Sept. 9, 1952 D. M. McFARLAND 2,609,750

PROCESS OF BLASTING

Filed May 16, 1946

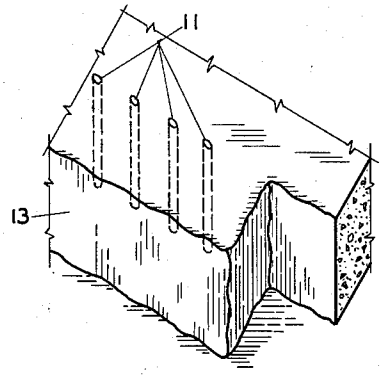

Fig. 1

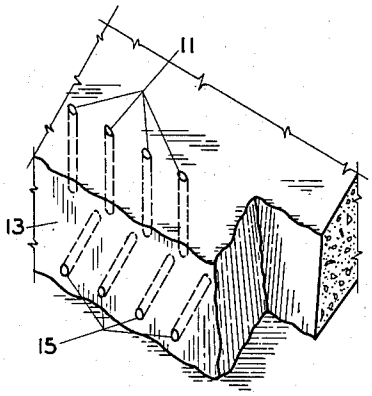

Fig. 3

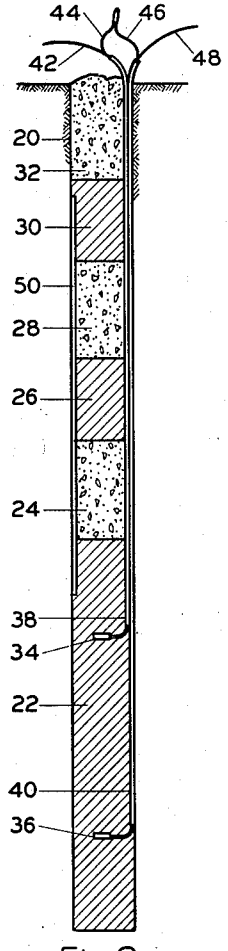

Fig. 2

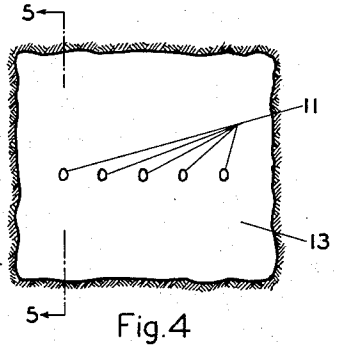

Fig. 4

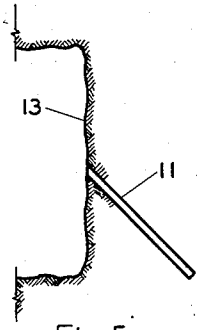

Fig. 5

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PROCESS OF BLASTING

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Application May 16, 1946, Serial No. 670,193

14 Claims. (Cl. 102—23)

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The present invention relates to blasting methods.

An object of the invention is the provision of a method of blasting productive of improved breakage of burden.

Another object of the invention is the provision of a method of blasting productive of reduced conditions of backbreak.

A further object of the invention is the provision of a method of blasting productive of reduced vibration conditions.

Still another object of the present invention is the provision of a method of blasting productive of lessened throw of broken material.

Other objects of the invention will be apparent from the following description.

Blasting operations of any considerable size, such as, for example, quarrying for the production of stone suitable for crushing, are usually conducted by detonating explosive charges in a plurality of bore holes drilled in a row behind and generally parallel to a face. The explosive charges in the individual bore holes are conventionally practically simultaneously initiated by such means as electric blasting caps or detonating fuses. The blast pushes out the burden in front of the holes creating a new face along the line of bore holes.

It is desirable that the blast break the blasted material into sizes which permit ready removal by power shovels, drag lines, or other loading equipment. Usually, however, customary blasting operations, such as have been just described, result in a throwing out of much of the burden in large solid blocks which cannot be adequately handled but which must be individually further drilled, charged with explosives, and blasted to break them up into manageable sizes (secondary blasting).

Another disadvantage which commonly results from the customary method of blasting described above is the occurrence of a large amount of backbreak. Backbreak is the formation of an uneven face and of large crevices which extend into the newly created face. Backbreak is an indication that the explosive has worked not only on the burden in front of the line of bore holes but also on the rock in back of the line of bore holes.

Backbreak is highly undesirable, as it makes subsequent blasting difficult for at least three reasons. First, the irregular face produced by backbreak results in uneven burdens on the different bore holes of a subsequent blast. Second, the presence of crevices interferes with the positioning, drilling, and loading of a new line of bore holes. Third, crevices permit wastage of explosives in subsequent blasts due to premature escape of gases through the crevices without effective action on the burden.

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Customary blasting technique is productive of another serious difficulty in the vibrations produced. Many quarries and other blasting sites are located near inhabited or manufacturing areas, and the vibration waves set up by blasting are blamed for much damage to structures and equipment. To prevent complaints, many quarries must seriously limit the size and number of bore holes in each blast despite the fact that for best blasting efficiency a large number of bore holes in a blast is desirable.

A further difficulty often encountered in blasting operations is excessive throwing of the blasted material. Undue throw often covers tracks used for haulage or damages equipment, and in spreading the blasted material over too large an area, makes its subsequent handling slow and expensive.

According to the present invention, a method is provided by which the above-mentioned disadvantages are in a large measure avoided.

It has been found that if, in a blast of a row of at least three bore holes aligned to break through a face and form a new face therebehind, the explosive charges in adjacent bore holes are detonated at slightly differing times the action of the blast is usually radically altered with the production of much improved breakage, greatly reduced backbreak, a most considerable diminution of vibrational effects, and much reduced throw.

Firing time separations should not be sufficiently great that the unity of the blast and the well known desirable action of multiple hole blasts on the burden are destroyed, and separations which are productive of optimum results vary somewhat with the nature of the material being blasted. In general, separations as high as about 150 milliseconds and as low as about 2 milliseconds produce improved results, but it is usually preferred that the amount of separation lie between about 20 milliseconds and about 75 milliseconds.

As will hereinafter be more fully described, the firing time separations employed in accordance with the present invention may be obtained by a number of different means, as for example, by the use of electric blasting caps having different firing times, electric blasting caps connected to different circuits which are energized

at separate times, and particular arrangements of detonating fuse.

The method of the invention may be performed in a number of ways. In a preferred method of operation, charges in a row of at least three bore holes arranged generally parallel to a face are detonated in two different groups, each hole of a first group alternating in position and in firing time with a hole of a second group and being initiated at substantially zero time after the actuation, in each hole of the first group, of the detonation initiator therein. For example, the bore holes of a first group may advantageously be initiated by means of instantaneous electric blasting caps in a single circuit, while the bore holes of a second group, each of which is in alternating position with a bore hole of the first group, are then initiated at a time or times slightly separated from and after the time of initiation of the bore holes of the first group by means of short delay electric blasting caps connected in the same circuit as the instantaneous electric blasting caps utilized to initiate the bore holes of the first group. In this manner all of the explosives in the blast may be detonated within a very short time period, as from about 2 to about 150 milliseconds and preferably from about 20 to about 75 milliseconds, and firing time separations of the same order between the initiation of the explosive charge in each bore hole and the initiation of the charge or charges in the hole or holes adjacent to it may be positively obtained.

Since it is chiefly important that firing of adjacent holes be separated by times within the effective range, desirable blasting effects may also be obtained without the alternating scheme just described. Thus a blast according to the invention is conducted when a second hole is fired after a first hole and a third hole is fired after a second hole, provided that the difference in firing time between adjacent holes is within the effective range. The difference in firing time between the first and third holes may be outside the effective range.

Moreover, as it is the time differential between adjacent holes that is important, it can be seen that it is not necessary to fire any hole at substantially zero time after the actuation, in each hole, of the detonation initiator therein. Thus, where the bore holes are grouped and initiated in alternating relation, as described above, there may be a time interval or delay between the initiation of the blasting caps relied upon to initiate the bore holes of the first group and their actual initiation of the bore holes, provided that the time interval or delay between the initiation of the blasting caps relied upon to initiate the bore holes of the second group is longer and provides the proper differential between the initiation of the explosive charges in adjacent holes. It is usually preferred, however, that all holes in a blast which are fired in accordance with the process of the present invention be fired within as short a time as is practicably consonant with the obtention of effective time separations between adjacent holes. Accordingly, it is usually desirable that all holes in a blast which are fired in accordance with the present system be fired within a few tenths of a second and preferably within about 300 milliseconds of the time of actuation of the detonation initiator in the first firing bore hole. Thus, where a blast is initiated by the use of electric blasting caps having differing firing times it is desirable that the blast be completed within about 300 milliseconds of the time of electrical actuation of the caps.

While the short delay periods utilized according to the present invention may be obtained in any convenient manner, it is usually preferred to obtain them by means of delay electric blasting caps having particularly short delay periods not greater than a few tenths of a second and preferably not greater than about 300 milliseconds.

Delay electric blasting caps, as is well known in the art, are blasting caps which fire a delayed period after the application of current to them. Most delay electric blasting caps obtain their delay period by means of a fuse train located between the ignition material and the primary detonating composition in the cap, and the delay time is determined by the burning time of the fuse train.

While particular short delay electric blasting caps form no part of the present invention it may be explained that a preferred short delay electric blasting cap may be provided by interposing a fuse element, or delay train, made up of a metal tube into which is pressed a charge of black powder, between an initiating means such as an electric match and a primary detonating explosive in the cap. When the delay train is made of a metal tube 0.140 inch in diameter and $\frac{5}{8}$ inch long into which 30 to 96 mesh granular black powder is pressed under about 450 pounds to a height of about 0.068 inch, a delay period averaging about 40 milliseconds with a standard deviation (the square root of the sum of the firing time deviations of a number of caps from the average delay period of the caps divided by the number of caps i. e. the root mean square deviation) therefrom of about 16 milliseconds is obtained. Caps of this type will hereinafter be designated as "A" type short delay electric blasting caps. When somewhat more black powder is employed so that the height of the black powder charge is about 0.133 inch and when an electric match is spaced about $\frac{9}{16}$ inch above the metal delay tube, a short delay electric blasting cap having a delay time of about 113 milliseconds and a standard deviation therefrom of about 16 milliseconds is obtained. Delay electric blasting caps of this type will hereinafter be called "B" type short delay electric blasting caps.

The short delay electric blasting caps just described are carefully sealed and are not vented as is customary in conventional delay electric blasting caps of longer delay periods employing black powder delay trains, for the building-up of pressure in the caps is generally important to the development of high burning rates.

Delay electric blasting caps applicable for use in the present invention are more specifically described and claimed in co-pending application, Serial No. 682,995, filed July 12, 1946, by John E. Jeffery for Delay Electric Blasting Caps.

It is to be particularly noted that short delay electric blasting caps as described above normally vary somewhat in delay period. The variation in timing is in each case within the effective range of time separation required for the present invention. It can be shown by conventional statistical methods that when caps having a standard deviation of 16 milliseconds, such as the A or B caps noted above, are distributed at random among a series of bore holes, 80% of the adjacent holes will be expected to fire with time separations within the limits of about 3 milliseconds and about 37 milliseconds (see Simon's Engineers' Manual of

Statistical Methods, 1941, John Wylie & Sons, Inc., New York, especially chapter XII and appendix C). Hence the invention may be practiced by initiating a row of holes by means of a number of similarly prepared short delay electric blasting caps when the individual variations in firing times among the caps are adequate to provide the desirable effects.

Another method by which the present invention may be employed makes use of ordinary instantaneous electric blasting caps connected to different circuits, the flow of current in which is initiated at spaced times by electrical or mechanical means which close the different circuits a short time apart. A multiple switch blasting machine is an example of a firing means which may be used when the invention is performed in this manner.

The multiple circuit method of obtaining the delay means, as just described, is not preferred for use in some formations where the firing of the holes in the first circuit may lead to the breaking of the wires of the second circuit before that circuit is energized, for under such conditions misfires in the second circuit may well result. Delay electric blasting caps are not subject to this disadvantage since they may all be initiated at the same time when connected in single circuit.

A further manner in which the present invention may be practiced is by the use of detonating fuse. Normally when detonating fuse is used, a trunk line of detonating fuse is connected to branch lines which run to individual bore holes. By varying among the different holes the length of fuse extending from a bore hole to a trunk, the time of initiation of different holes may be easily varied to provide the desirable effects of the present invention. However, since detonating fuse detonates at an exceedingly high velocity, the obtention of the desired variation in firing times requires the use of very considerable lengths of fuse, and the practice of the invention by this last-mentioned means is not usually preferred.

Another manner in which detonating fuse may be used to produce the effects of the present invention in a substantial way is by initiating a long row of bore holes by means of two trunk lines of detonating fuse. One trunk line may be connected to branch lines leading to one group of alternating holes, and the other trunk line may be connected to other branch lines leading to the other group of alternating holes. The trunk lines may be then initiated from opposite ends of the row. It may be seen that in this way the greater number of the adjacent holes are detonated at separated times. This same general method may be performed with a single blasting cap if the trunk line of detonating fuse detonated by it is joined to the other trunk line at the opposite end of the row.

The present invention is not limited in its application to blasting with a single row of bore holes, but may be applied where more than one row of holes parallel to a face are fired. When multiple rows are employed, it is preferred for the obtention of optimum effects that each row of holes be shot with a variation in timing amongst the holes as set forth above in describing single row blasts. Also when multiple row blasts are made it is usually preferable to time the firing such that holes in successive rows fire somewhat behind holes nearer the blasting face.

The invention finds application in many different types of blasting operations. A number of these will be described in connection with the drawings in which:

Figure 1 is a diagrammatic isometric view of a quarry face with bore holes drilled therein.

Figure 2 is a diagrammatic cross sectional view of a loaded bore hole.

Figure 3 is a diagrammatic isometric view of a bank provided with horizontal bore holes.

Figure 4 is a diagrammatic elevational view of a tunnel face, and

Figure 5 is a cross sectional view taken on line 5—5 of the face shown in Figure 4.

For quarry blasting shots it is usually preferred that a line of holes 11 be drilled generally parallel to a vertical quarry face 13 as shown in Figure 1. In a preferred use of the invention bore holes such as are shown in Figure 1 are initiated by a series of short delay electric blasting caps of two different periods arranged in alternating relation. Thus one group of alternating bore holes may be initiated by means of "A" type short delay electric blasting caps while the intermediate group may be initiated by "B" type delay electric blasting caps, or short delay electric blasting caps may be alternated with instantaneous blasting caps. In an alternating system of blasting it is usually preferred that the times of initiation be arranged so that the hole nearest an open end of a row be fired before its adjacent holes.

According to another method of operation, each hole can be fired by means of short delay electric blasting caps which have a normal variation in firing time amongst them of an amount sufficient to produce effective time separation.

Often in quarry blasting it is desirable that more than one row of holes parallel to a face be employed. The setup for such a blast would look similar to that shown in Figure 1 except that at least one more row of holes would appear behind those already shown. Multiple row blasting provides an opportunity for combining blasting operations according to the present method with more conventional blasting operations, although it is usually preferred that all holes be fired in accordance with the present invention. Thus a front row of holes might be fired with instantaneous electric blasting caps or with alternating instantaneous electric blasting caps and "A" type short delay electric blasting caps, while a back row might be fired with "B" type delay electric blasting caps.

In Figure 2 is shown an exemplary loading scheme for bore holes such as may be employed according to the present invention. In the bore hole, represented generally at 20, is shown a main explosive charge 22, a charge of gravel stemming 24, an explosive deck charge 26, a further gravel stemming charge 28, a second explosive deck charge 30, and a final stemming charge 32. The bore hole is initiated in the main charge by means of two similar electric blasting caps 34 and 36 to which current is led by wires 38 and 40, each of which includes two individual leg wires 42 and 44, and 46 and 48. The deck charges are initiated from the main charge by means of a line of detonating fuse 50 running from the main charge to the top deck charge.

The present invention is not limited to any particular loading schemes. That just described has been found productive of particularly good results but other systems may be employed. For example, the individual holes instead of being directly initiated by electric blasting caps may be initiated by lines of detonating fuse which are

in turn initiated by means of electric blasting caps located either inside or outside the bore holes.

In Figure 3 is shown a setup for horizontal blasting such as is used in a stripping operation where a seam of coal is to be uncovered. Horizontal holes 15 are drilled into a bank 13 and generally parallel to the material to be uncovered. Usually it is preferred when the bank is high also to drill a row of vertical holes 11.

The firing of a row of horizontal holes in a stripping blast according to the invention finds particular advantage because it is often productive of much less undesirable shattering of the material to be uncovered. The improved breaking and vibration conditions effected by the present invention are, of course, also important in stripping operations. When vertical holes are employed in addition to horizontal holes they also may be fired according to the present invention, or they may be so fired and the horizontal holes fired conventionally.

It should be noted that in stripping operations where both horizontal and vertical holes are shot, it is often desirable that one of the series be fired somewhat ahead of the other. Whether a horizontal series or a vertical series is fired first usually depends upon the handling equipment which is available for removal of the blasted material.

For example, a horizontal row of holes might be fired with alternating instantaneous electric blasting caps and "A" type short delay electric blasting caps while a vertical row of holes might be fired by means of "B" type short delay blasting caps.

In some stripping blasts, it is desirable to provide multiple rows of either or both of vertical and horizontal holes.

Figures 4 and 5 illustrate a setup for use where the process of the invention is employed in underground work. Figure 4 represents a front elevation of the face 13 of a tunnel with a row of holes 11 drilled across it. As appears from Figure 5, the row of holes is drilled downwardly and at an angle. In this way the lower corner of the face is blasted out. The individual holes in the row are discharged at a number of separated times within the effective range. In angle blasting of this type it is usually preferred that the angle made by the holes with the face be not less than 45°. Subsequent rows of holes may be drilled parallel to the row just described.

The invention will be further illustrated by the following examples which describe specific blasting operations:

Example I

A blast was made in a quarry from which a massive blue dolomitic limestone is mined and crushed for firing. The stone at this particular quarry has long been noted for being especially hard to break up into manageable sizes without excessive secondary blasting. A line of seven seven inch diameter holes was drilled according to the general scheme shown in Figure 1 of the drawing. Each hole was loaded principally with low velocity 60% strength dynamite in the general manner shown in Figure 2 of the drawing except that five of the holes were supplied with a third deck charge. The explosive for all but the top deck charge was in the form of six inch diameter 25 pound cartridges. 1¼ by 8 inch cartridges were used to make up the top deck charge. The stemming was finely crushed stone. Each hole was initiated in the main charge by two primer cartridges each made up of a short delay electric blasting cap embedded in a 1¼ by 8 inch dynamite cartridge. One primer was inserted just prior to the second cartridge loaded into the hole, and the other primer was inserted just prior to the last cartridge of the main charge. "Primacord" detonating fuse was used to carry detonation from the main charge to the deck charges. More specific data relative to the charging of the various holes is set forth in the table below. The blasting caps were all fired in a single series.

TABLE

Hole No.	Hole Depth	Height of Face	Distance from Hole to Face	Distance from Preceding Hole	Estimated weight of Burden	Weight of Dynamite in Main Charge
	ft.	*ft.*	*ft.*	*ft.*	*tons*	*lbs.*
1	61	56	14	[1] 24	1,568	325
2	62	57	13	17	1,049	350
3	62	57	13	17	1,049	325
4	62	57	13	18	1,111	325
5	63	58	13	16	1,005	325
6	63	58	13	17	1,068	350
7	63	58	12	17	986	350
Total					7,836	2,350

[1] Distance from termination of preceding blast.

Hole No.	Height of main charge	Depth of bottom of first deck charge	Weight of explosive in first deck charge	Depth of bottom of second deck charge	Weight of explosive in second deck charge	Depth of bottom of top deck charge	Weight of explosive in top deck charge
	ft.	*ft.*	*lbs.*	*ft.*	*lbs.*	*ft.*	*lbs.*
1	42	30	12½	20	12½	6	5
2	42	33	50	20	37½	6	5
3	43½	32	50	none	none	6	5
4	43	33	50	20	37½	6	5
5	43	26	50	none	none	6	5
6	42	33	50	20	37½	6	5
7	43	33	50	20	37½	6	5
Total			312½		162½		35

The short delay electric blasting caps used were of the "A" type. It is to be noted that the minimum time separation between adjacent holes is lessened when two short delay electric blasting caps are employed in each hole, as in this example. The expected separation under these conditions is the value obtained for the use of one cap in a hole, as noted above, divided by the square root of two. Thus, when two caps are used in each hole if the caps are from a group having a standard deviation of 16 it will be expected that in at least 90% of the cases the separation in firing time between adjacent holes will be at least about 2 milliseconds.

When the blast was set off very little vibration was noticeable and the noise was greatly muffled as compared with instantaneously fired blasts. The breakage obtained was excellent as evidenced by comparison with a generally similar blast made immediately prior and adjacent to it and initiated entirely with the use of instantaneous electric blasting caps. After the prior blast it was necessary that 198 holes be drilled in the blasted rock for secondary blasting operations. After the blast of this example only 19 holes were drilled for secondary blasting.

Example II

Another blast was made in the same quarry as that in which the blast described in Example I was made. The manner of loading this blast was generally similar to the blast of Example I. However, in this blast each of the 1st, 3rd, 5th, and 7th holes was initiated by means of instantaneous electric blasting caps, while each of the 2nd, 4th, and 6th holes was initiated by means of "A" type short period delay electric blasting caps, all caps being fired in a single series. The results of this blast were better even than those of Example I and this alternating method of blasting is usually preferred, for it insures an effective separation in firing time between all adjacent holes.

Example III

Another blast was made in the same quarry in which those of Example I and II were made. The same general loading scheme was employed except that in this last blast there were only six holes. The holes in this blast, however, were loaded with dynamite of two different low velocities, a dynamite of lower velocity (about 3,600 feet per second measured unconfined in 1¼ by 8 inch cartridges) being employed in holes 1, 3, and 5 and a dynamite of a higher velocity (about 6,800 feet per second measured unconfined in 1¼ by 8 inch cartridges) being employed in holes 2, 4, and 6. Holes 1, 3, and 5 were initiated by means of "A" type short delay electric blasting caps and holes 2, 4, and 6 were initiated by means of instantateous electric blasting caps.

This blast appeared to move out unusually slowly and produced a peculiarly muffled sound. The breakage produced was very good.

Example IV

Still another blast was made in the quarry where the blast of Example I was made. This was a nine hole blast, and it was loaded generally similarly to the blast of Example I except that alternate holes were fired by means of "A" type short period delay electric blasting caps of the type employed in the blast of Example I and "B" type short period delay electric blasting caps.

The method of shooting of this example produces adequate separation of firing times between adjacent holes and also avoids simultaneous firing even of alternate holes. This blast came out well and the breakage produced was exceptionally good.

Example V

In another limestone quarry a blast of thirty-four holes each about 5½ inches in diameter was made. In this blast the holes were divided into two parallel rows of seveneteen holes. The dynamite employed was packaged in five inch diameter 25 pound cartridges. In the front row beginning with the first hole, alternating holes were initiated by means of "A" type short period delay electric blasting caps and beginning with the second hole alternating holes in the front row were initiated by means of instantaneous electric blasting caps. In the back row each hole was initiated by means of "B" type short period delay electric blasting caps. This blast was also highly successful and produced a degree of breakage not ordinarily experienced at this location.

Example VI

In the limestone quarry of Example V, a six hole blast was made in each hole of which the charge consisted of a main charge and one deck charge. Beginning with the first hole the main charge in each alternating hole was initiated by means of an "A" type short delay electric blasting cap and beginning with the second hole each main charge was initiated by means of an instantaneous electric blasting cap. In this blast, however, each deck charge was fired by means of an "A" type short delay electric blasting cap, no detonating fuse being employed.

Example VII

In a mining operation in which a bank of overburden was stripped from a coal seam a single row of fourteen five inch horizontal holes averaging 39 feet in length were drilled. Each hole was charged with a main charge of low velocity dynamite and a deck charge of dynamite of somewhat higher velocity. Beginning with the first hole each alternate main charge was initiated by means of instantaneous electric blasting caps and beginning with the second hole each alternate main charge was initiated by means of "A" type short delay electric blasting caps. The deck charges in alternating holes, beginning with the first hole, were initiated by means of "A" type short delay electric blasting caps. Beginning with the second hole the deck charges were initiated by means of "B" type short delay electric blasting caps. The breakage produced in this blast was exceedingly good.

Example VIII

In a granite quarry having a face about 20 feet in height, 145 vertical holes were arranged in three parallel rows. Each hole was about 2 inches in diameter, and about 22 feet deep. The holes were about five feet apart, and each had been sprung with one 1¼ by 8 inch gelatin dynamite cartridge. They were loaded with a total of 1800 pounds of 1½ by 12 inch 60% gelatin dynamite cartridges. In the front row beginning with the first hole, each alternate hole was initiated by means of instantaneous electric blasting caps, and beginning with the second hole in the front row each alternate hole was initiated by means of "A" type short delay electric blast-

ing caps. Each hole in the second row was initiated by means of "A" type short delay electric blasting caps. The third row of holes was initiated by means of "B" type short delay electric blasting caps. This blast showed a marked improvement in breakage over conventional prior blasts using all instantaneous caps. A particularly great improvement obtained as a result of the blast of this example was practical elimination of backbreak which had been particularly serious at this quarry.

Example IX

In a limestone mine the face of a tunnel was drilled with fifteen 1½ inch diagonal holes in the general manner shown in Figures 4 and 5 of the drawing. Each hole was approximately 10 feet in depth and about 6 feet of tamping was used after the charge in each hole. A total of about 59 pounds of 40% gelatin dynamite was contained in all the holes. Beginning with the first hole, each alternate hole was fired by means of an "A" type short delay electric blasting cap having an average delay period of about 40 milliseconds and each alternate hole beginning with the second hole was fired by means of an instantaneous electric blasting cap. The results of this blast showed much improvement over prior conventional type blasts. Normally about seventy blocks requiring secondary blasting were produced. Only twenty-five required secondary blasting as a result of this blast.

Example X

In another limestone quarry a further type of blasting in accordance with the invention was performed. A row of 20 six inch holes were each loaded with 75 pounds of 50% strength ammonia gelatin dynamite and 100 pounds of 60% strength ammonia gelatin dynamite. Each hole was 30 feet deep and the holes were spaced 12 feet apart and 12 feet from the face of the quarry. The first six successive holes were each initiated by means of instantaneous electric blasting caps. The next seven successive holes in the row were initiated by means of "A" type short delay electric blasting caps, and the last seven holes were initiated by means of "B" type short delay electric blasting caps. This blast was productive of very good results, and while the breakage was good all along the line of holes, it was noted to be particularly good in front of the holes in which the short delay electric blasting caps were used.

By the term "initiation of a bore hole" is meant initiation of detonation of the explosive charge in a bore hole by a detonation initiator such as, for example, an electric blasting cap or detonating fuse.

By the term "actuation of a detonation initiator in a bore hole" is meant the application of the first force in the bore hole starting the functioning of the initiator, such as for example, the passing of current through the bridge wire of an electric blasting cap within the hole or the first detonation of fuse within the bore hole where a line of detonating fuse running into the bore hole is relied upon to initiate the hole.

What is claimed is:

1. A process of cooperative multiple bore hole blasting, wherein the blast is primarily detonated by electric blasting caps, which comprises detonating a row of at least three charged bore holes generally aligned so as on firing to break away a face and form a new face therebehind, the charges in the adjacent of at least three successively adjacent bore holes in said row being detonated at times separated by from 2 to 150 milliseconds and within about 300 milliseconds of the time of electrical actuation of the first firing blasting cap.

2. A process of cooperative multiple bore hole blasting wherein a row of at least three charged bore holes is generally aligned so as on firing to break away a face and form a new face therebehind which comprises detonating the charges in alternate bore holes substantially simultaneously, the charges in intermediate bore holes being detonated at times separated from 2 to 150 milliseconds from the time of detonation of charges in adjacent bore holes and within approximately 300 milliseconds of the time of actuation of the detonation initiator in the first firing bore hole.

3. A process of cooperative multiple bore hole blasting which comprises detonating a row of at least three charged bore holes generally aligned so as on detonating to break away a face and form a new face therebehind, the charges in the adjacent of at least three successively adjacent bore holes in said row being detonated at times separated by from 2 to 150 milliseconds and within approximately 300 milliseconds of the time of actuation of the detonation initiator in the first firing of said last mentioned bore holes, said time separation of from 2 to 150 milliseconds being sufficient to provide a high degree breakage on the burden but insufficient to destroy the cooperative effect of multiple hole blasting on the burden among said last mentioned holes.

4. A process according to claim 1 wherein said row is generally parallel to said face.

5. A process according to claim 2 wherein said charges in intermediate bore holes are detonated at times separated by from approximately 20 to approximately 75 milliseconds from the time of detonation of adjacent bore holes.

6. A process of cooperative multiple bore hole blasting wherein a row of at least three charged bore holes is generally aligned so as on firing to break away a face and form a new face therebehind which comprises detonating the charges in alternate bore holes substantially instantaneously, the charges in intermediate holes being detonated from about 20 to about 75 milliseconds from the time of detonation of charges in adjacent bore holes.

7. A process according to claim 3 where said time separation is a period from approximately 20 to approximately 75 milliseconds.

8. A process according to claim 3 wherein the charges in said boreholes are detonated in two different sets, each hole of one set alternating in position with a hole of a second set and each hole of said first-mentioned set firing before each hole of said second-mentioned set.

9. A process according to claim 3 wherein the charges in each successively adjacent bore hole in said row are detonated sequentially.

10. A process according to claim 3 wherein said time separation is a period of from approximately 20 to approximately 75 milliseconds, and wherein the charges in said bore holes are detonated in two different sets, each hole of one set alternating in position with a hole of a second set and each hole of said first mentioned set firing before each hole of said second mentioned set.

11. A process according to claim 1 wherein said time separation is a period from approximately 20 to approximately 75 milliseconds and where-

in said electric blasting caps are simultaneously electrically actuated.

12. A process according to claim 1 wherein said time separation is a period from approximately 20 to approximately 75 milliseconds and wherein the charges in said bore holes are detonated in two different sets, each hole of one set alternating in position with a hole of a second set and each hole of said first mentioned set firing before each hole of said second mentioned set.

13. A process according to claim 2 wherein the blast is primarily initiated by electric blasting caps which are electrically actuated simultaneously.

14. A process of cooperative multiple bore hole blasting which comprises detonating a row of at least three charged bore holes generally aligned so as on detonating to break away a face and form a new face therebehind, the charge in the adjacent of at least three successively adjacent bore holes in said row being detonated at times separated by from approximately 20 to approximately 75 milliseconds, the charges in said last-mentioned bore holes being detonated in two different sets, each hole of one set alternating in position with a hole of a second set and each hole of said first-mentioned set firing before each hole of said second-mentioned set, said time separation of from approximately 20 to approximately 75 milliseconds being sufficient to provide a high degree breakage on the burden but insufficient to destroy the cooperative effect of multiple hole blasting on the burden among said last-mentioned holes.

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