BLASTING IN MINES.

It must not be thought that, because an explosive is on the Permitted List, it is therefore unable to ignite firedamp underground. Permitted explosives are not flameless and they are quite capable of initiating a mine explosion unless proper precautions are taken. The conditions under which the explosive is fired are of prime importance in deciding whether an ignition of firedamp can take place or not.

It will be understood, of course, that constant developments are taking place in the field of explosives, both in the composition of the explosives themselves, and in the technique of shot firing. New and even safer explosives may well become available, and new rules of procedure laid down, and students must endeavour to keep in touch with these as they arise.

Firedamp may be ignited in various ways by explosives acting either singly or (more probably) in combination:—

(a) By the flame and hot gases accompanying the shot, unless the heat generated is effectively converted into mechanical work.

(b) By incandescent particles ejected from the shothole, if they succeed in penetrating the dense cloud of smoke and fumes which surrounds the site where a shot has been fired and forms a protective shield or blanket.

(c) By the compression wave set up by the explosive, especially in a break adjacent to the shot hole.

(d) By incompletely detonated explosive continuing to burn in contact with the external atmosphere.

The first major precaution is to make certain that no firedamp is present in the vicinity of the hole at the moment of firing the shot. It is laid down in the Explosives Order that no shot may be fired in any ventilating district unless the firedamp content is being regularly determined in that district, or on the return side of any place where the firedamp content is found to exceed 1¼%. Moreover, it is the duty of the shotfirer to examine for gas in the area concerned and in the approaches thereto, within a prescribed distance from the shothole and at the hole itself, both before charging the hole (or round of holes) and also before charging each shot (or round). If these examinations are properly carried out, there is reasonable certainty that no gas is present in the general body of the air or in accessible places. There remains the possibility that gas may be hidden in breaks crossing, or running along, the shothole and this danger will now be considered.

Breaks and Fissures.

It has been proved that one of the commonest factors in explosions of firedamp due to shot firing is the presence of a break or fissure in or near the shothole and containing an inflammable mixture of firedamp and air. Where such a break exists, the shothole is "open" and **the explosive acts there as it would do if unstemmed,** in so far as the explosive next to the break is concerned. The gas may conceivably be ignited by adiabatic compression alone, but, more probably, by compression acting in conjunction with the flame and hot gases, the effect of the compression being to widen the range of inflammable mixtures outside the normal limits of 5% to 15% of methane in air. If an ignition occurs in a break, **the resulting flame may then be communicated** by channels in the coal or adjacent strata **to larger bodies Of gas** a considerable distance away, e.g. in the goaf or old workings, and *so* cause a major explosion.

It is the duty of a workman who detects a break in a shothole whilst it is being drilled to inform the shotfirer, and the latter must himself search every hole for breaks with an approved break detector before charging it. **If any break is found, the shot must not be fired.** It may happen, however, that a break exists, e.g. in a roof ripping, but is not detected and, to guard against this danger the appropriate precautions are as follows:—

(1) Push a plug of stemming to the back of the hole, so sealing off any break at its inner end.

(2) Use only an authorised type of explosive (namely an Eq.S. or a sheathed explosive, or such other still safer type as may be developed and prescribed.)

(3) Stem the hole tightly to the mouth.

STEMMING MATERIALS.

The object of "stemming" or "tamping" a shothole is to confine the explosive, help to ensure complete detonation, and reduce the risk of igniting gas, if present. It may be accepted that, from the safety point of view, it is impossible to "over-stem" a shothole and the best practice is to stem all shotholes to the mouth. Stemming materials include moist clay, sand, (or limestone chippings), and a sand-clay mixture. Let us consider each in turn.

(a) Moist clay. This has the advantages that it is cheap and plentiful, it needs no preparation before being taken underground, it is easily moulded, it is incumbustible and, when moistened, it remains moist for a considerable time. Nevertheless, it is found that clay stemming is liable to be ejected in mass by the explosive charge and it then fails to fulfil its intended purpose.

(b) Sand. This offers a very high resistance to dislodgment. It is almost impossible to push a plug of sand 2 ins. in length along a borehole and this will often stick in the hole and become immovable. Sand therefore forms a most effective stemming material but it cannot be inserted in the normal way in horizontal or upwardly inclined holes. One way of overcoming this difficulty is to use sand-filled non-inflammable paper cartridges which can be pushed into the hole by a stemming rod. Another method is to use the Hurricane Air Stemmer, using damp limestone

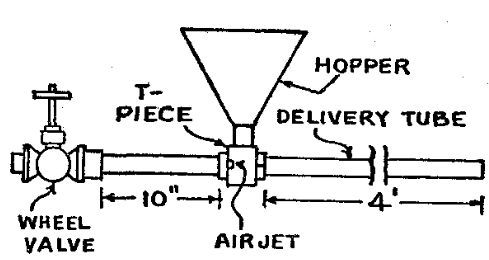

Fig. 1. Hurricane Air Steamer.

chippings as the stemming material in order to avoid the danger that would arise from airborne quartzitic dust.

The Air Stemmer consists of a conical hopper filled with the limestone chippings and connected by a T-piece to a pipe fitted with a control valve and delivery tube which is f in. less than the diameter of the hole. The delivery tube is inserted 2 to 3 ft. into the hole and the compressed air turned on. The machine is gradually withdrawn as the hole fills, the whole process taking only a few seconds. Essential precautions are (1) a plug of clay must first be placed in each hole to prevent the chippings being blown between and around the explosive cartridges; and (ii) the stemmer must be effectively earthed unless anti-static hose is used.

(c) Sand-clay mixture. This is generally accepted as the **most convenient and effective for** general use. It is as easy to handle as clay alone and offers almost as high a resistance as sand alone. The mixture should consist of 3 parts of coarse sand, brick dust, or ground clinker to 1 part of good quality surface clay, together with about 5% calcium chloride to keep it moist. Water should be added to make a stiff paste, not too wet, (say up to 10% water) which will neither flatten nor break up when a cartridge of the stemming is dropped from a height of 4 ft.

In some coal seams, it is found that more round coal is obtained if an air space is left between the outermost cartridge and the stemming, a procedure which is called "cushion firing." The method is useful where the shothole is long in relation to the burden to be blasted, e.g. in thin seams or rippings. Its effect is to lessen the shattering effect of the explosive, by distributing the pressure over a larger area, although the method is not successful in all seams.

PREPARING A CHARGE.

Among the points to be considered when a charge is being prepared are the following:—

(1) The weight of charge should be carefully chosen to ensure that it is correctly proportioned to the work it has to do so that (a) it may perform its work effectively and (b) the maximum amount of heat is transformed into work, so quickly lowering the temperature of the gases. The correct weight of charge to use in any given case depends on the kind of rock, the location of the shotholes, the number of free faces, and the presence of planes of weakness. It can only be judged by experience.

(2) **The diameter of the cartridges should be just slightly less than the diameter of the hole.** Small diameter cartridges in a large diameter hole are liable to incomplete detonation.

(3) **Every charge should consist of the fewest possible number of separate cartridges** so as **to** reduce the risk of air spaces (possibly filled with small coal or dirt) between adjacent cartridges, a condition which may prevent the transmission of detonation through the charge, The ideal would be one cartridge per hole, but this is impracticable for it would involve the shotfirer carrying round with him too large a number of cartridges of different sizes to suit the varied requirements met with on his round.

(4) The detonators must be properly secured in the primer cartridge, e.g. by tying the detonator leads in a half-hitch around the cartridge. The detonator is inserted by first opening the cartridge at the end and making a hole with a pointed wooden pricker and then burying the detonator until it is entirely covered by explosive.

Position of Detonator.

Two methods of placing the detonator in a charge are shown in Fig. 2.

(a) **Direct initiation or "front priming."** In this case, the primed cartridge containing the detonator is inserted last of all with its "business end" pointing towards the back of the hole.

(b) Inverse or indirect initiation or "back priming." In this case, the primed cartridge is inserted first, with its "business end" pointing towards the front of the hole.

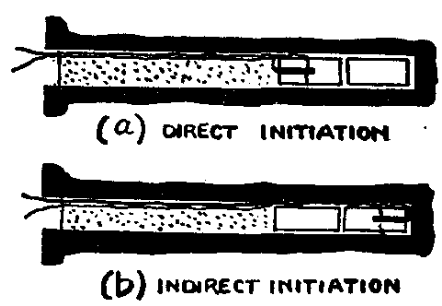

Fig. 2.
(a) Direct and (b) Inverse Initiation.

There has been much argument among mining men as to which of these methods is …………. results of further ……….. as follows :—

(1) Direct initiation is the less likely to cause ignition of firedamp and, as this is the primary consideration in a coal mine, it should be adopted for all normal shotfiring, other than delay blasting.

(2) Direct initiation reduces the risk of blown-out shots and more certainly ensures complete detonation of the whole charge, for the strongest detonation is directed towards the back of the hole when the explosive is most effectively confined.

(3) **Inverse initiation must be used for multi-shot delay blasting** because it is necessary in this case to ensure that, if a hole and its charge are partly destroyed by an earlier shot in the round, the detonator will explode what is left of the charge and so avoid a socket containing part of the charge unexploded.

(4) **Inverse initiation is said to give a better rock pull in "sumping" or "cut" holes** in shafts and drifts because greater advantage is taken of the shock wave of the exploding charge and less power absorbed in striking against solid immovable ground.

MISS-FIRED SHOTS.

A miss-fired shot is one in which the **detonator fails to explode,** or having exploded, fails to ignite the charge. **Imperfect detonation** of the charge may occur if the explosive is not in sound condition (e.g. if ammonium nitrate explosives are allowed to become wet): if the cartridges do not touch each other; if cartridges of too small a diameter are used; or if the hole is not properly stemmed. **Complete failure of the detonator** to explode may be due to:—

(1) Defective shot-firing exploder by which the required voltage is not generated.

(2) Bad connection between exploder and shot-firing cable.

(3) Defective shot-firing cable, e.g. broken wires or damaged insulation.

(4) Dirty connections between cable and detonator leads.

(5) Broken detonator leads, or insulation damaged when charging.

(6) Faulty detonator, e.g. broken wire bridge or defective priming composition.

The necessary precautions include: (a) careful testing and maintenance of exploders, (b) use of good shot-firing cable; (c) careful making of connections; (d) storage of detonators in cool dry magazines; and (e) careful handling of detonators to avoid damaged leads. The manner of dealing with a miss-fire, if one occurs, is laid down in detail in the Explosive Orders to which reference should be made.

MULTI-SHOT BLASTING.

This term is applied to two methods of shotfiring known respectively as:—

(a) **Simultaneous shotfiring** in which a round or group of shots is fired with **instantaneous detonators.**

(b) **Delay firing** in which a round is fired with **half-second or milli-second delay detonators** so that groups of shots (termed sumping or cut shots, easers, and trimmers) within the round are timed to explode at short pre-determined intervals. This enables a large number of holes in a round to be charged together and fired in one operation.

Under present regulations, rounds of up to six shots may be fired simultaneously anywhere in the mine, but larger rounds and delay firing are restricted to stone drifts and sinking pits except by special permission. Some relaxation of these rules may well occur as time goes on.

The advantages of multi-shot blasting are:—

(1) Reduced risk of igniting gas, for it is often the second or subsequent shot of a number fired singly that ignites firedamp set free by a previous shot. Even with half-second delay detonators, the last shots must go off within 4 seconds of the first and the risk of igniting gas is small, whilst with milli-second delays, only a fraction of a second elapses between the first and last shots and the blast may be regarded almost as simultaneous.

(2) Fewer examinations for gas are required and these are made under the most favourable-conditions.

(3) Greater safety for the shotfirer, for he has not to return several times to the face during shotfiring operations and is not so much exposed to falls of roof and side.

(4) Greater safety for the workmen, for they have only to take cover once.

(5) Great saving of time, tending to ensure greater care taken by the shotfirer.

(6) Blasting may be carried out between shifts, after withdrawal of the men.

(7) Reduced cost of explosives, fewer shots being needed: or a reduced charge per hole.

The chief disadvantage of multi-shot blasting is that a miss-fire may occur and remain undetected.

It is therefore essential (a) to reduce to a minimum the risk of a miss-fire occurring, and (b) to make a careful examination for miss-fires after each round of shots.

Equipment and precautions necessary.

(1) Only low-tension detonators, or delay detonators, as the case may be, to be used. The leads must be of copper and long enough to enable the shots to be connected in series without using odd bits of wire.

(2) Two single-core cables (lead and return) to be used in stone drifts, one along each side of the road, in order to (a) prevent short-circuiting between conductors, (b) enable a fault in either cable to be more easily traced, and (c) facilitate series connection of the shots.

(3) All joints in the firing circuit to be adequately insulated by approved plastic tape or a neoprene sleeve, especially in wet places, to avoid risk of a miss-fire.

(4) An exploder of adequate capacity to be used, capable of supplying sufficient current (about 1-5 amp) at the moment of firing.

(5) The cable and the complete firing circuit to be tested for continuity and resistance by an approved circuit tester before the round is fired.

(6) Shotfirers to be special trained in multi-shot blasting.

SHOTHOLES IN COAL.

The placing of holes in coal is governed by the thickness of the seam, the position of the undercut, the presence of hard bands (if any), the type of roof or floor parting and the direction of the cleats. These are all variable factors and some experiment must be carried out in every case to find the best method. In the average normal ease, the shot is arranged as in Fig. 3, the length of the shothole being 6 in. less than the depth of undercut and the "burden" (or the distance from the hole to the undercut) being about two-thirds to three-quarters of the length of the hole. The spacing between the holes may be 4 ft. 6 ins. to 8 ft., being greater as the burden increases, and the charge may range from 4 oz. to 14 oz., depending on the

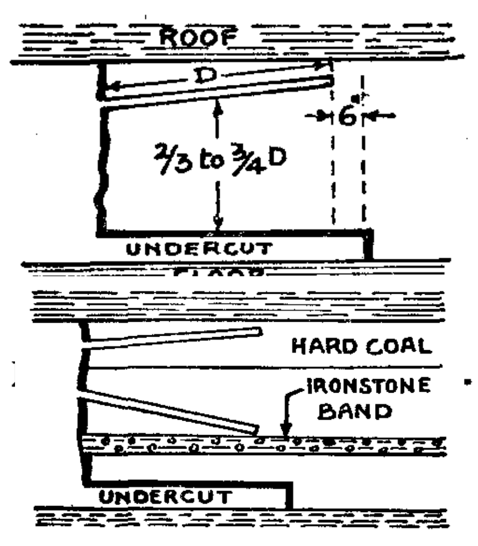

Fig. 4.
Coal with Ironstone Band.

burden and the hardness of the coal. As far as possible all holes should cross the main cleats at right angles. In thin seams, or where a middle cut is used, closer spacing may be necessary because the burden is small. In thick seams, 5 ft. or more, a double row of holes may be necessary to get well-balanced shots.

Fig. 4 illustrates a seam where there is a hard band of ironstone about 1 ft. above the floor. In this case, it is necessary to fire easer shots just above the hard band to break it down, as well as the normal shots to bring down the hard coal next to the roof.

SHOTHOLES IN RIPPINGS.

The essentials in roof ripping are that good breaking off bars and props should be set and good fragmentation must be obtained. The burden in medium ground should not exceed 3 ft. and in hard ground 2 ft. and this often necessitates the ripping being taken in two, or three, lifts. Charges may range from 10 to 20 oz. in hard shale, but down to 6 oz. in soft shale and up to 28 oz. in hard sandstone. In all cases, it is desirable to keep the ripping as near to the face as circumstances permit in order to reduce the dangers arising from the development of roof breaks and bed separations.

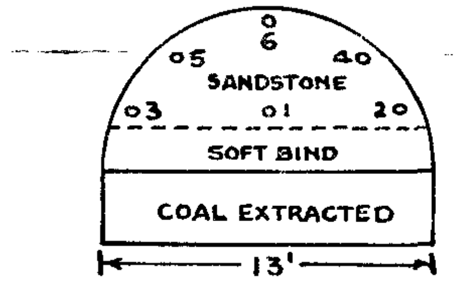

Fig. 5. Shotholes in Roof Ripping.

Fig. 5 shows a common arrangement of holes in hard ground, although both a smaller, and a larger, number of holes may be required in different cases. The shots may be fired singly in the order named but this involves the shotfirer going to the face six times for charging the holes, testing for gas and coupling up. Fragmentation also may be poor. Alternatively, the holes in each row, i.e. on each horizon, may be fired simultaneously with instantaneous detonators, first holes 1, 2 and 3 together, then holes 4 and 5, and finally hole 6 by itself. This involves only three visits to the face and it results in better fragmentation. It is rarely advisable to fire the shots in two or more horizons simultaneously, because the burden of the shots in the second and third horizons is likely to be too great and fragmentation ineffective.

In cases where **delay firing,** using milli-second delay detonators, is permitted, the same pattern of holes in three horizons may be used but **only one delay number must be used on any one horizon** in order to reduce the possibility of a "cut-off" in which an earlier shot cuts across a later shot. **The advantages likely to accrue from milli-second delay firing in rippings** are (1) reduced danger of ignition of gas because the full round is fired within a small fraction of a second; (2) reduced consumption of explosives; (3) less roof disturbance; (4) cleaner cut road sides; and (5) still better fragmentation, so facilitating the removal of debris and its stowage in the packs.

SHOTFIRING IN STONE DRIFTS.

The technique of blasting in stone drifts naturally differs from that in coal and rippings because there is no free face until one is created by blasting. It is therefore necessary to arrange the holes in such a way, and fire them in such a sequence, that each group of holes in succession provides a free face for the next following group. Various patterns of holes have been used, including (a) drag cut, (b) fan cut, (c) pyramid cut, (d) wedge cut and (e) burn cut. Of these, the wedge cut has been the most widely used, and both this, and the burn cut, have given excellent results, and high rates of advance, in large stone drifts. Delay firing is standard practice in major drifting work, but is not universally employed in the smaller drifts where high-speed drivage is not essential.

(a) Drag cut.

This is applicable chiefly to small or narrow drifts where other methods would not be applicable because of restricted width. Each group of holes, termed cut holes, lifters, easers, and trimmers, and marked 0, 1, 2, and 3 respectively, is fired simultaneously in that order, using instantaneous detonators. Alternatively, if desired, the whole round may be fired by half-second delay detonators. Where necessary, as in hard ground, an additional set of shorter cut holes may be needed, just below those marked 0, to form an initial sump.

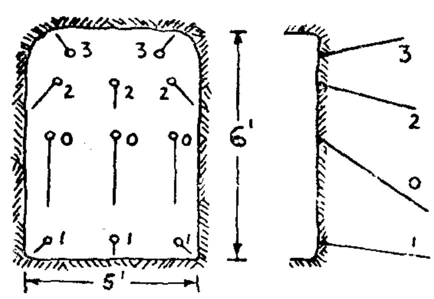

Fig. 6. Drag Cut.

(b) Fan cut.

Fig. 7 shows this method as applied at a Scottish colliery, firing being **carried out in two operations.** First, the 9 holes shown by black dots within the dotted rectangle were drilled by air-leg mounted machines, charged with Polar Ammon Gelignite, (permitted explosives not being required) and fired with half-second delay detonators, using, 0, 1, 2, and 3 delays, so forming a "cut" 1 ½ to 2 ft. high. There after the remaining 25 holes were drilled, charged and fired in the similar way. The total weight of the for a complete round with a 6 ft. pull was of the order of 45 lb. in shale and 60 lbs. in sandstone. It was claimed that the method had the following advantages :—(1) the total number of holes and the consumption of explosives per round could be reduced because the second series of holes was drilled after the result of the cut was observed ; (2) the possibility of damage to arches as the result of "gunning" due to shots not pulling, was remote ; (3) drillers could take

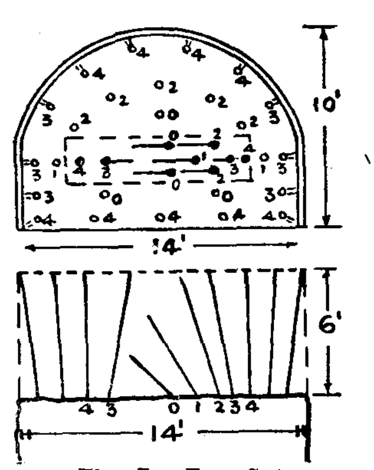

Fig. 7. Fan Cut.

full advantage of natural breaks ; and (4) the amount of material to be loaded at one time was reduced—a decided advantage where high density loading cannot readily be arranged.

(c) Pyramid cut.

This consists of four, five, or six sumping or cut holes marked 1, drilled *so* that they almost meet at a common point and so form a pyramidal sump. The remaining holes are then arranged as shown and the completed round fired by delay detonators in the usual way. The method has been applied in hard homogeneous ground but is not frequently used.

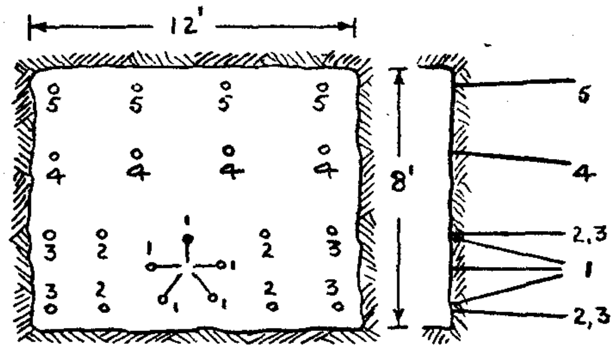

Fig. 8. Pyramid Cut.

(d) Wedge cut.

Fig. 9 shows a typical round of shots, using the wedge cut, in a stone drift, 15 ft. *x* 12 ft., using **half-second delay detonators.** The drilling pattern should be based on the lateral enlargement of the cut almost to the full width of the drift before the top and bottom sections of the face are fired. The round consists of three pairs of cut holes marked 0 directed towards each other, so breaking out a wedge-shaped prism at or near the centre line of the drift. In addition, two shorter central "stab" holes are drilled straight in to split up the wedge so formed. Thereafter, the remaining holes, 1, 2, 3, 4, 5, and 6, are drilled as shown, and the complete round fired in one operation with delay detonators having the delay numbers stated.

A similar pattern of holes may be fired by **milli-second detonators.** Some difficulty was experienced at first when blasting with these detonators because of the extended length of the rock pile which reduced the efficiency of mechanical loading. It has been shown, however, that, by increasing the delay interval to at least 100 milli-seconds between the cut shots, first easers, and second easers, the length to which the rock pile is thrown can be reduced to a reasonable figure. It is generally considered that the advantages of milli-seeond blasting in drifting are (1) better fragmentation, (2) avoidance of cut-offs, (3) reduced fumes, (4) slight reduction in explosives used, and (5) increased safety in the presence of coal seams due to the shorter overall period of delay.

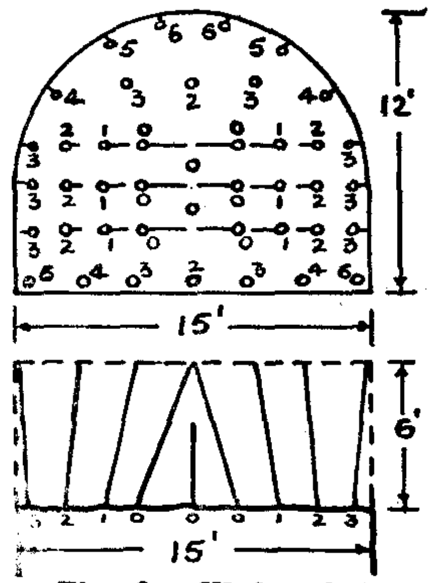

Fig. 9. Wedge Cut.
(*Half-second Delay Detonators*).

The number of holes required in the wedge cut depends on the cross-sectional area of the drift and the nature of the strata, 'out not on the depth of pull. The following figures are based on practice and are put forward tentatively as suitable for the conditions stated:—

Area.	Number of holes.		
100 sq.ft.	23-25 in soft shale,	32-34 in hard shale,	38-42 in sandstone.
130 sq.ft.	28-30 „ „ „	35-37 „ „	42-44 „
160 sq.ft.	31-33 „ „ „	39-42 „ „	46-48 .,

It will be understood that particular drifts may not conform to these figures, but they will be a guide to students who may have to "make an estimate" at an exam.

The weight of explosive per round depends on the cross-sectional area, the nature of the strata, and also the depth of pull. The area and the pull together determine the volume of extraction and this forms the most convenient basis for estimating the total charge per round, having due regard also to the nature of the strata. Suggested figures are as follows, assuming a 6 ft. pull for each of the areas previously given:—

Volume.	Total weight of explosive in lb,		
600cub.ft. ...	18-20 in soft shale,	36-42 in hard shale,	60-72 in sandstone.
780 cub. ft. ...	24-26 „ „ „	48-56 „ „	72-84 „
960 cub. ft. ...	28-32 „ „ „	60-68 „ „	84-96 „

The terms soft shale, hard shale, and sandstone, of course, are rather indefinite and there are many intermediate kinds of rock to consider. In the final analysis, the correct weight of explosive to use must be determined by experience in the drift concerned.

The weight of charge per hole will obviously depend on the total charge divided by the number of holes and may be less than 1 lb. per hole in soft shale, up to If lb. per hole in hard shale, and up to 2 lb. per hole in hard sandstone. These are average figures, but it is usual to charge the cut holes and corner holes more heavily than the others. The maximum permitted charge in stone drifts, of course is now 48 ozs., although this is normally required only in very hard ground or where a pull in excess of 6 ft. is aimed at. -

(e) Burn cut or shatter cut.

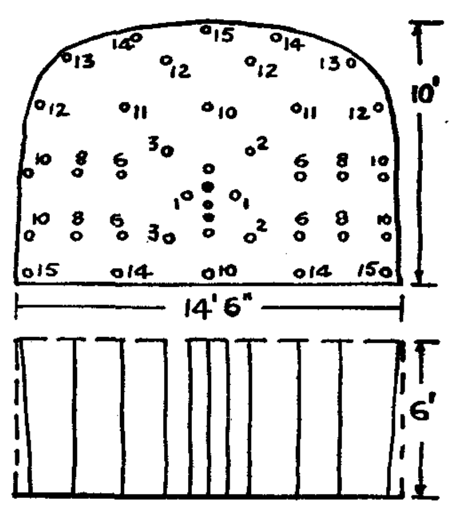

Fig. 10. Burn or Shatter Cut.
(● = Holes cushion-stemmed).

This cut originated in Cornwall, was developed in metal mines in Canada and the U.S.A., has been much used in hydro-electric tunnel schemes in Scotland, and is now being successfully applied to stone drifts in coal mines.

The principle of the Burn cut is to drill a series of 5, 6, or more parallel holes in a cluster at right angles to the face and at close and uniform centres (about 5 in.) in order to form the initial cut. One or more of the holes is left uncharged with explosive to form a free face, the charged holes breaking out into the empty holes. Alternatively, as in Fig. 10, one or more of the holes may be charged, but cushion stemmed. The holes may be arranged symmetrically in a box-shaped pattern, or in a straight-line pattern as shown in the sketch, this having been found to reduce the distance to which the initially shattered material is projected. Thereafter the cut is enlarged to almost the full width of the drift, by a suitable selection of delay numbers, before the top and bottom sections are fired.

The weight of explosive required for the Burn cut appears to vary widely in different cases. In the drift shown in Fig. 10, driven in medium hard shale, all 40 holes were charged with 28 oz. per hole, giving a total of 70 Ib. for the complete round. In another case, where the drift was 18 ft. wide by 13| ft. high, driven through shale and fireclay, 44 holes were drilled, 43 were charged, and the total charge was 112 Ib. for a pull of 6 ft. Individual charges ranged from 32 to 48 oz.

It is stated that the Burn Cut is most effective in hard, brittle, homogeneous strata, but less successful, especially with long pulls, in spongy ground where there is neither regular jointing nor bedding, and in broken and well laminated ground.

The advantages of the Burn Cut are claimed to be as follows:—

(1) The drilling time per round may be reduced because all holes are drilled straight and parallel into the face instead of at various angles, as with the wedge cut. This enables maximum advantage to be taken of drill rigs and saves the time otherwise spent in setting the machines.

(2) **The designed pattern of holes is more easily achieved,** with less supervision and without the use of hole directors. On the other hand, great care must be taken to align the central cluster of holes accurately in order to avoid their meeting or crossing at the back of the holes.

(3) **The possible depth of pull is independent of the size of the drift** and is determined only by the hardness of. the ground and the permissible charge of explosive, due regard also being paid to the depth of the round it is desirable (or possible) to drill, fire, and load per shift.

(4) **The quantity of projected material is likely to be reduced** because the shatter area *is* small and, after the cavity has been made, the remaining holes break inwards.

TEST PAPER MK/12.

1. (a) Explain the term "permitted explosive," (b) To what extent is a permitted explosive safe ?
2. (a) What steps would you take to ensure complete detonation of a charge of high explosive in a shothole ? (b) What disadvantages are attached to incomplete detonation?
3. (a) What are the objects of stemming a shothole ?
(b) What do you regard as the most suitable material for stemming? (c) What do you understand by cushion blasting?
4. (a) What *is* meant by "direct initiation" and "inverse initiation" of a charge ? (b) What are the arguments in favour of each method ?
5. (a) Explain the danger arising during shotfiring operations from the presence of breaks in a roof ripping, (b) Draw a plan and section of part of a longwall face to illustrate your answer, (c) What precautions can be taken against the danger you describe ?
6. Describe, and show by a sketch, the placing of the shotholes in the driving of a cross-measure drift, 15 ft. by 12 ft. excavated, in strong shale. Details to be given should include (a) type of explosive used, (b) depth of holes, (c) number of holes, (d) amount of explosive used per round, and (e) method of firing.
7. (a) Describe with the aid of a sketch the principle of the milli-second delay-action detonator. (b) What advantages has this type of detonator over the one-second delay detonator in stone drifts, and over the instantaneous detonator in roadway rippings?
8. Outline clearly, but concisely, in your **own** words, the prescribed procedure in case of a single-shot miss-fire, the shot having been fired electrically.

MINE ΩOPKINΓ

Answers MK/12

BLASTING IN MINES.

1. (a) Explain the term "permitted explosive." (b} To what extent is a permitted explosive safe?

PERMITTED EXPLOSIVES.

(a) **A permitted explosive** is one of a number of high explosives which have been approved for use in mines where safety lamps are used, or in any part of any mine where coal dust is a hazard. Such explosives have passed certain prescribed official tests involving the firing of shots, both stemmed and unstemmed, into an explosive firedamp-air mixture, and unstemmed into a gallery containing coal dust. No ignition must have occurred in any of the tests and the explosive must behave in a manner deemed satisfactory by the testing officer.

(b) **Permitted explosives cannot be regarded as inherently safe,** for they all depend on their effectiveness on the heat generated by their detonation. **They are not "flameless"** and are therefore capable of igniting firedamp under conditions that may occur underground. Nevertheless, by admixture with cooling agents, by the use of sheathed explosives, and by the development of Eq.S. explosives, the risk of igniting gas or coal dust has been greatly reduced. And, if the explosive is charged, stemmed and fired in accordance with regulations, the danger becomes almost negligible. Further, if the technique of infusion blasting is adopted, whereby a suitable water-resisting gelatinous explosive is fired in a shothole filled with water at the moment of firing, the danger of ignition of gas is virtually eliminated.

"Ultra-safe" explosives are also being developed which, whilst not absolutely and intrinsically safe in the presence of gas, have a much greater factor of safety than previous types of permitted explosive. Such explosives are of low density and low power (about 30% of that of blasting gelatine) and are likely to have a wide field of usefulness in coal and roof rippings.

2. (a) What steps would you take to ensure complete detonation, of a charge of high explosive in a shothole ? (b) What disadvantages are attached to incomplete detonation?

ENSURING COMPLETE DETONATION.

(a) Assuming that the explosive supplied is in sound condition and that a normal standard detonator is used, the necessary precautions are :—

(1) See that the hole is properly cleaned out to ensure that the cartridges, when pressed home, are touching one another.

(2) See that the diameter of the cartridges is just slightly less than the hole diameter.

(3) Use as few cartridges as possible to make up the required weight of charge.

(4) With sheathed explosives, avoid the sheath becoming damaged or displaced.

(5) Avoid using ammonium nitrate explosives in wet shotholes, especially those of the non-nitro-glycerine type.

(6) Stem the hole thoroughly with an adequate amount of stemming.

(b) The disadvantages of incomplete detonation are that (1) some of the power of the explosive is wasted, (2) the danger of igniting firedamp is increased, and (3) the production of carbon monoxide and nitrous fumes is increased.

3. (a) What are the objects of stemming a shothole ? (b) What do you regard as the most suitable material for stemming? (c) What do you understand by cushion blasting?

STEMMING A SHOTHOLE.

(a) **The purposes of stemming** are (1) to confine the explosive so as **to ensure complete detonation** and the development of maximum power; and (2) **to prevent the ignition of firedamp** either by flame from the explosive or by incandescent particles which may otherwise be ejected from the shothole.

(b) **The most convenient stemming material** for normal use is generally regarded as **a moist 3: 1 sand-clay mixture** containing a little calcium chloride, this mixture being readily formed into plugs and offering greater resistance to ejection than clay alone. **The most effective material is sand** which, for convenience in handling, may be formed into sand-filled non-inflammable paper cartridges. Alternatively, limestone chippings may be used, this material being blown into the shothole by compressed air through the medium of an appliance known as a Hurricane Stemmer.

(c) **Cushion blasting** is a technique whereby an air space is left between the stemming and the explosive charge, so spreading the force of the explosive over a greater area and reducing its shattering effect. It is likely to be advantageous when the "burden" is small in relation to the length of the shothole, or in friable coal where the production of large coal may be increased.

4. (a) What is meant by "direct initiation" and "inverse initiation" of a charge ? (b) What are the arguments in favour of each method?

DIRECT AND INVERSE INITIATION.

(a) These terms refer to the position of the detonator in a charge. With **direct initiation,** the detonator is placed at the outermost end of the charge, next to the stemming, the "business" end of the detonator pointing to the back of the hole. Conversely, with **inverse initiation,** the detonator is placed at the innermost end of the charge, with the "business" end pointing towards the front of the hole.

(b) **The arguments in favour of direct initiation** are that (1) ignition of firedamp is more certainly prevented, (2) complete detonation is more certainly ensured, and (3) a blown-out shot is less likely to occur.

The arguments in favour of inverse initiation are that there is less risk of (1) the detonator being pulled inadvertently out of the primer cartridge, and of (2) the detonator being accidentally fired when the hole is being stemmed, although both these drawbacks of direct initiation are negligible if ordinary care is used. Moreover, (3), in delay firing, there is less risk of unexploded cartridges being left in sockets if a later charge in the round is partly destroyed or displaced by an earlier charge. It is also claimed that (4) inverse initiation gives a better rock pull in sumping or cut holes in stone drifts.

5. (a) Explain the danger arising during shotfiring operations from the presence of breaks in a roof ripping, (b) Draw apian and section of part of a long-wall face to illustrate your answer.' (c) What precautions can be taken against the danger you describe?

DANGER OF BREAKS IN ROOF RIPPING.

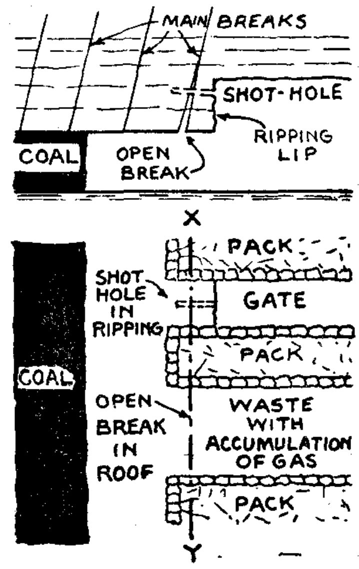

Fig. 1.
Plan and Section of Face.

(a) The danger arising from roof breaks is that **gas therein may be ignited** by the flame and hot particles from a shot, assisted by the effect of compression, **and the resulting flame may then be transmitted for an indefinite distance** via breaks and bed separations into the adjoining waste or other place where a large body of gas is present. Many ignitions have occurred in this way, some with serious results.

(b) **The adjoining plan and section** show a gate-end on a longwall strip-packed face. The shothole in the ripping intersects an open break **XY** extending along the face and communicating with an adjacent waste. The danger arising from this situation is obvious. Further, if bed separation extends back over the goaf, gas much further back in the waste may also be ignited.

(c) **The precautions to be taken** include: —

(1) The ripping should be kept as near to the face as possible (or in advance of the face, where practicable) so that it is in ground least affected by breaks.

(2) **The roof in front of the ripping should be adequately and promptly supported** so as to minimise the formation of breaks.

(3) **Every shothole must be examined for breaks** and, if any are found therein, the shot must not be fired.

(4) **Only an authorised type of explosive must be used** in ripping shots (e.g. an Eq.S. explosive or such other explosive as may be developed and prescribed) and both the back and front of the charge must be sealed by stemming material.

(5) **Some** alternative **method of ripping should be considered,** e.g. Cardox or mechanical picks.

It may also be stated that, where several shots are to be fired in a ripping, the firing of one shot may open up previously closed breaks which will then be a danger with subsequent shots. This danger may be countered by firing the complete round with milli-second detonators so that all the shots are fired within 75 milli-seconds or so before breaks have time to develop. The danger of igniting gas is thereby reduced.

6. Describe, and show by a sketch, the placing of the shotholes in the driving of a cross-measure drift, 15 ft. by 12 ft. excavated, in strong shale. Details to be given should include (a] type of explosive used, (b) depth of holes, (c) number of holes, (d) amount of explosive used per round, and (e) method of firing.

SHOTHOLES IN STONE DRIFT.

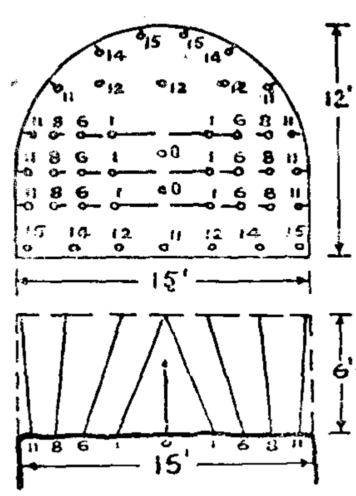

Fig. 2. Milli-second Delay Blasting with Wedge Cut.

The adjoining sketch shows a suitable pattern of holes in the drift referred to, using the wedge cut with milli-second delay blasting.

The central stab holes are first fired instantaneously to shatter the wedge and the remaining holes are fired by detonators having the delay numbers specified. The complete round is fired within a period of 0-7 second. Further details are:—

(a) The type of explosive used would be a permitted gelatinous nitroglycerine explosive such as unsheathed Polar Ajax.

(b) The depth of the holes would be 6 ft., but the wedge holes may be bored to a slightly greater depth in order to ensure that the remaining charges pull as near as possible to the full depth.

(c) The number of holes, based on a sectional area of about 160 sq. ft., would be 42, subject to variation in the light of experience.

(d) The weight of **explosive used per round,** assuming an excavated volume of 960 cub. ft., would be **in excess of 60 lb. and may be as much** as 70 lb., or even more, depending on the hardness of the shale.

(e) The method Of firing is essentially described by the term "milli-second delay blasting", but this may be amplified by stating that (i) all the shots would be connected electrically in series ; (ii) two single-core cables would be used to prevent the risk of short-circuiting between conductors ; (iii) all joints would be carefully made ; (iv) the circuit would be tested for continuity and resistance before firing ; and (v) the firing station would be at least 200 yds. from the face.

7. (a) Describe with the aid of a sketch the principle of the milli-second delay-action detonator, (b) What advantages has this type of detonator over the one-second delay detonator in stone drifts, and over the instantaneous detonator in roadway rippings ?

MILLI-SECOND DELAY DETONATORS.

(a) A delay detonator resembles a low-tension instantaneous detonator in that its components include (i) a copper tube sealed by a neoprene plug, (ii) an electric low-tension fuse, connected to copper leading wires, (iii) a priming charge of A.S.A. composition (lead azide, lead styphnate, and aluminium) and (iv) a base charge of P.E.T.N. or tetryl which detonates the explosive charge.

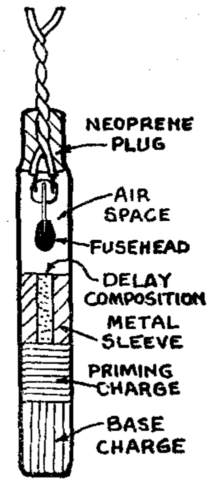

Fig. 3.
Delay Detonator.

It differs from an ordinary detonator in that it contains (v) a delay element consisting of a metat-sleeve filled with a special delay composition. With, one-second and half-second delays, this is a mixture of antimony and potassium permanganate. With milli-second delays, it is a red lead-silicon mixture, but it must be understood that new delay materials may be introduced as time goes on. Short delay detonators are made so that the delay period between successive delays is measured in 20, 25, 50, and up to 85 milli-seconds (according to type and delay number) but these are "nominal" delays and it must be recognised that detonators of the same delay number do not all fire at precisely the same instant, but with some degree of "scatter." The current required to fire a single detonator with certainty is 0-5 amp., but, for rounds up to 25 shots, the current should be not less than 1-5 amps., and for greater numbers, 2 amps.

(b) Detonators compared.

In stone drifts, milli-second delays are to be preferred to one-second delays (which have now been discontinued) because:—

(i) A larger number of delays can be arranged within the limiting period of 5 seconds, only 4 delays being permissible with one-second delays, whereas the whole range of 0—15 delays in the milli-second type can be spanned in less than one second. Much larger rounds can therefore be fired effectively in one operation, without too great a burden being placed on shots having the same nominal delay period.

(ii) The chances that firedamp released by earlier shots may be ignited by later shots in a round are greatly reduced. This is of special importance when a stone drift is near to, or passing through, a coal seam.

(iii) Experience has shown that milli-second delays result in better fragmentation, reduced fumes, less risk of cut-offs, and slight reduction in explosives consumption.

In roadway rippings, the advantages of the milli-second delay detonator over the instantaneous detonator are:—

(i) The whole of a high roof ripping may be blasted effectively in one firing operation, the holes being arranged in two (or three or four) horizons, and only one delay number being used on any one horizon. Conversely, with instantaneous detonators, the shots must be fired singly, or in groups (entailing several visits 1,o the ripping and extra tests for gas) or the whole ripping must be fired simultaneously, thereby placing too great a burden on the upper shots and bringing about an ineffective blast.

(ii) The chances of gas being ignited in breaks formed by the earlier shots are greatly reduced, as compared with firing the shots singly or in groups, for the whole blast is completed with a small fraction of a second.

(iii) Milli-second delay blasting results in less roof disturbance, cleaner cut road sides, reduced consumption of explosives, and better fragmentation.

8. Outline clearly, but concisely, in your own words, the prescribed procedure in case of a single-shot miss-fire, the shot having been fired electrically.

PROCEDURE AFTER A MISSFIRE.

If a shot fails to explode, the shotfirer must:—

(1) Disconnect cable of firing handle and wait 5 minutes.

(2) Examine cable for connections and defects and remedy them.

(3) Make a further attempt to fire, using, if necessary, a multi-shot explodei

(4) If the shot still fails to explode, wait a further 5 minutes.

(5) Drill a fresh hole at least 12 in. away, of equal depth and parallel to first hole.

(6) Secure detonator leads of miss-fire and charge and fire the new hole. If the miss-fire is not dislodged, repeat the procedure.

(7) If dislodged, search for the miss-fire detonator an<4 charge and, if not found, load the stone or mineral and convey it out of the mine separately.

Further points are:—

(a) No part of the charge of a miss-fired shot shall be removed.

(b) If a shotfirer leaves the place before recovering the miss-fire, he must inform the deputy and erect fences and warning notices.

(c) Before leaving the mine, he must report to the senior official on duty and record the miss-fire in his daily record of shots.

(d) As an alternative to drilling fresh holes, it is permissible to remove the stemming with water or an approved device. An additional primer may then be inserted and the shot duly fired.

Additional precautions are laid down in the Explosives Order for shots fired in a round, and students are referred to the Order for details.

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