriming or reblasting was included in the total amount of explosive shown in the data listed.

Precautions were taken to secure similar loading conditions in all tests. To keep the diameter of the drill holes uniform, the drill bits were measured at frequent intervals and discarded before the loss of gauge exceeded 0.06. of an inch. In order to assure breakage of the cartridge wrappers, use was made of a tamping pole with a copper spike extending beyond one end and held in place by a ferrule, consisting of a copper ring around the outside of the same extremity of the pole. Care was taken to maintain the same tamping force in the loading of all drill holes because of the importance of the effect of volumetric density upon the velocity of detonation. According to

Grageroff[12], the rate of detonatior tends to increase with

12. Grageroff, I., Explosives and Their Properties, Arizona Mining Journal, 15 May 1928, p. 13.

the density up to a point where it begins to decrease until the powder fails to detonate.

Dimensions of the drift openings were 6½ feet wide by 7 feet high as shown on the sketches of the test rounds. The order of firing the blast holes is shown in Roman numerals on the sketches. In some rounds, the hole groups were fired separately, but in normal order, to allow observation of their contribution.

A study was made of each post-blast rock surface to determine the overall effect of the explosives used during the given tests. The rock broken in each test was loaded into the mine cars by means of the pneumatic loader and was then trammed by hand to the mine dump. Every fifth car was dumped on the grizzly screens and the rock retained on each screen was weighed on the scale. This procedure gave an average measurement of the plus 12-inch fragments and of those between 4 and 12 inches in size. The quantity of minus 4-inch material was calculated by subtracting the above weights from the total weight of muck (1997 pounds) in a mine car. These quantities were converted into percentage figures and are so listed under "Description of Tests".

DESCRIPTION OF TESTS & DATA

Drift rounds, D-1 through D-7, were drilled and blasted in the pattern of an 18-hole, 7 foot burn-type round, (Figure 3). The explosives used in each case are specified in the data given below:

Round No.	D-1	D-2	D-3	D-4
Average Hole Length	7.07	7.18	7.0	7.0
Type of Explosive	Gelex #2	50% Sp. Gelatin	50% Sp. Gelatin	60% St. Dynamite
Hole Size (Inches)	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$
Loading (Number of Cartridges)				
Hole No. 1	18	0	16	0
2	0	16	0	16
3	18	0	16	0
4	0	16	0	16
5	15	12	12 + 4	12
6	15	12	12	12
7	20	12	12 + 4	12
8	15	12	12 + 4	12
9	6	10	9	Boot-legged 3.5'
10	6	10	9	
11	6	10	9	
12	5	10	9	
13	6	10	5	
14	6	10	9	
15	6	10	9	
16	7 + 10	10	12	
17	8 + 10	10	12	
18	8 + 10	10	12	

Round No.	D-1	D-2	D-3	D-4
No. Cartridges	195	180	187	
No. Lbs. Explosives	81.3	86.6	90.0	79.0
Average Advance (ft.)	6.73	4.33	6.90	
Lbs. Explosives per ft. Advance	12.0	20.0	13.2	
Cars of Muck	29	18	33	
Tons of Muck	29.0	18.0	33.0	
Tons per pound of Explosive	0.357	0.207	0.367	
Fragmentation:				
+ 12	1.5%	0%	0%	
+ 4 - 12	14.5%	24.1%	15.8%	
- 4	84.0%	75.9%	84.2%	

Round No.	D-5	D-6	D-7
Average Hole Depth	7.0	7.0	7.7
Type of Explosive	60% St. Dynamite	40% Red Cross Extra	50% St. Dynamite
Hole Size (inches)	2¼	2¼	2¼
Loading (No. of Cartridges)			
Hole No. 1	0	16	16
2	16 + 4	0	0
3	0	16	16
4	16 + 4	0	0
5	12 + 4	12	12
6	12 + 4	12	12 + 10
7	12 + 4	12	12 + 10
8	12 + 6	12	12 + 10
9	6 + 6	8	8

Round No.	D-5	D-6	D-7
Hole No. 10 . . .	6 +	8	8
11 . . .	6	8	8
12 . . .	6	8	8
13 . . .	6 + 4	8	8
14 . . .	6	8	8
15 . . .	6	8	8
16 . . .	12 + 6	10	10
17 . . .	12	10	10
18 . . .	12	10	10
No. Cartridges	200	166	196
No. Lbs. Explosives	87.6	88.6	96.0
Average Advance (Ft.)	4.33	Failed Completely	3.53
Lbs. Explosives per ft. Advance	20.2		27.2
Cars of Muck	17		20
Tons of Muck	17.0		20.0
Tons per pound of Explosive	0.194		0.208
Fragmentation:			
+ 12	0%		0%
+ 4 - 12	6.5%		11.3%
- 4	93.5%		88.7%

Test D-1, in which Gelex #2 (12,800 feet per second) was used, broke clean. In an attempt to secure further confirmation and comparative knowledge of previous experimental work[13, 14] in which special gelatin and Gelex #2 had

13. Shaffer, L. E. and Noren, C. H., op. cit. p. 1-48.

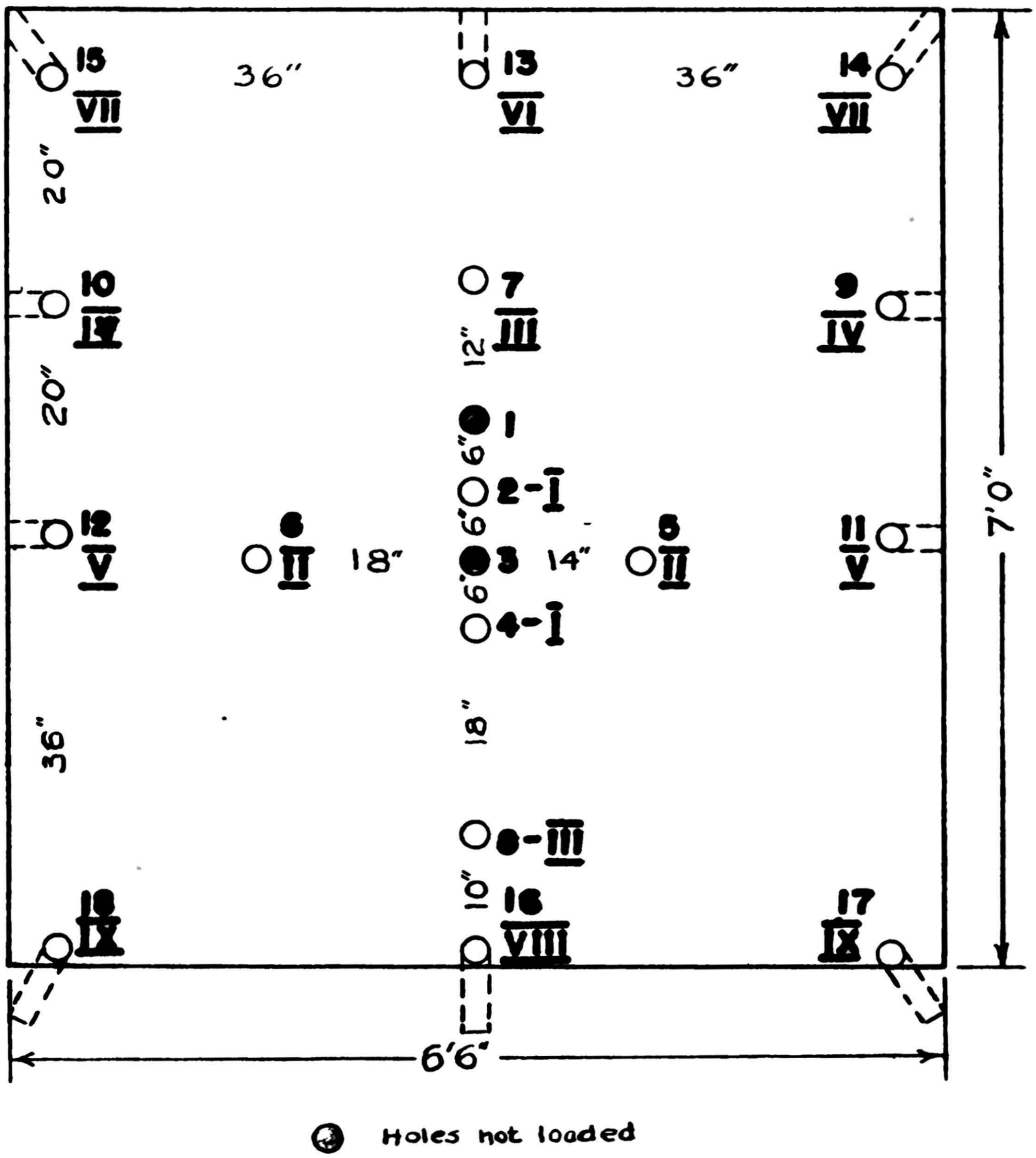


Figure 3. 7-Foot Burn Round

Arabic numerals: Hole numbers
Roman numerals: Firing order
Hole measurements: Center to center
Scale: 3/4" = 1'

14. Ackermann, K. G., Op. cit., p. 1-75.

been used in 5-foot, burn-cut rounds; Rounds D-2 and D-3, in which 50 per cent special gelatin (15,000 feet per second) were to be used were drilled in the 7-foot round. Test D-2 did not break well because of the failure of cut holes to detonate. Round D-3 was drilled and loaded in duplication of D-2, producing good results even though three of the first relief holes did not fire properly. A comparison of the results of Rounds D-1 and D-3 show slightly better fragmentation for the latter which confirms the previous tests conducted at the Experimental Mine which show that 60 per cent and 50 per cent special gelatins (15,400 feet per second and 15,000 feet per second respectively) are generally more efficient for a five foot, burn-cut round in the dolomitic limestone than are either Gelex #2 or 40 per cent special gelatin (14,400 feet per second). The results of tests D-1, D-2, and D-3 indicate that Gelex #2 and 50 per cent special gelatin may be used effectively when properly fired in a 7-foot, burn-cut round drilled in similar dolomitic limestone.

Drill Rounds D-4 and D-5 were drilled and charged with 60 per cent straight dynamite (19,000 feet per second) in the same pattern and manner as those of D-1, D-2 and D-3. On blasting, very poor results were obtained. D-4 bootlegged about 3.5 feet in the burn and first relief holes. Only one report was heard when Round D-5 was blasted and the results of the round were poor. Large cracks developed vertically and across the face extending through the holes which have detonated, probably by propagation from the first delay caps in the burn holes. Seven holes failed to fire; the primers and charges remained intact and they were used again in reblasting the round. For some reason, ample current to detonate the caps did not reach them in the holes that misfired. Little rock was pulled by the round. This was from around the collars of the holes. In several cases, the bootleg portion of the hole was clean and almost its normal size even though the surrounding ground was cracked. It is apparent that 60 per cent straight dynamite is too fast to be used successfully in a 7-foot, 18-hole, burn-cut drill round in dolomitic limestone. The bootleg holes were reloaded and the round was refired. The total amount of the explosive expended is listed with the rest of the data.

Drill Rounds D-6 and D-7 were tested to obtain information on: (a) an explosive (40 per cent extra ammonia dynamite, 10,000 feet per second) of less speed than Gelex #2; and (b) a dynamite (50 per cent straight dynamite , 18,000 feet per second) intermediate between 50 per cent special gelatin and 60 per cent straight dynamite. These tests were an attempt to determine minimum and maximum limits of adaptability of commercial explosives when used in an 18-hole, 7-foot, burn-cut drill round.

Round D-6 failed completely, only 5 cars of muck being yielded. It is apparent that 40 per cent extra ammonia dynamite does not have sufficient speed to be applicable under the particular conditions of the test.

The results obtained in D-7 indicate that the blasting effects, principally bootleg and fragmentation, of 50 per cent straight dynamite are more like those of 60 per cent straight dynamite than those of 50 per cent special gelatin. This is not unexpected, of course, as its speed is much closer to that of the former than to that of the latter. The holes of the round bootlegged for distances of from 2.3 feet to as much as 5.2 feet and cracks were formed as a network from hole to hole in the ground which did not pull. The 50 per cent straight dynamite is believed to be too fast to be efficiently applied under the conditions of the given test.

In order to check the possibility that the 7-foot, burn-cut drill rounds being used were placing too much burden on the higher speed explosives and thereby contributing to their failure during the tests, a 5-foot, burn-cut, drill round, D-8, was prepared and loaded with 60 per cent straight dynamite (see Figure 4). On firing, the round did not break clean; the burn and first relief holes bootlegged and had to be reblasted to pull the ground. The test demonstrated that the 7-foot round is not too burdensome when blasted with a suitable explosive.

<u>Round No.</u> <u>5-foot Burn</u>	<u>D-8</u>
Average Depth of Hole (ft.)	5.0
Type of Explosive	60% St. Dynamite
Hole Size (in.)	1½
Loading (Number of Cartridges)	
Hole No. 1	7
2	0
3	8
4	0
5	7
6	6 + 7
7	6 + 7
8	4 + 17
9	4
10	5 + 5
11	5
12	4 + 17
13	3
14	4
15	6
16	4
17	4
18	6
19	4
20	6
21	6
22	4

Round No. 5-foot Burn	D-8
Loading (Number of Cartridges)	
Hole No. 23	4
24	4
25	4
No. Cartridges	168
No. Lbs. Explosives	73.7
Average Advance (ft.)	3.57
Lbs. Explosives per ft. Advance	20.7
Cars of Muck	16
Tons of Muck	16.0
Tons per pound of Explosive	0.217
Fragmentation:	
+ 12	0%
+ 4 - 12	6.0%
- 4	94.0%

Drill rounds D-1 to D-8, inclusive, confirm results of Ackermann's tests and demonstrate that Gelex #2 and 50 per cent gelatin dynamites yield better results than other commercial explosives when used in a 7-foot, 18-hole, burn-cut underground drift round in dolomitic limestone.

As the foregoing tests deomonstrated that the 18-hole, burn-cut round is not suitable for use with higher speed explosives, and as military explosives normally have still higher rates of detonation, drift round D-9 was prepared as a 17-hole, wedge-type round (Figure 5-a) in an attempt to find a drill hole pattern which would be applicable to the

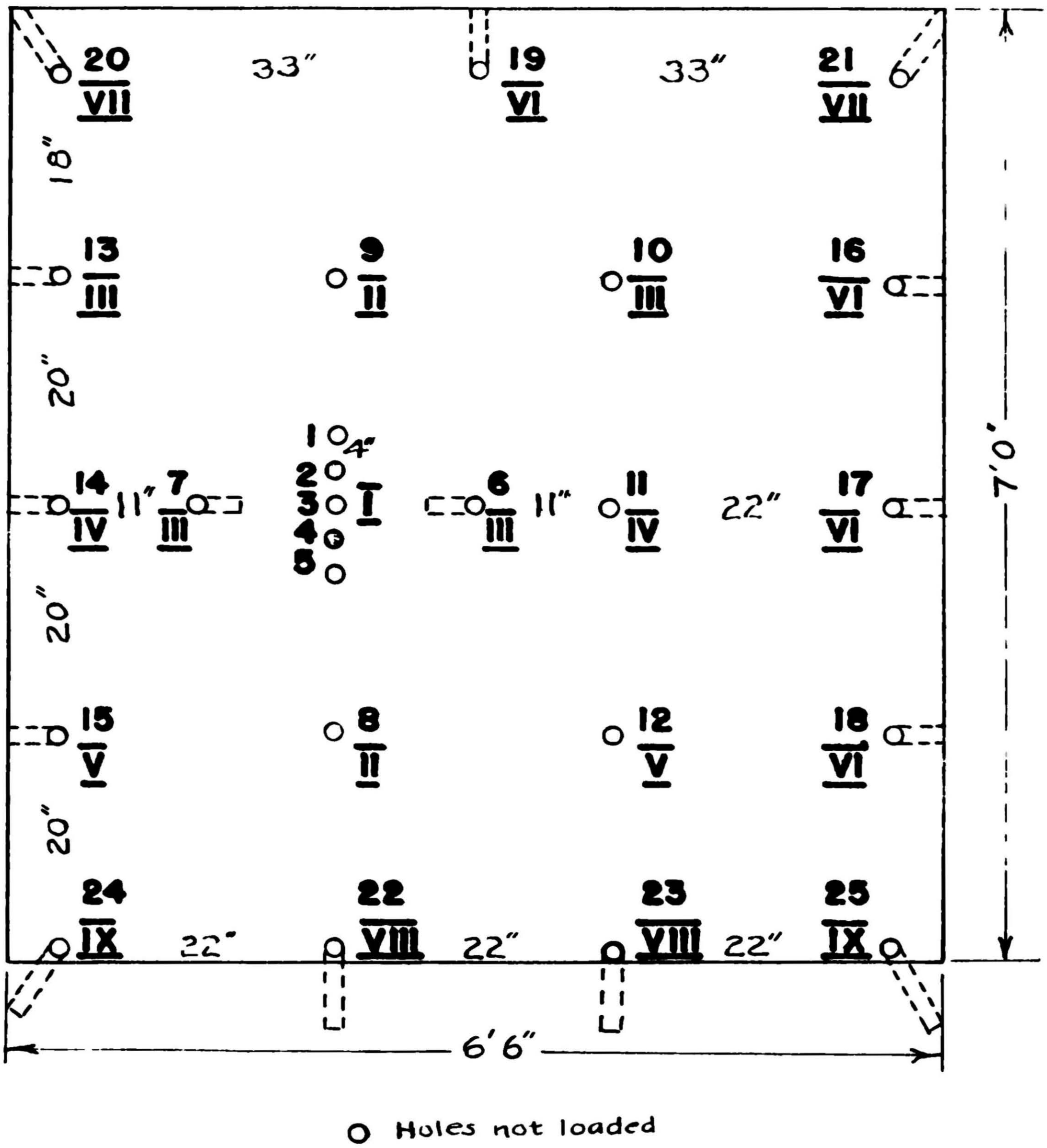


Figure 4. 5-Foot Burn Round

Arabic numerals: Hole numbers
Roman numerals: Firing order
Hole measurements: Center to center

use of fast explosives. The test was made with 60 per cent straight dynamite. Excellent breakage ensued on firing the round which left a clean face. The fragmentation was good (see data, below) and it is evident that the wedge round is much more suitable to blasting with fast explosives in the dolomitic limestone than is the burn-cut round.

Round No. (Wedge)	D-9
Average Depth of Hole (ft.)	5.16
Type of Explosive	60% St. Dynamite
Hole Size (in.)	2
Loading (No. of Cartridges)	
Hole No. 1	10
2	10
3	10
4	5
5	5
6	5
7	5
8	5
9	5
10	5
11	5
12	5
13	5
14	5
15	6
16	7

Round No. (Wedge)	D-9
Hole No. 17	7
No. Cartridges	105
No. Lbs. Dynamite	46.1
Average Advance (ft.)	5.13
Lbs. Explosives per ft. Advance	8.99
Cars of Muck	22
Tons of Muck	22.0
Tons per pound of Explosive	0.478
Fragmentation:	
+ 12	1.1%
+ 4 - 12	9.7%
- 4	89.2%

Drift round D-10 was drilled in the same pattern (17-hole wedge) as D-9 which had given excellent results when fired with 60 per cent straight dynamite. The round was loaded with amatol (14,750 feet per second) and when detonated the cut holes failed to pull. An extra hole then was added to the wedge pattern and on firing with amatol gave an even, though short breakage. It was reasoned that more holes were necessary in order to achieve satisfactory results. Data of D-10 are:

Round No. Wedge	D-10	Remarks
Average Depth of Hole (ft)	5.0	Cuts failed, but broke as shown with an additional relief hole.
Type of Explosive	Amatol	
Hole Size (in.)	2	

Round No. Wedge	D-10
Loading (No. of Cartridges)	
Hole No. 1	10
2	1
3	10
Extra 1st Relief	≁ 7
4	7
5	7
6	7
7	7
8	6
9	6
10	7
11	7
12	6
13	6
14	6
15	8
16	8
17	8
No. Cartridges	133
No. Lbs. Explosives	49.6
Average Advance (ft.)	4.23
Lbs. Explosives per ft. Advance	11.70
Cars of Muck	14.67
Tons of Muck	14.7
Tons per pound of Explosive	0.297

Round No. (Wedge)	D-10
Fragmentation:	
+ 12	0%
+ 4 - 12	6.2%
-4	93.8%

In view of the experience gained from D-10, the pattern of Round D-11 was modified by adding two additional first relief holes (Figure 5-b). Good results were attained on firing this modified round with amatol. A similar round, D-12, was drilled and fired with pentolite. The cut holes failed to pull in this last mentioned test. Data of Rounds D-11 and D-12 are given below:

Round No. (Modified Wedge)	D-11	D-12
Average Depth of Hole (ft.)	5.0	5.0
Type of Explosive	Amatol	Pentolite
Hole Size (in.)	2	2
Loading (No. of Cartridges)		
Hole No. 1	10	9
2	10	9
3	10	9
4	8	7
5	7	7
6	7	7
7	7	7
8	7	7
9	7	7

Round No. (Modified Wedge)	D-11	D-12
Hole No. 10	7	Cut failed.
11	7	
12	7	
13	7	
14	5	
15	5	
16	5	
17	6 + 1	
18	6 + 1	
19	6 + 2	
No. Cartridges	138	
No. Lbs. Explosive	51.5	
Average Advance (ft.)	4.90	
Lbs. Explosives per ft. Advance	10.5	
Cars of Muck	16	
Tons of Muck	16.0	
Tons per pound of Explosive	0.315	
Fragmentation:		
+ 12	0%	
+ 4 - 12	4.1%	
- 4	95.9%	

Drift round D-13 was a 20-hole modified diamond-cut round (Figure 6), in which the cut holes were drilled so as to cross each other about 1 foot from their bottoms. On charging and blasting with pentolite the cuts failed to break clean. Round D-14 was drilled as a 21-hole, diamond

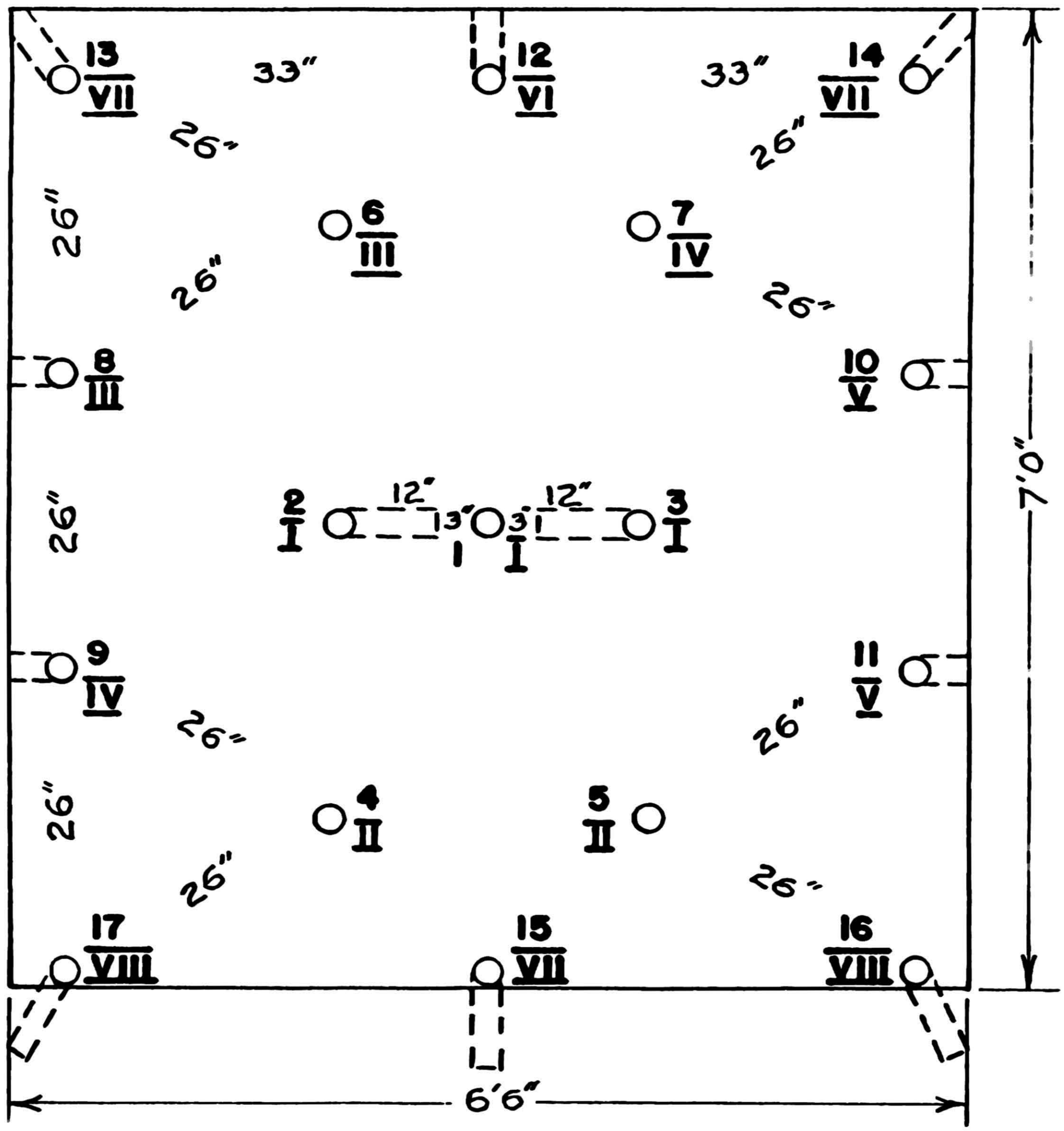


Figure 5-a. 5-Foot Wedge Cut Round

(17 Holes)

Arabic numerals: Hole numbers
Roman numerals: Firing order
Hole measurements: Center to center
Scale: 3/4" = 1'

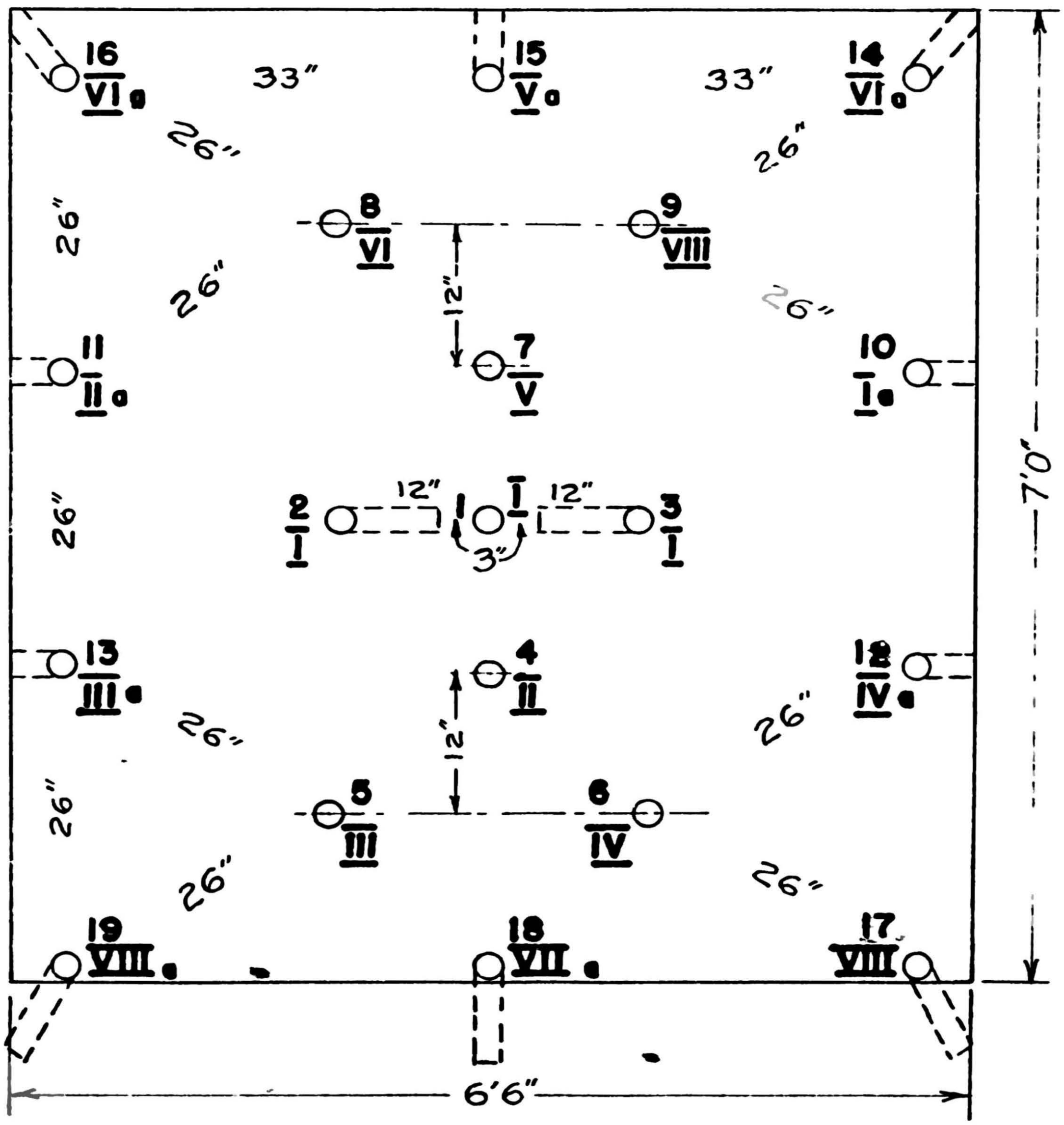


Figure 5-b. 5-Foot Wedge Round--Modified

(19 Holes)

Arabic numerals: Hole numbers
Roman numerals: Firing order
Hole measurements: Center to center
Scale: 3/4" = 1'

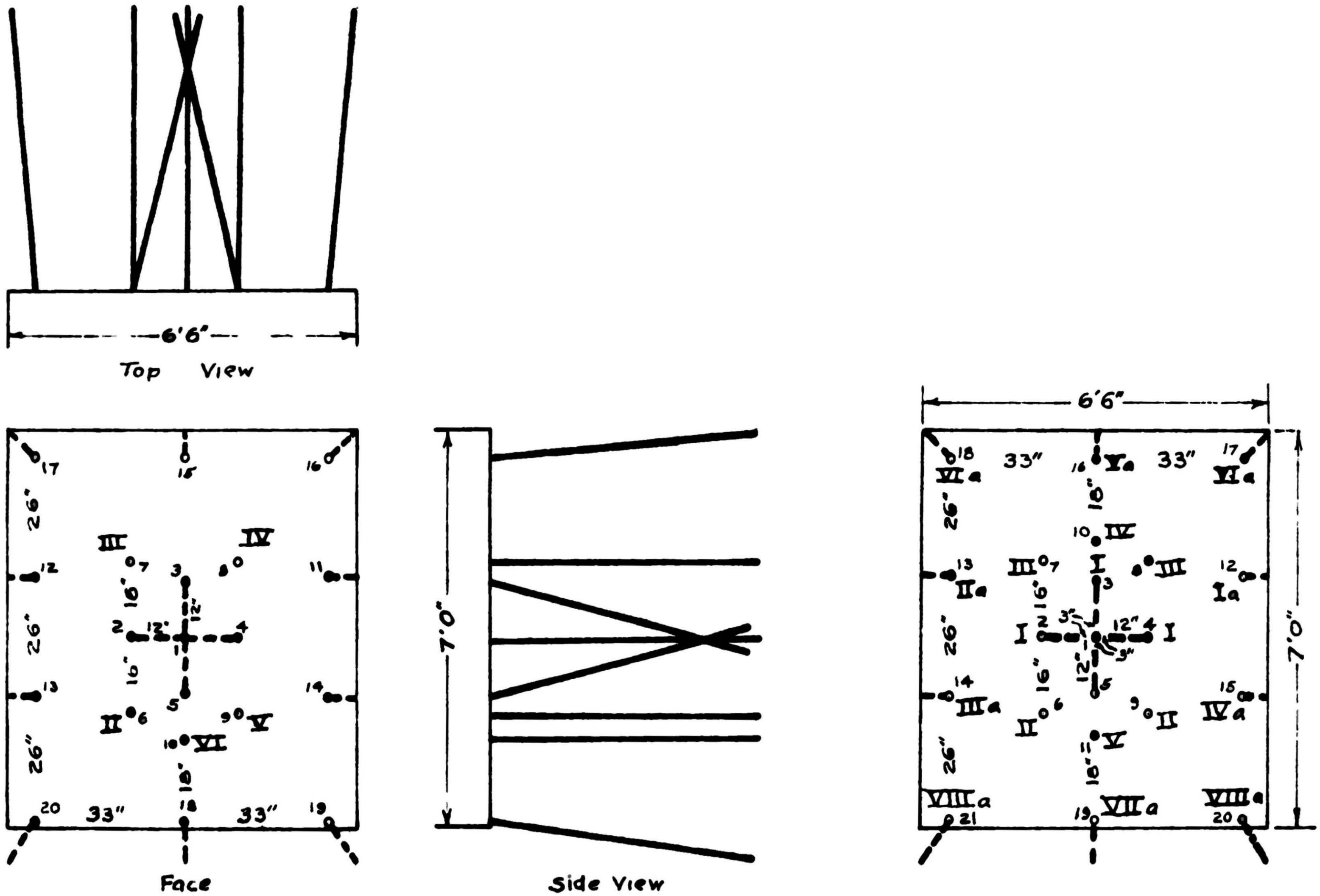
cut pattern in such a manner that the lower ends of the cut holes were separated by about 3 inches of ground. Good breakage was attained on firing with pentolite. Data of Rounds D-13 and D-14 are as follows:

Round No. (Diamond)	D-13	D-14
Average Depth of Holes (ft.)	5.25	5.0
Type of Explosive	Pentolite	Pentolite
Hole Size (in.)	2	2
Loading (No. of Cartridges)		
Hole No. 1	25	0
2	0	6
3	0	6
4	0	6
5	0	6
6	8	6
7	8	6
8	8	6
9	8	6
10	6	6
11	Cut failed.	6
12		6
13		6
14		6
15		6
16		6
17		6
18		6

Round No. (Diamond)	D-13	D-14
Hole No. 19		10
20		10
21		10
No. Cartridges		132
No. Lbs. Explosives	59.6	45.3
Average Advance (ft.)		4.60
Lbs. Explosives per ft. Advance		9.84
Cars of Muck		18
Tons of Muck		18.0
Tons per pound of Explosive		0.397
Fragmentation:		
+ 12		0%
+ 4 - 12		5.6%
- 4		94.4%

In Round D-15 a barrel type round was drilled with 2-inch bits, (Figure 7). The center, barrel, 1st and 2nd relief holes were loaded with a total of 65 sticks (19.7 pounds) of 1¼-inch TNT. On blasting, they failed to break although a large pocket was formed at the back of each hole.

The same barrel type pattern of holes was used in Round D-16. However, before being fully loaded the center hole was sprung with two sticks of the 1¼-inch Composition C-3. Time fuse and Corps of Engineer Special Blasting Caps were used to detonate the charges. The center hole was blasted first and produced a cavity 0.5 feet x 0.7 feet the length of the round. The remaining holes then were



MODIFIED DIAMOND - 20 HOLE
Used in Round D-13

Scale 1"=3'
• Holes not loaded

DIAMOND - 21 HOLE
Used in Round D-14

Arabic numerals: Hole numbers
Roman numerals: Firing order

Figure 6. 5-FOOT DIAMOND CUT ROUNDS

loaded and also were fired with C-3 in a suitable delay sequence as obtained by properly cutting the fuses to fixed lengths. The round gave excellent results:

Round No. (Barrel Type)	D-15	D-16
Average Depth of Holes (ft.)	5.0	5.0
Type of Explosive	TNT	C-3
Hole Size (in.)	2	2
Loading (No. of Cartridges)		
Hole No. 1	5	2 (to 11 spring)
2	4	6
3	6	6
4	5	0
5	5	6
6	5	6
7	5	0
8	5	6
9	5	5
10	5	5
11	5	5
12	5	5
13	5	5
14	Failed completely.	5
15		4
16		4
17		4
18		6
19		5

Round No. (Barrel Type)	D-15	D-16
Hole No. 20		5
21		6
22		6
23		6
No. Cartridges		119
No. Lbs. of Explosive		58.8
Average Advance (ft.)		5.03
Lbs. Explosives per ft. Advance		11.7
Cars of Muck		21
Tons of Muck		21.0
Tons per pound of Explosive		0.358
Fragmentation:		
+ 12		0%
+ 4 - 12		9.8%
-4		90.2%

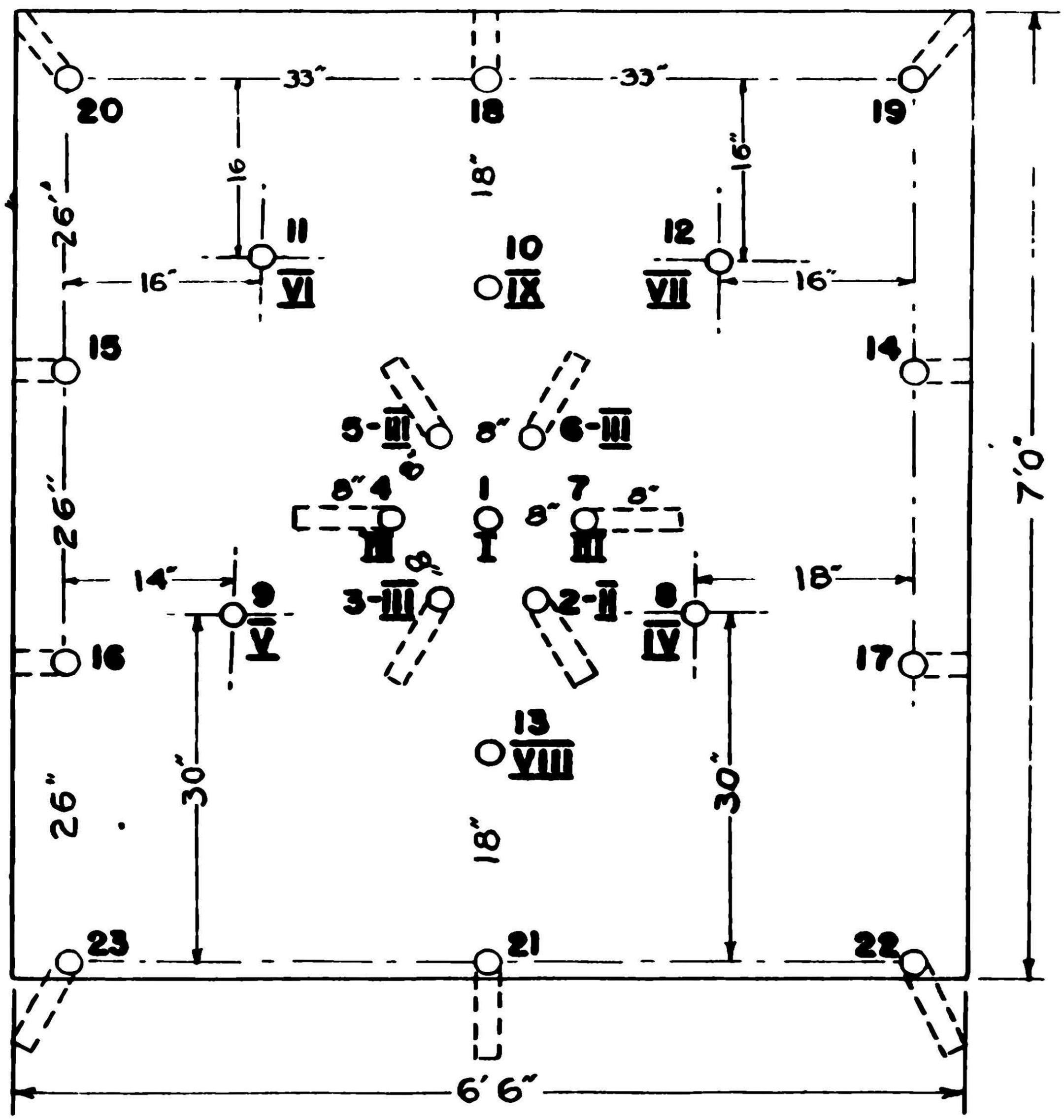


Figure 7. 5-Foot Barrel Round

Arabic numerals: Hole numbers and firing order of D-16
Roman numerals: Firing order of D-15
Hole measurements: center to center
Scale: 3/4" = 1'

DISCUSSION

It must be kept in mind that there are factors other than the rate of detonation which affect the strength and effectiveness of an explosive, such as the density and the distribution in the drill hole. To quote Gardner[15]: "The strength of an explosive is apparently the resultant of three factors: 1. the heat generated; 2. the volume of gases produced; and 3. the speed at which the gases are evolved (rate of detonation)."

15. Gardner, E. D., Drilling and Blasting in Metal-Mine Drifts and Crosscuts, U. S. Bureau of Mines, Bulletin 311, 1929, p. 5.

In these tests, results attributable to the third factor were given special consideration.

Tests D-1 to D-7 inclusive, indicate that Gelex # 2 (12,600 feet per second) and 50 per cent Special Gelatin (15,000 feet per second) are more effective than the other explosives used in the 7-foot, burn-cut drift round in dolomitic limestone, that is, the slower speed 40 per cent Red Cross Extra Ammonia dynamite (10,000 feet per second) and relatively fast speed 50 per cent and 60 per cent straight dynamites (18,000 and 19,000 feet per second).

Experiment D-8 demonstrated that 60 per cent straight dynamite was also too fast for the 5-foot burn-cut round, whereas D-9 shows that, by varying blasting conditions, fragmentation can be obtained in limestone with most commercial dynamites.

The failure of the relatively slow-speed amatol (14,750 feet per second) to pull the cut holes of Round D-10 may have been due to factors other than its rate of detonation, that is, its density and distribution. Two relief holes were added to the original wedge pattern that was used successfully with the heavier and faster 60 per cent straight dynamite. Time did not permit further testing to determine if amatol would prove satisfactory in the burn-cut rounds which were so effective with 50 per cent special gelatin dynamite (15,000 feet per second). D-10 and D-11 were fired before the velocity of detonation of amatol was known. It was believed to be somewhat faster than it actually was when the tests were made.

After experimenting with different patterns, successful fragmentation was obtained with pentolite (22,500 feet per second) in Round D-14 with a diamond, or pyramid, cut.

A barrel-type round gave good results with C-3 (25,600 feet per second) but failed when used with TNT (20,400 feet per second). It is believed that a wedge or diamond type pattern would give favorable results for the latter.

Apparently, blasting conditions can be varied to obtain fragmentation by the use of almost any explosive if economical efficiency is not a primary requisite.

The following overall conclusions may be drawn:

1. Explosives with unlike characteristics, such as rate of detonation require different conditions for use in drift rounds.

2. Successful rounds and techniques can be developed to fit the characteristics of many individual explosives.

3. Some explosives have properties that make them more effective in one rock type than other explosives.

SUMMARY

Sixteen drift rounds were fired at the Experimental Mine of Missouri School of Mines and Metallurgy. Explosives with different rates of detonation were used. Low speed 40 per cent Red Cross Extra Ammonia dynamite (10,000 feet per second) and relatively high speed 60 per cent straight dynamite (19,000 feet per second) failed in a 7-foot burn round whereas Gelex #2 and 50 per cent special gelatin (12,600 and 15,000 feet per second respectively) gave very good results. The 60 per cent straight dynamite was successfully used in a 5-foot wedge round. Modifications were necessary to break the same type round with amatol (14,600 feet per second).

After pentolite (22,500 feet per second) had failed in this modified round, two types of diamond-cut rounds were needed before attaining success with this explosive. Favorable results were obtained with Composition C-3 (25,600 feet per second) when fired in a special barrel round.

Two screens were installed to measure the broken rock. Plus 12, and plus 4 minus 12-inch particles were weighed and the amount of minus 4-inch was calculated. When converted to percentage, this fragmentation gave a basis for comparison between the various tests.

BIBLIOGRAPHY

1. Ackermann, K. G., The Influence of Grade Strength on the Efficiency of Gelatin Dynamite, Thesis, Missouri School of Mines and Metallurgy, 1948, 75 pp.

2. Bebie, J., Explosives, Military Pyrotechnics, and Chemical Warfare Agents, New York, Mcmillan Co., 1943, p. 171.

3. Brunswig, H., Explosives, Translated by Monroe and Kibler, New York, John Wiley & Sons, 1912, 350 p.

4. E. I. du Pont de Nemours & Co., Blasters Handbook, 12th Edition, 1949, 453 p.

5. Gardner, E. D., Drilling and Blasting in Metal-mine Drifts and Crosscuts, U. S. Bureau of Mines, Bulletin 311, Government Printing Office, 1929, 170 pp.

6. Grageroff, I., Explosives and Their Properties, Arizona Mining Journal, 15 May 1928, pp. 13, 14 and 25.

7. Meyer, M., Explosives, An Introduction to Their Chemistry, Production, and Analysis, New York, Thomas Y. Crowell Co., 1943, 452 p.

8. Shaffer, L. E., and Noren, C. H., The Influence of Cartridge Diameter on the Effectiveness of Dynamite, Technical Series, Vol., 19, No. 1, March 1948, 43 pp.

9. War Department, Technical Manual, FM 5-25, Government Printing Office, 1945, 145 p.

VITA

Harve Preston Nelson was born in Greenville, Texas, on March 31, 1909, and attended the elementary schools there. He was graduated from the El Paso, Texas High School in 1926.

One year was spent at Texas A. & M. College, and he obtained a Bachelor of Science degree in Minin Engineering at Texas College of Mines and Metallurgy in 1930.

During the school year, 1947-48, Mr. Nelson served as an instructor in the Engineering and Mining Departments of the Texas College of Mines and Metallurgy, where he recieved an Engineer of Mines degree in August, 1948.

In Se tember, 1948, he enrolled in Missouri School of Mines and Metallurgy and has served since that date as a Research Fellow in Mining Engineering.

His professional experience consists of six years of military service in the Corps of Engineers; four years as Mine Engineer at the San Pedro Unit, American Smelting and Refining Company, San Luis Potosi, S. L. P., Mexico; three years with Patino Mines and Enterprises, Llallagna, Bolivia, from Mine Surveyor to Engineer-in-charge of engineering and sampling at the Tatasi Mine; two years as Draftsman with the Mountain States Telephone and Telegraph Company, El Paso, Texas.