Chapter 7
Explosives and Blasting
THE EXPLOSIVES

Type of Explosives to be Used in Mines

No explosives, except that provided by the mine management shall be used in a mine. The explosives provided for use shall be of good quality, and, as far as can be known, in good condition.

In any colliery workings belowground, no liquid oxygen explosives shall be used.

The Coal Mines Regulations do not prohibit the use of the liquid oxygen explosives in the opencast coal mines. However, for better safety against the danger of fire, the liquid oxygen explosive charges should be properly stemmed, all combustible material removed from the vicinity, and all spillage of the liquid oxygen removed forthwith from the site of blasting. It would be better if the liquid oxygen explosive is not used for blasting the overburden within 15 m of the underground workings of the coal seam immediately below, or in the vicinity.

Appendix-34 gives the Model Rules governing blasting with the liquid oxygen explosives in the opencast mines.

Many mines have adopted the use of Ammonium Nitrate (AN), sensitised by the addition of a small percentage of Fuel Oil (FO) — any diesel oil with the flash point higher than 38 C, as a low cost explosive. A license for the preparation of the ANFO explosives, and permission for the transport of the same, on the surface, has to be obtained from the Chief Controller of Explosives, Nagpur, by the management desirous of using it in the mines, either opencast or underground. If a mechanical mixer is used for mixing of AN and FO, it should be approved by the Chief Controller of Explosives. For using ANFO for blasting in mines, either opencast or underground, the management should obtain prior permission from the Chief Inspector of Mines.

Cap-Sensitivity Test. All field-mixed compositions should be regularly and routinely tested, for sensitivity to inflation, by a No. 6 detonator. If found cap-sensitive, the ANFO should be treated with the care normally given to high explosives. The sensitivity of the ANFO is greater if AN contains little or no inert coating. The ANFO, prepared from AN of small particle size, such as crushed prills or fines, are generally more sensitive than ordinary prills, and may even be cap-sensitive.

Fire Hazard, AN should not be stored with any of the high explosives. The AN or ANFO fires can be fought with copious amounts of water, which acts as a cooling agent to cool down the burning mass to a temperature below auto-decomposition range.

If high explosives are in the same premises where AN/ANFO fire is underway, first attempt should be to remove the high explosives from the danger area. If this is not possible, the entire area may be evacuated in anticipation of detonation, and the fire should be allowed to burn.

In pyrite bearing ores, if ANFO is used as a blasting agent, the temperature can increase by oxidation. At increased temperature, the ANFO reacts exothermally with pyrite, and the reaction becomes self-sustained at 120 *1*10 C. Necessary precautions have to be taken in such a case. *5%,* by weight, of Urea has been found sufficient to slow down the above reaction.

Underground Application. For small diameter blasting underground, there are certain cap-sensitive ANFO compositions. But generally non-cap-sensitive ANFO is blasted with a high explosive booster (say S.G. 60%). ANFO should not be used in underground coal mines, but may be used for underground non-coal mines with additional precautions.

Reaction with Metals. Zinc should be avoided for mixing or as packaging equipment as it promotes or accelerates decomposition of AN. Copper is unsatisfactory because of corrosion problems. Aluminium is the most suitable metal. Wooden container with wooden shovel can also be used for mixing.

Oxygen Balance Reaction. *5-7%* No. 2 fuel oil, by weight, gives oxygen balanced reaction with pure AN. With deficiency of fuel oil, AN decomposes giving nitrous fumes and, with excess of fuel oil, the reaction tends to give carbon monoxide. Thus proper proportioning and thorough mixing are a must.

Priming and Boostering of ANFO. High velocity primers, inserted at intervals in ANFO column, have given improved blasting results. It is suggested that the distance between boosters in the ANFO column* should be 1—*Vi* times the burden on the shot hole, the top and bottom boosters being placed at a distance of half the burden from the top and bottom of the ANFO column.

Compositions to be Avoided. Crude oil and crank-case oil should not be used because they may contain volatile constituents that increase the hazard of vapour explosion (fire) or may include gritty particles that might increase the sensitivity of the resulting ANFO. -

Metal dust (e.g., Al powder), sulphur, perchlorates, or explosives (N.G.-type or other types), should not be used to sensitise the AN unless strict standards of an Explosives Plant, with due permission from the Chief

Controller of Explosives, are maintained. Nitrates and chlorates should never be used in the ANFO compositions.

Hazard of Static Electricity. In pneumatic loading of small diameter holes, premature initiation of priming charge is quite possible. Therefore, the pneumatic loading equipment should be properly earthed. The hose connecting the loading machine to the charging hole should be semi-conductive type, having a total resistance low enough to permit dissipation of static electricity, and high enough to limit the flow of stray electric currents to safe level. Wire-countered hoses should not be used because of the potential hazard of stray electric currents. A semi-conductive hose, having a resistance of not less than 5000 ohms per foot, with not more than 2 mega ohms for the total length, is satisfactory.

Even with the nitre-glycerine based explosives, the nitrous fumes produced during plaster shooting are as much as 21/2 times of those produced in normal shothole blasting. For ANFO, the corresponding figures are even higher. So no plaster shooting with ANFO should be carried out belowground.

Appendix-35 suggests a number of precautions recommended for the storage, mixing, and use of field-mixed ANFO uon-cap-sensitive blasting agent.

Permitted explosives

Only permitted explosives shall be used in:

(i) a gassy metalliferous mine, or part or where the Regional Inspector may require by an order in writing,

(ii) coal mines, in case of simultaneous shotfiring belowground.

However in —

(a) a stone drift, if it does not contain dry coal dust, and,

(b) a sinking shaft, non-permitted explosives can be used.

In a gassy seam of II or III degree of gassiness, no explosives other than a permitted sheathed explosive, or other explosives equally safe, or any device or apparatus for breaking coal, approved by the Chief Inspector shall be used, while, in a seam of I degree of gassiness, permitted explosives may be used. It is recommended that, in a seam of III degree of gassiness, only P_5 type of permitted explosives should be used.

The Chief Inspector may, by an order in writing and subject to such conditions as he may specify therein, permit, in any gassy seam of I degree, the use of any explosives other than the permitted explosives. . With permitted explosives, only electrical detonators with copper tube shall be used. Recently, double copper coated, and zinc coated (with copper flash) steel tube delay detonators have been approved provisionally for use in the gassy mines of I degree. However, it is statutorily obligatory for the management to obtain an exemption from the Chief Inspector for the use of detonators other than copper tube detonators before using them.

It is apprehended that rusting of the steel tube detonators may constitute a hazard in their handling and use. Adequate steps should, therefore, be taken during storage of these detonators to obviate the risk of rusting. A competent person should examine these detonators before they are issued for use. If any signs of rusting are noticed, the rusted detonators shall **not** be issued for use, and the matter shall be reported to the Chief Inspector and the Regional Inspector.

The shots of permitted explosives shall be fired only by an approved shotfiring apparatus (exploder). However, where special conditions exit, the Chief Inspector may, by an order in writing, and subject to such conditions as he may specify therein, permit the use of any other shotfiring apparatus.

Where more shots than one are charged for firing, the shots shall be fired simultaneously. The aggregate charge in any round of shots to be **fired** in coal shall not exceed such **permissible maximum** charge as the Chief Inspector may, by notification in the Official Gazette, lay down for the kind of the permitted explosives used. No delay action detonator shall be used except with the previous permission, in writing, of the Chief Inspector, subject to such conditions as he may specify therein.

Provisional approval, for a maximum period of one year, to a new explosive composition is granted on the basis of the satisfactory test report from the Central Mining Research Station, Dhanbad, and 'such other considerations as deemed fit'. One of them is its performance, from both safety and productivity points of view, **in field trials,** carried out at a few selected mines, jointly by the representatives of the concerned mine managements and the manufacturers of the new explosive composition.

The trial blasts for determining the post-detonation fumes should be conducted at faces which have advanced at **least 30m** from the last ventilation connection. At the end of the field trials, a report on the performance is prepared and submitted to the Chief Inspector for his approval.

A new explosive composition, after receiving the provisional approval, may be supplied and used at a large number of mines. During this stage, the mine managements, as well as the Inspectorate, are expected to watch the performance of the new explosives and submit their report on the same **within** 6 months of its introduction. These reports enable the Chief Inspector to consider the grant of regular approval to the new explosive composition. The concerned explosive composition manufacturers are also expected to keep a similar watch and submit their performance report at the expiry of the period of provisional approval of the new explosives.

Whenever a new explosive under provisional approval is supplied to any mine, the explosive manufacturers shall inform the concerned mine management and the Inspectorate regarding the same so that they may keep a watch on its performance and send reports to the Chief Inspector.

Under the Explosives Rules, the various explosives and accessories, used in mines, may be classified under one or more of the following headings:

Class 1— Gunpowder.
Class 2— Nitrate Mixtures (Not common in mines).
Class 3— Nitro-compounds—
Div. I— Blasting gelatine, Special gelatine, Permitted explosives, etc.
Div. II- Gun cotton, FETN, TNT, PRIMAX, etc.
Class 4— Chlorate Mixtures (Not common in mines).
Class 5— Fulminate (Not common in mines).
Class 6 — Div. I— Safety fuse, Ignitor cord, Safety electric fuse, Percussion caps.
Div.II — Plastic ignitor cord, Detonating fuse (Cordtex), Electric fuse, Fuse igniters, etc.
Div. III — Detonators, Delay detonators, Relays, etc.
Class 7— Fireworks (not Common in mines).
Class 8— Liquid Oxygen Explosive (an absorbent carbonaceous material, such as, wood pulp, carbon black, metal power, coal dust, etc., impregnated with liquid air or liquid oxygen with or without the addition of other substances).

Explosives are divided into 4 categories according to the risks which they present when initiated:

(i) Category X — those explosives which have a fire or a slight explosion risk, or both, but the effect is local.
(ii) Category Y— those explosives which have a mass fire risk or a moderate explosion risk, but not the risk of mass explosion.
(iii) Category Z — those explosives which have a mass explosion risk and major missile effect.
(iv) Category ZZ— those explosives which have a mass explosion risk and minor missile effect.

Schedule VIII of the Explosives Rules gives the Table of Safety Distances to be observed from the magazines, licensed for the storage of high explosives, of different capacities, for the different categories (X,Y,Z,ZZ) of the explosives (summarised in Table 7.1):

(i) to and between the magazine and the magazine office,
(ii) the railways, roads, etc.,
(iii) to dwelling houses, offices, factories, etc.

The Permitted Explosives have been classified into the following types:

P_1— *(e-g-*, Ajax-G, Viking-G, Godyne, Monodyne, Permaflow-I)— used in drifting, simultaneous blasting in coal and ripping, should be fired without any delay in undercut/overcut/sidecut faces, maximum charge per hole — 794 g.

P_2— (Sheathed Permitted Explosives)— not manufactured in India, used for simultaneous blasting in coal and ripping, mostly replaced by P3 type Permitted Explosives, (Now obsolete.)

P_3 — (Eq. S. Permitted Explosives, *e.g.*, Permadyne, Unisax-G, Unifrax-G) — used in places where, Patype were previously approved, maximum charge per hole— 1kg.

P_4 — not manufactured in India, used for delay blasting in ripping, in the undercut/ overcut/ sidecut coal, and in cross-measure drift.

P_5 — (e.g. Soligex, Pentadyne) — Primarily designed for delay ('lasting in solid blasting (blasting-off-solid), and in III degree gassy coal seams.

P1, P_3, P_5 may be used in I degree gassy coal seams. Only P_3 and P_5 are to be used in II and III degree gassy coal seams.

Storage of Explosives

The mine management shall not store, nor knowingly allow any other person to store, within the premises of a mine, any explosives otherwise than in accordance with the provisions of the rules made under the Indian Explosives Act, 1884. The explosives shall not be taken into or kept in any building except a magazine.

Under the Explosives Rules, every application for the grant of license, in Form 22, to possess explosives for use shall be submitted to the Licensing Authority (Controller of Explosives, authorised by the Chief Controller of Explosives, for capacities not more then 2000 kg of explosives, and the Chief Controller of explosives for capacities exceeding 2000 kg of explosives and any quantity of liquid oxygen explosives). The application shall be in Form 5, and shall be accompanied by:

a. plans, drawn to scale, of the proposed premises anU of the site on which such premises are situated:
(The site plan should show clearly the complete approach road network, nearby landmarks, distances from nearby protected works.)
b. drawings of the premises and the mounds, if provided;
c. in case where the application is made in the name of the company, the name and address and specimen signatures of person or persons authorised to sign correspondence in respect of license applied for. -

It the operations are to be carried on within 100m of a railway line, the applicant shah[1] obtain from the railway authority concerned a certificate to the effect that there is no objection to the applicant receiving the license for the site proposed, and forward this certificate to the Licensing Authority with his application.

SAFETY DISTANCES FOR EXPLOSIVES MAGAZINE BUILDINGS

Quantity of Explosives	To and between Magazine		To Railway, Road Etc.	To Dwelling houses, offices, factories etc.
	Mounded	Unmounded	M/UM	M/UM
Kg	(m)	(m)	(m)	(m)
50	10	14	21	45
100	11	17	33	45
200	14	21	45	52
400	18	27	45	82
600	21	31	54	107
800	23	34	65	129
1000	24	36	74	148
1500	28	42	96	192
2000	31	46	113	226
2500	33	49	129	257
3000	35	52	142	283
3500	37	55	152	304
4000	38	57	163	325
4500	40	60	172	343
5000	41	…	180	359
10000	52	…	236	471
15000	60	…	280	560
20000	65	…	303	605
30000	75	…	345	690
40000	82	…	380	760
50000	89	…	410	820

On receipt of the application, the Licensing Authority shall forward to the Applicant a statement showing the safety distances, in Form 17, which should, in his opinion, be kept in and around the magazine premises, or any part thereof, and from other buildings and works (Schedule VIII of the Explosives Rules and Table 7.1).

On receipt of Form 17, the applicant shall enter the exact distances which can actually be so kept clear, and shall return it, together with any representation which he may desire to make, to the Licensing Authority. The safety distances may be proportionately reduced where any building or works is, in the opinion of the Licensing Authority, effectively screened from the magazine by:
either

(i) natural features of the ground,or
(ii) good and substantial artificial mounds of earth or mine refuse, of such height that a line, drawn from any part of the building/works in question, will pass through the intervening ground or mound.

In view of the expanding population and industries, more and more land is getting occupied for residential and other purposes, thus encroaching on the existing safety distances and consequently reducing the magazine capacity to uneconomic levels, if the present safety distances are to be maintained. Therefore, a serious re-thinking in this regard of safety distances is called for.

The Licensing Authority may ask the applicant to make the changes considered necessary. Then it shall refer the application to—

(i) the district authority concerned, together with a description of enquiries to be carried out, a draft license, and a statement in Form 18 showing the distances which he considers should be kept clear in and around the magazine;
(ii) any other authority for such enquiry as deemed necessary.

The district authority shall forthwith cause a notice to be published of such application and of the time and place at which he will be prepared to hear it, calling upon any person, objecting to the establishment of the magazine on the proposed site, to give a notice to him, and to the applicant, of not less than 7 clear days before the day fixed for hearing the application, together with his name, address, and calling, and a short statement of the grounds of his objections.

Where the site of the proposed magazine lies within 1.5 km of the limits of the jurisdiction of any town planning municipal authority, the applicant shall serve on such authority a notice of the application and of the date of the said hearing.

The notice shall be published/served, at the expense of the applicant, by the district authority not less than one month before the said day of hearing. The day of hearing the application shall be a day following as soon as practicable after the expiry of the period of one month.

On completion of the enquiry, the district authority shall forward the application, statement and plans to the Licensing Authority, together with a report of the procedure followed by him, and whether he has any objection to the applicant receiving a license at the proposed site [a No Objection Certificate (NOC)]. The district authority shall complete his enquiry and forward the report to the Licensing Authority as expeditiously as possible but not later than 6 months of the date of the reference made by the Licensing Authority. The authority, refusing to grant the NOC, shall record, in writing, its reasons for such refusal and communicate such reasons and facts of the case to the Licensing Authority. The reasons may also be communicated to the applicant, if demanded, unless, in the opinion of the Licensing Authority, such reasons cannot be divulged in the public interest.

On receipt of the NOC, the Licensing Authority may make such other enquiries as deemed necessary and take further action for the grant of License.

An application for grant of license

(a) to manufacture ANFO explosives for own immediate use, or

(b) to possess, for own use, liquid oxygen explosives, shall be accompanied by a certificate from the Chief Inspector of Mines that the site where such explosives are to be manufactured, possessed and used is under the purview of the Mines Act, and that the applicant is authorised to use the LOX or ANFO explosives and conduct mining operations in the area proposed to be covered in the license. In such cases the license shall be issued by the Chief Controller of Explosives.

Every license, granted or renewed under the Explosives Rules, shall remain in force until the expiry of the financial year *(i.e.,* 31st March) immediately following the financial year in which it was issued.

Where the quantity of explosives, proposed to be possessed for own use under a licence in Form 22, does not exceed 100 kg, the applicant may apply directly to the district authority, together with an application in Form 5, statement in Form 17, and the necessary plans for the grant of NOC; and the district authority shall, if he sees no objection after conducting enquiries, grant such certificate to the applicant, who may forward it to the Licensing Authority together with his application. To secure a license for storing more than 100 kg explosives may take some time. It is, therefore, advisable to secure, in the first instance, a license for 100 kg of explosives, and then to get the licensed capacity increased to a larger amount.

Two copies of every license, granted by the Chief Controller or Controller of Explosives, shall be forwarded to the district authority. In case the Licensing Authority is the Chief Controller of Explosives, the original license shall be forwarded to the Controller in whose jurisdiction i he premises are situated,

If, after the inspection, the Controller is satisfied that all the requirements of the Explosives Rules and the conditions of the license have been complied with, he shall forthwith endorse the license, but unless and until so endorsed, the license shall not come into force.

An application for the renewal of license shall be made so as to reach the Licensing Authority at least 30 days before the date on which the license expires. The license shall be deemed to be in force until such date as the Licensing Authority renews the license, or until an intimation, that the renewal of the license is refused, has been communicated to the applicant.

The application for renewal shall be accompanied by—

(i) application in Form 13;

(ii) the original license together with its enclosures, approved plans, Schedules, and Forms;

(iii) prescribed renewal fee.

The license shall be renewable for 2 years provided that there has been no contravention of the Indian Explosives Act or the Explosives Rules, or of any condition of the license so renewed. When a license is renewed by the Chief Controller/ Controller, an intimation to that effect shall be sent to the district authority concerned, and when the license is renewed by the district authority, the intimation shall be sent to the Controller having jurisdiction.

Appendix-36 gives the provisions of the Explosives Rules regarding the storage of explosives in a magazine under the license in Form 22. For the storage of—

(a) Class 2 and/or Class 3 type explosives not exceeding 5 kg, electric or ordinary detonators not exceeding 100 numbers, and safety fuse not exceeding 200m, or

(b) gun-powder not exceeding 5kg and safety fuse not exceeding 50 m (in the states of Bihar, Kerala, and West Bengal), an application in Form 5 can be made directly to the district authority, who is empowered to issue the license, for a maximum period of 15 days, in Form 23.

The quantity of any kind of explosives kept in any licensed magazine shall not exceed the quantity entered in the license against such kind of explosives. However, the Chief Controller may issue a permit on payment of the prescribed fee, for keeping of explosives In excess of the licensed quantity if he is satisfied that such excess storage is essential and unavoidable due to circumstances beyond the control of the licensee. The validity of such a permit shall not exceed 30 days. Such a permit shall not be issued if the magazine cannot observe the requisite safety distances for the licensed quantity plus the additional quantity. The permit may again be refused if such storage capacity is of a repeated nature. No explosive in

excess of the licensed quantity shall be stored in the magazine unless the permit is obtained from the Licensing Authority by a letter or telegram.

TABLE 7.2
DISTANCES TO BE KEPT CLEAR FOR TEMPORARY MAGAZINES AT OR NEAR THE ENTRANCE TO THE MINES

	Distances *be*tween magazine and room or works used in connection with the magazine; any other explosive magazine or store for explosives with the consent in writing of the Occupier / Magazine Office.	Distances between magazine and magazine keeper's or chowkidar's dwelling house, railway including mineral and private railway, canal (in active use) or other navigable water, dock pier or jetty, market place, public recreation and sports ground, or other place where the public are accustomed to assemble, public highways, private road which is a principle means of access to a temple, mosque, church, gurudwara and other places of worship; hospital, college, school or factory; river wall, sea wall, reservoir or bunded tank.	Distance between magazine and dwelling house, retail shop, Govt. and public buildings; temple, mosque, church, gurdwara, or other places of worship, college, school, hospital, theatre, cinema, or other buildings where the public are accustomed to assemble; factory, building or works used for the storage in bulk of petroleum, spirit, gas, or other inflammable or hazardous substances, buildings or works used for the storage and manufacture of explosives or of articles which contain explosives, aerodrome, furnace, kiln or chimney, quarry or mine pit heads, power house, wireless station, warehouse or other buildings.
(1)	(2)	(3)	(4)
For magazines storing explosives not exceeding 100 lbs.	44' mounded	44'moundcd	75'
For magazines storing explosives not exceeding 150 lbs.	44' mounded	44'mounded	100'
For magazines storing explosives not exceeding 200 lbs.	44' mounded	44'mounded	150'
For magazines storing explosives not exceeding 400 lbs.	44' mounded	80'	159'
For magazines storing explosives not exceeding 500 lbs.	51' mounded	104'	208'

The Regional Inspector may, by an order in writing and subject to such conditions as he may specify therein, permit the use of any stores or premises, specially constructed at or near the entrance to a mine, for the temporary storage of

(i) explosives intended for use in the mine, or

(ii) Surplus explosives brought out of the mine at the end of a shift.

Of course it should be kept in mind that necessary license for such a magazine for temporary storage of explosives has to be obtained from the Licensing Authority (usually the Chief Controller of Explosives).

Every license, granted by the Licensing Authority under the Indian Explosive Act, 1884, for the storage of explosives, or a true copy thereof, shall be kept at the mine office.

The main features of safety of a typical large magazine are as follows:

1) The detonator store should be separated from the explosives stores by a door, opening outwards, and a brick-wall, 2’ (0.6 m) thick, and a lobby, 5’ (1.5 m) wide.
2) The explosives stores should be provided with a separate entrance porch or lobby.

3) It should have a roof of reinforced cement concrete, and the floor should consist of 4" (100 mm) lime concrete with 1" (25 mm) cement plaster on its top to render it damp-proof.
4) All the doors and windows should open outwards. The main door should be made of 1/4" (6 mm) wrought iron plate, faced inside with wood and having brass hinges and fittings. The inner doors and the door of the detonator annexe should be made of wood with brass hinges and fittings. The windows should be made of wood with brass fittings. All the doors should be provided with locking arrangements.
5) The magazine should be provided with Z-type ventilators [9" X 4½" (225 X112) mm]size fitted with a frame of iron bars set firmly in the wall on the outer face, and the inner opening protected with brass wire gauze of 8 mesh to the linear inch at a safe height at least 6' (1.8 m).
6) At the entrance, a water pit should be provided for persons to wash their feet before entering the magazine.
7) The magazine should be provided with an effective lightning arrester, which should be isolated by elevation or be securely guarded. All its non-current-carrying parts should be earthed, unless effectively isolated or guarded from the live parts of the circuit to which the arrester is connected.
8) The surrounding ground should slope **away** from the magazine building for drainage.
9) All electric wires in any magazine should be protected by fuses (maximum capacity—10A), and enclosed in conduit, and no line or wiring should be within 1.5 m of the explosives stored therein,
10) In storing explosives, boxes or cartons should not be stored so that the cartridges of dynamite **stand on end.**
11) Around each bench of explosives boxes, a clear space of 0.6m should be allowed.
12) All nails in the interior of the magazine should be counter- sunk.
13) Detonating fuse should not be stored with detonators, but may be stored with other explosives.
14) Ignitor cord, because of its sensitivity to impact and friction, should not be stored with detonators or other explosives.
15) Capped safety fuse should not be stored in an explosives magazine, but may be stored in a magazine with other detonators.
16) The magazine should be kept well ventilated. It is advisable to keep the magazine open every day for **at least** one hour.
17) Explosives should always be issued in strict rotation according to its date of manufacture. It is liable to deteriorate if subjected to prolonged storage in high temperature and humidity.
18) The magazine should always be kept in good repair. At the time of repairs, all the explosives should be removed from it, and the interior thoroughly washed with water. Should the repairs take more than one day, some arrangement has to be made for transferring the explosives to some other approved place of storage. Nevertheless, it is advisable to run down the stock of explosives in the magazine before undertaking reapirs to enable easy handling.
19) A copy of the license and lightning conductor test certificate should be kept in the magazine.
20) The manager, or under manager, etc., should daily check the main stock book (Entries in Form 36 of the Explosives Rules) of receipts and issues, and sign against all entries. He should also check the stock in the magazine with the balance shown in the stock book once at least in every 14 days. The findings should be recorded in the stock book.
21) The various kinds of explosives should be separated by aisles, and be indicated by notices.
22) Inflammable substances should not be stored within 50m of the magazine.
23) Empty containers, wrappers, and other packing materials should be removed daily from the magazine.

Portable Magazine

Portable magazines are available in capacities up to 500 kg, or 44,000 detonators, or 10,000 m detonating fuse. One such magazine may weigh only 425 kg, and can be installed in about 8 hours. The outer shell is an integrated all-welded construction of m.s. plates, 5-6 mm thick. The interior is lined with smooth, joint less, warp-proof wooden boards of minimum 12 mm thickness. There is no gap at the corners or elsewhere to conceal the spilt explosives. The door is also made of m.s. plate, lined with similar wooden boards. The hinges, door catch, and hold-fasts are completely concealed and made of non-ferrous metal to prevent sparking. The design provides efficient ventilation. The magazine is coated with anti-corrosive plant.

The portable magazine may be useful —

(i) during the construction of the main magazine, and
(ii) as an immediate solution in an isolated place, obviating the danger of unauthorised and unsafe storage of explosives in lamp rooms, attendance rooms, stores, etc.

The portable magazine should preferably be sited on a high ground. The following minimum safety distances may be maintained:

(i) From all houses, buildings, etc. 95 m
(ii) From all roads, railway lines, canals, reservoirs, tanks, river banks, etc. 50 m

Underground Magazine

Explosives shall not be stored belowground in a mine except with the approval, in writing, of the Chief Inspector, and subject to such conditions as he may specify therein. Such underground storage shall be done only in a magazine, or magazines, duly licensed in accordance with the provisions of the Explosives Rules.

The capacity of the underground magazine may be sufficient to carry 3-4 weeks' consumption. It may be possible to transport all the explosives from the surface magazine to the underground magazine on weekly rest days, when a minimum number of persons are present in the vicinity of the shaft, and the operation can be carried out under the personal supervision of an assistant manager, etc. The pilferage from an underground magazine may be reduced as the blaster is not required to go out of his way to the surface magazine to return the explosives left over at the end of the shift. Thus he will not be tempted to—

(i) consume all the explosives by overcharging the shot holes near the end of the shift, or

(ii) store them at some unauthorised place in the underground workings.

The Indian Regulations are silent about the provisions regarding the underground magazine. The ILO Code (1986) recommends that in any mine, where large quantities of explosives are transported and stored belowground, the manager should prepare a "Scheme" for dealing with the handling transport, and storage of such explosives, specifying:

(i) the location, construction, ventilation, and marking of each underground magazine, and the names of the persons who have the custody of the keys thereof;

(ii) the design and construction of the special carriage for the explosives;

(iii) the supervision of, and the precautions to be taken during, the transit of the carriage;

(iv) the supervision of the explosives held in the underground magazine;

(v) the manner in which large quantities of explosives are taken to any working face;

(vi) the maximum quantity of the explosives to be stored in the underground magazine at one time;

(vii) the control of the issue of explosives from the magazine, and the return of such explosives;

(viii) the duties of the person in charge of the underground magazine to ensure security and safety; and

(ix) the precautions to be taken in case of fire or explosion.

The following provisions may be considered regarding an underground magazine:

1. The magazine should be so sited that the surface is protected against the effects of an explosion.
2. The magazine should be at least 100m from the main exits to the surface, and at least 10m from other mine workings, used for travelling or haulage, both distances being reckoned in the direction of i he air current.
3. The magazine should be kept at not less than 50m from any Reserve Station underground.
4. The magazine should have a direct connection with the main return airway so that fumes of any explosion cannot reach the active mine workings,
5. The roads, constituting the immediate approaches to the magazine, should not be in a straight line. At the bends in these roads, and opposite to the entrance to each of the explosives chambers, blind headings, at least 4 m deep, should be provided.
6. If separate entrance and exit roads cannot be provided, the approach roads should be so separated by barriers that the workers entering and leaving them do not meet each other.
7. The individual chambers of the magazine should be separated from one another by walls at least 5m thick.
8. Chambers, in which more than 100 kg explosives arc stored, should, if the explosives are issued from the chamber, have an ante chamber that is separated by a wall from the storage chamber. In the ante-chamber, a room should be provided for the storage of the explosives returned at the end of the shift. This room should be separated from the ante-chamber by a strong door. However, in magazines, in which not more than 100 kg explosives are stored, the returned explosives may be stored in the storage chamber itself.
9. All rooms in the magazine should have a clear height of at least 2.2 m.
10. The magazine should be kept perfectly dry.
11. If the ground is not stable, the magazine should be lined with masonry. The chambers should be isolated in a fire-proof manner. Openings required for ventilation should be protected against the penetration of flame.
12. In every chamber, there should be a thermometer. The temperature should not exceed 40° C. In storage chambers for the explosives that are liable to freeze, the temperature should not fall below 8° C.
13. Fixed lighting should be provided by fixed electric filament lamps. The switches and fuses for the lamps should be outside the chambers. If portable lamps are required to be used, only approved safety lamps should be permitted.
14. On the outside of the main approach doors of the magazine, notice boards should be affixed with the words—"CAUTION - EXPLOSIVES - ADMISSION PROHIBITED TO UNAUTHORISED PERSONS."
15. Inside the magazine, a notice should be put at a prominent place, indicating the maximum quantity of explosives that may be deposited in the magazine.

16. The explosives should be so stored in the magazine that the whole quantity can be seen at a glance.
17. The floor of the magazine should be made of wood or other non-ferrous material.
18. The magazine should be kept in a clean condition, and adequately ventilated.
19. Cases containing explosives should not be stacked more than two tiers high. Between each series of two tiers, there should be a space of at least 50 mm. The bottom of the highest cases should be not more than 1.2 m above the floor. The cases should not be opened in the magazine.
20. If detonators are also stored in the magazine, they should be kept in a separate room which should be at least 15 m in size.
21. The magazine should be entered only with boots or overshoes without nails.
22. In the immediate vicinity of the magazine, either an adequate quantity of sand in a bucket, together with a shovel, or some other means of extinguishing fires should be kept ready for immediate use.
23. In the magazine, no greater quantity of explosives should be stored than is considered adequate for one week's consumption, subject to a maximum of 150 kg, together with 300 detonators, ignition devices, and other shotfiring requisites.
24. The magazine should be protected on both sides by thick stone dusting of the roads.
25. The distance between the floor of the magazine and the explosives cases should not exceed 500 mm.
26. Only wooden or copper tools should be used for opening the explosives cases.
27. The transport of the explosives and ignition devices should be effected safely, and as far as possible, when little or no transport is in operation.
28. If a magazine is discontinued in use, the Inspectorate should be informed, in writing, forthwith.
29. The magazine should be so located that it is out of line of blast, not less than 15 m from the face, and 4.5 m from any pipeline, power line, rail track, or conveyor. If constructed in a niche in stone, the distance from the pipeline, etc., may be reduced to at least 1.5 m.
30. In no case should explosives or detonators be stored in places where there is a likelihood of a train or tub colliding with the containers of the explosives/detonators.
31. Explosives/detonators should be transferred from a designated storage place to other designated storage places or points of use without undue delay.
32. Detonators should be stored in a separate magazine, and located at least 30m away from any other magazine in which any explosives is stored.
33. Any timber within 7.5m of any magazine should be made fire-resistant.
34. In magazines, where explosives may become damp, electric lights may be installed for drying purposes. Such lights should be enclosed in vapour-tight globes, and should be kept at least 1.5 m from explosives.
35. The wiring should be in conduit, and the switch located outside the magazine. No other wiring should be permitted within 1.5m of any magazine.
36. Combustible rubbish should not be permitted to accumulate within 30m of any underground magazine.

When explosives are stored in a cool, dry, magazine, the gelatinous type explosives can be stored for at least one year, and the Nitro-glycerine Powder type for at least 6 months. The T.N.T, or Ammonium Nitrate types do not store quite as well, and they should generally be used within 3 months. Of course, detonators can be stored for several years without any risk of deterioration.

In every instance, once a case of explosives has been opened, the explosives should be used within a few days. Under the Explosives Rules —

1. The explosives shall be visually examined, before use, for visible defects and any defective explosives shall not be used. Any explosives showing signs of deterioration of any kind shall be reported immediately to the Licensing Authority, and such explosives set aside for examination by such authority.
2. Gunpowder, which is found to be caked owing to moisture, shall not be used.
3. Frozen nitro-compounds shall not be used until thawed under the supervision of experienced persons. Where freezing is likely to occur, only low-freezing explosives shall be used.

Sometimes old stocks of explosives are kept in storage beyond their shelf life. Such old stock should not be used in the mine, and immediate action, as given in Appendix-37, should *be* taken to destroy such old stock.

Every magazine, etc., shall be under the charge of a 'magazine in charge'. The appointment and duties of the magazine incharge are discussed in Chapter IV.

Explosives shall not be issued from the magazine, etc., unless they are required for immediate use. If any explosives are returned to the magazine, etc., they shall be issued before fresh stock is used. They shall be issued only to the explosives-carriers upon the written requisition, signed by the shotfirer / blaster, or by an official authorised for the purpose, and only against the signature or thumb impression of the recipient. The requisition shall be preserved by the magazine incharge.

The magazine incharge shall maintain a clear and accurate record of the **issue and return** of the explosives issued to each explosives-carrier.

Handling and Transport of Explosives

The preparation of cartridges from loose gunpowder, the drying of gunpowder, and the re-construction of damp cartridge, shall be carried out (1) by a competent person, and *(2)* only in a place

approved by the Licensing Authority, in accordance with the Explosives Rules. The use of a bare iron sheet in preparing the cartridge of gunpowder is not permitted. Tin sheets may, however, be used for the purpose.

It is considered advisable that only dry gunpowder is issued to the explosives-carriers; otherwise, besides the usual dangers, the shot-firers/blasters may be tempted to have a tendency to take it to a fire for drying it out.

It is emphasised here that gunpowder is not being used commonly in mines now-a-days.

No explosive, other than a fuse or detonator, shall be issued for use in a mine, or taken into, or used in any part of a mine unless it is in the form of a cartridge. Cartridges shall be used only in the form in which they are received. In metalliferous mines, the Chief Inspector may grant exemption from this provision.

A similar provision of exemption may be made in the Coal Mines Regulations also because the explosive slurries are made at the site of blasting, or are pourable, which do not require cartridging. There is **no danger** in cutting the cartridges of the slurries.

No explosives shall be issued from the magazine, or taken into any mine except in a case or container (a) of substantial construction, and (b) securely locked. Cases/containers made of iron or steel shall be **heavily** galvanised^ As an alternative to galvanising, the inner surface of the ungalvanised containers should be covered with panels of wood or pressed board (masonite) or plywood or wooden-board, and the outer surfaces may be protected with a heavy coat of paint.

No case/container, provided for carrying detonators, shall be constructed of metal or other conductive material. A leather box, with polythene compartments, may be used for carrying detonator The detonator cases should be so constructed and maintained that," when any case is closed, it is impossible for any detonator, or the leads of any detonator, contained in the case, to touch any metal thereof which is exposed inside or outside the case.

The detonator leads should remain connected in such a way that they are **electrically continuous.** A detonator case should not contain a delay detonator as well as a detonator which is not a delay detonator.

Every delay detonator should be **clearly marked** with a number which indicates the **period of delay.**

Apart from any table of circuit resistances and any check sheet for recording shots fired by the shotfirer/blaster, nothing except detonators should be kept in the case.

It is preferable if the locks of containers are operated by the exploder key. In any case the locks should be operated by master key/keys, and these master keys should be issued **only** to the magazine incharge and the authorised shotfirers/ blasters.

No detonators shall be kept in a case/container, which contains other explosives, materials, or tools, and two or more types of detonators shall not be kept in the same case/container. However, this provision shall not restrict the conveyance of primer cartridges, fitted with the detonators, in the same case/container for use in a wet working or in a sinking shaft/winze.

No detonator shall be taken out from a case/container unless it is required for immediate use. Except for the bulk transport of the explosives for deep-hole blasting in opencast mines, and for the underground magazines in metalliferous mines, no case/container shall contain **more than 5 kg** of explosives, and no person shall have, in his possession, at one time, in any place, more than one such case/container. However, the Chief Inspector may, by an order in writing and subject to such conditions as he may specify therein, permit the carrying of (a) larger quantity of explosives in a single case/container, or (b) the use at one time in one place of more than one such case/container. Such permission may be necessary in case of deep-hole blasting in the opencast mines, and solid blasting in the underground coal mines.

The following conditions are generally imposed by the Inspectorate:

1. Explosives shall be carried in securely locked cases/containers, the key of which shall not be in the possession of the explosives-carrier.
2. Each such case/container shall contain not more than 5 kg of explosives. Not more than 2 such cases/containers shall be carried by one person. He shall not carry any other load on his person at that time.
3. The timing of movement of each explosives-carrier shall be so arranged that there is no other person with him, either in the cage, or while moving underground to reach the 'Reserve Station' (discussed in detail later in the chapter).
4. At the 'Reserve Station', the cases/containers (each carrying 5 kg) shall always be kept not less than 10 m apart. The case/container carrying detonators shall also be kept not less than 10 m apart from any case/container of explosives.
5. For priming operations, only the quantity or number of explosives and detonators, necessary for the immediate next round of blasting, shall be carried to a place, not less than 10 m from the rest of the explosives.
6. Only a limited number of such carriers shall be authorised to carry such cases/canisters, and the number of such carriers shall be intimated to the Inspector.

It is suggested that, in the Regulations itself, the maximum quantity in each case/canister be raised to 10 kg, and the upper limit on the quantity of explosives in the possession of a single person at a lime at any one place be increased to 20 kg.

Every case/container shall be numbered. As far as practicable, the same case/container shall be issued to the same shotfirer/ blaster every day.

The key of every case/container shall be retained by the shotfirer/ blaster in his own possession throughout his shift.

Where explosives are being carried on a ladder, every case/container shall be securely fastened to the person carrying it.

In a sinking shaft/winze, no person other than a shotfirer/blaster shall carry any priming cartridge into the shaft/winze. Such a cartridge shall be carried only in a thick felt bag or other container, sufficient to protect it from shock.

In metalliferous mines only:

(i) While explosives in bulk are lowered/ raised in a shaft/ winze, a distinguishing mark shall be attached to the cage, skip or bucket containing the explosives; or the person in charge of explosives shall travel in the same cage, skip or bucket.

(ii) Every cage, skip or bucket, containing explosives, shall be gently lowered/raised, and it shall be the duty of the banksman or bellman, as the case may be, to adequately warn the winding engineman before the cage, skip or bucket is set in motion.

It is suggested that the above provisions should be included in the Coal Mines Regulations also.

The manager should make "Bulk Transport Rules" for the conveyance of explosives in opencast and underground mines. The Rules should specify—

(a) Opencast Mines:

a. precautions to be taken during the transit of explosives;
b. procedure for the storage and supervision of explosives at the working place;
c. the maximum quantity of explosives to be stored at any one place;
d. a requirement that the quantity of explosives conveyed during the shift does not exceed the quantity estimated to be required for that shift;
e. a requirement that, at the end of the shift, all unused explosives shall be returned to the magazine; and;
f. a requirement that, except for the purpose of charging a blasthole, no explosives in bulk shall be taken nearer than 15 m to a working place.

(b) Underground Mines:

(i) is same as (i) of (a);
(ii) the location, construction and marking of each "RESERVE STATION" and underground magazine, if any, and the custody of the keys thereof;
(iii) storage and supervision of any explosives at a "Reserve Station";
(iv) if necessary, the bulk transport of the explosives to any working place; and
(v) the maximum quantity of explosives permitted at any "Reserve station"/underground magazine at any time.

A copy of the Rules in force should be supplied to the Regional Inspector, and to each shotfirer/ blaster employed in the mine.

The necessary provisions/precautions, to be followed during the transport of explosives in bulk in (a) opencast mines and (b) underground mines, have been given in Appendix-38.

Pilferage of Explosives

[A] check at the Magazine

To check for pilferage of explosives, the original explosives boxes (usually containing 50 lbs of explosives) shall be opened in the magazine in the presence of an assistant manager, or any other competent person (other than the magazine incharge), specially authorised by the manager for the purpose. Whenever possible, the number of explosives cartridges, found in each box, shall be counted and entered in a book along with their weight.

TRANSIT SLIP

In addition to the requisition slips by the shotfirers/blasters, transit slips shall be prepared by the under-manager/assistant manager/over-man/foreman. (For a specimen, please see Appendix-10).

As far as possible, the above slips shall be prepared after enquiring about the amount of balance coal/ore left during the previous shift, and the number of shots required during the shift. For development galleries, the manager may fix the number of shots per cut for the guidance of his assistants.

The number of cartridges of explosives and detonators, issued to every shot firer/blaster, shall be counted by the magazine incharge and noted by him in the transit slip. He shall then sign the same, put it inside the box, close the box, and hand over the exploder key, or the key of the lock (if it is oilier than [he exploder key) to the shotfirer/blaster.

Any overwriting of entries in the transit slip shall be countersigned by the person making the same.

The manager or an assistant manager, specially authorised by the manager for (he purpose, shall, once at least in every week, cheek the stock of explosives in the magazine, and compare it against the records maintained by the incharge.

The lid of the box containing explosives and detonators shall be self-locking in the sense that the lid must lock automatically when it is fully closed. The lock may open only by the exploder key, or by any other suitable device, which is in the possession of the shotfirer/blaster at all times.

All boxes used for carrying of explosives and detonators shall be coloured. The colour of the boxes shall be different for different shifts, *e.g.*, the colour of boxes used in three shifts may be:

First shift : Red
Second shift : Yellow
Third shift : White

All boxes shall be numbered serially in each colour.

Each shot firer/blaster shall be allotted one particular number irrespective of his shift. Thus if No. 1 is allotted to a particular shotfirer/ blaster, he would lake Red Box No. 1 in I shift. Yellow Box No. 1 in II shift, and White Box No. 1 in III shift.

Spare boxes of different colours shall be kept available in the magazine.

[B] Check at the Pit Top (Beginning of Shift)

1. At the pit top or incline mouth, every box of explosives shall be opened and checked by the attendance clerk, who shall note the amount of explosives found in every box and make an entry thereof in the transit slip. He shall then sign the slip, put the slip inside the box, close it and then hand over the key to the shotfirer/ blaster.

[C] Checks Underground

At the end of shotfiring operation, and at least once more during the shift, the sirdar/mate shall count the number of cartridges and detonators left with the shotfirer, make an entry thereof in the transit slip, and sign the same.

(i) During the shift, the overman/foreman and assistant manager shall check the boxes occasionally, and sign the transit slip.

(ii) At the end of the shift, the overman/foreman shall check the boxes, enter the balance quantity of explosives in the transit slip, and sign the entry.

[D]Check at Pit Top (End of Shift)

The shotfirer/blaster shall get his boxes checked by the attendance clerk on duty at the end of the shift. The attendance clerk shall count the number of cartridges and detonators, make an entry thereof in the transit slip, and sign it.

The shifts of shotfirers/blasters may be staggered to enable the attendance clerk to perform the checks properly and without any danger to work persons during rush hours.

Where it is not possible to stagger the shifts, the checks may be carried out by the Overman / foreman at the Reserve Station underground, or at the surface.

The attendance clerk (or the overman/foreman, as the case may be) shall directly return the transit slip to the manager for checking.

The manager, or an assistant manager, or any other competent person, specially authorised by the manager for the purpose, shall countersign every transit slip received from the attendance clerk, or the overman/ foreman, as the case may be. He shall check the entries in the slip against the entries made in the explosives Issue and Return Register.

[E] Return cf Unused Expletives to Magazine

The shotfirer/ blaster shall return the boxes to the magazine, and deposit the key of the boxes with the magazine incharge. Reserve Station

No case/container, containing explosives, shall be kept or left underground, except in a "Reserve Station", fixed by the manger, in coal mines, and the manager or under manager, in metalliferous mines, so situated that

(i) it is not frequented by the work persons, and

(ii) legibly marked "RESERVE STATION".

The Reserve Stations should be so sited that —

(i) the place has no overhanging sides or prominent undercuts, the roof is adequately supported, and the place is kept white-washed,

(ii) the place is kept clean, is free from loose debris, and is adequately fenced,

(iii) no energised electric cables are allowed to pass within 90 m from the reserve station,

[In case it is not possible to maintain this distance, *e.g.*, in case of (a) small pillars, or (b) restricted number of galleries, headings, exemption may be obtained from the chief Inspector.

In U.S.A., if the explosives and detonators are kept in niches cut into the solid rock/coal, the above distance may be kept at not less than 1.5 m. The explosives and detonators are also separated from one another by a distance of at least 1.5 m.]

(iv) in coal mines, the Reserve station, and all places lying within 18 m of the same, shall be cleaned of coal dust, and the roof, floor, and sides in the area adequately treated with the approved type of stone dust. The floor of the workings in the 18 m zone shall be particularly treated with at least 20 mm thick layer of stone dust.

In some mines, Reserve Stations are used for storing the explosives required for the whole mine for the day. This practice is highly dangerous and is also in contravention of the Indian Explosives Act, 1884, since no explosives can be stored at any premises or place unless it is licensed under the Indian Explosives Act. The Reserve Stations are only meant for keeping the securely locked explosives canisters, issued to a shotfirer/blaster, for use during the shift.

THE BLASTING OPERATIONS

The preparation of charges and the charging and stemming of shotholes shall be carried out by or under the personal supervision of a shot firer/blaster. The shotfirer/blaster shall fire the shots himself. The appointment and the duties of the shotfirer/blaster have already been given in Chapter IV.

The manager shall fix, from time to time, the maximum number of shots that a shotfirer/blaster may fire in any shift. Such number shall be based on:

(i) the time normally required to prepare and fire a shot in accordance with the provisions of the Regulations;
(ii) the time required for that shotfirer/blaster to move between places where shots are fired;
(iii) the assistance, if any, available to him in the performance of his duties; and
(iv) any other duties, assigned to him, whether statutory or otherwise.

Table 4.1, in Chapter IV, gives the maximum number of shots which can be fired by a shotfirer/ blaster in a shift in the different mines.

The Regional Inspector may, by an order in writing and subject to such conditions as he may specify therein, permit or require the manager V to fix the maximum number of shots to be fired by a shotfirer/blaster differently from the limits specified above.

The number of detonators issued to, and in the possession of, a shotfirer/blaster during his shift shall not exceed the maximum number of shots that he is permitted to fire as stipulated above.

The Shotfirer's/Blaster's Tools.

Every shotfirer/blaster, on duty, shall be provided with:

a) a suitable electric lamp or torch;
b) a tool, made entirely of wood, suitable for charging and stemming shotholes, the tool should have a diameter slightly exceeding the diameter of the cartridge;

(Plastic tamping tools should not be used unless their use has been approved in writing by the Inspectorate. Some plastics may be too soft to withstand physical abuse, some too hard, some dangerously flammable, some may absorb nitro-glycerine, or some may generate hazardous accumulations of static electricity.

Mechanical tamping devices should be so constructed that no metal parts will enter the shothole unless such parts are effectively insulated so that no metal can come in contact with the explosives being tamped.)

(If the depth of a shothole exceeds 1.8 m, the tool for charging, stemming or testing the shot hole may be made of wood with joints made of any suitable non-ferrous material, so constructed that any such non-ferrous material docs not project beyond the general level of the wood and cannot come into contact with any explosive in the shothole

c) a scraper, made of brass or wood, suitable for cleaning out shotholes;
d) where fuses are used, a knife for cutting off fuses, and, unless machine-capped fuses are provided, also a pair of crimpers for crimping detonators;
e) where detonators are used, a pricker, made of wood or a non-ferrous metal, for priming cartridges;
f) where electric shotfiring is carried on, an exploder, shotfiring cable, and a circuit tester of the approved type; and
g) in coal mines only—
    i. a stop watch;

(Wrist watches or chronometers of the approved type may be given, but wearing or carrying of electronic watches maybe prohibited in underground mines, since an open spark in an electronic watch could cause ignition of CH_4 under certain conditions of concentration.)

Further, this provision may be made in the metalliferous mines also.)

    ii. belowground, a crack-detector approved by the Chief Inspector.

The crack-detector shall be a straight stiff rod or tube, made of copper or wood, with a flat prong at one end, which forms an integral part of U, or is securely attached to it, and which is made of, or tipped with, a hard-wearing metal. The length of the rod or tube shall be 150 mm longer than the depth of the shothole, but, in no case, more **than the length** or **the** shothole to be **normally drilled,** *i.e.*, about 13 m. The diameter of the rod or tube should be half the diameter of the shothole, but, in no case, more than 1/2"(12 mm). The length of the prong should be not less than 3/4" (18 mm) and more than 1" (25 mm) from the centre of the rod or tube to the tip of the prong. The width and thickness of the prong at tip should be not more than 3/32" (about 2 mm).

The crack-detector may incorporate a scraper attached to the outer end. The scraper attachment should comprise not more than half a disc.

No tool, other than that provided as above, shall be used by a shotfirer/blaster.

Drilling, Charging, Stemming and Firing of Shotholes

No drill shall be used for drilling a shothole unless it allows a clearance of at least 3mm over the diameter of the cartridge of explosives which it is intended to use.

No shothole shall be charged before it is thoroughly cleaned, and it's direction shall, where practicable, be distinctly marked on the roof or other convenient place.

The shothole should not be charged until immediately before firing. Not more that one case/canister of the explosives/detonators should be opened at any one time for charging shotholes. Only as many shots should be charged as the shotfiring apparatus can fire safely. No shotholes should be charged as one of a round until all shots in that round have been completely drilled. Charging should not be carried on simultaneously with the drilling or undercutting operations on the same face above or below each other, or within 7.5 m horizontal distance.

Charging should not commence at any place unless all electric power in that place has been cut *oft* and the flexible cable plugs of all machines within 10m of any shothole in that place have been removed from the gate end boxes concerned.

In opencast mines, the manager should specify the minimum distance between drilling operations and blasthole charging operations.

No detonator shall be inserted into a priming cartridge' until immediately before it is to be used. In case of wet workings, however, priming cartridges may be prepared at the nearest convenient dry place, and such primed cartridges shall be carried to the working place in a securely closed case/container. Detonators, once inserted into a priming cartridge, shall not be taken out.

Primers should be made up as near to their point of use as is practicable, and only in just sufficient numbers for the immediate work in hand.

The shotfirer/blaster should immediately remove the detonator from any cartridge which has been primed but not used. The priming should be sufficiently powerful to ensure, even in the open air, complete detonation of the primed cartridge. With delay detonators, the priming cartridge should be in the leading cartridge.

It is suggested to avoid any links in the detonator leading wires. When straightening them out, the detonators should not be held by the tubes. The wires should be gripped about 75 mm from the detonator tube with one hand, and the wires smoothened out with the other hand. This avoids any pull on the fuse head.

Where a round of shots is to be fired, as far as practicable, additional wire should not be used for connecting the detonator lead wires to each other.

The charge in any shothole shall consist of one or more complete cartridges of the same diameter and the same type of explosives. In metalliferous mines, however, the Chief Inspector may permit otherwise by an order in writing and subject to such conditions as he may specify therein. Similar permission may be statutorily granted in case of coal mines also. .

(For deep-hole/large diameter blasting in opencast mines, generally different types of explosives are used in individual holes. There are different combinations, *e.g.*, OCG-GN, OCG-ANFO, Primex-Poweflow-1/2/3-GN, Pentolite-Aquanite/Aquarem/Aquarex,Aquadyne-Super-gel/Energel, etc. For such use of different types of explosives in the same shothole, permission has to be sought from the Chief Inspector.)

The shotfirer/blaster shall, to the best of his judgment, ensure that no charge in a shothole is overcharged or undercharged, having regard to the task to be performed.

Every shothole shall be stemmed with sufficient and suitable non-inflammable stemming so as to prevent the shot being blown out. Only loosely filled in sand, or soft clay lightly pressed home, or a compact mixture of sand and clay, or water, shall be used as stemming. In coal mines, evidently, coal dust cannot be used for the purpose of stemming.

The clay plugs, commonly used as stemming material, usually attain a consistency similar to that of unburnt brick, and are often so hard that very forceful treatment is required in the shotholes to break them down. Such plugs are completely unsuitable as stemming material.

The stemming material should be compact but not hard. The use of a mixture containing 70% fine sand, 30% clay, and a small percentage of calcium chloride, to keep it in plastic condition, is recommended for the purpose.

The stemming rod should have its diameter slightly exceeding the diameter of the cartridge. Sufficient supply of stemming material should be provided as near to the working face as practicable (in the nearest cross-cut or other convenient place in the vicinity).

Exemption may be sought from the Chief Inspector for the use of an approved device of pneumatic stemming.

The PVC water ampoules may be used safely as a stemming material. The following guidelines may be useful in introducing the new system:

i. The ampoules should be self-sealing type. (In ampoules, meant for being filled inside the holes, a slit self-sealing valve should be provided.)

ii. The material chosen for the manufacture of the ampoules should be —
    a. non-inflammable,
    b. such as would not cause harmful effects to the skin when handled,
    c. adequately strong (minimum wall thickness — 0.01 cm)
    d. adequately resistant to wear by abrasion and to heat, and
    e. anti-static.
iii. The ampoule should be as close a fit as possible, and should have adequate holding ability in a shothole.
iv. Normally, one water ampoule, about 38 cm in length, may be used in a shothole upto 1.5 m in depth. Where the shotholes are deeper than 1.5 m, another ampoule may be inserted at the back of the hole.
v. A plug of solid stemming should be used at the inbye, as well as the outbye, ends of the shotholes,
vi. Shots, stemmed with ampoules, should be fired as quickly as possible, preferably within one hour of the commencement of charging.

No water- or gel-ampoule may be used in underground coalmines unless the same is of a type, make, and standard approved by the Chief Inspector. These ampoules are being progressively introduced as stemming, first in all II degree gassy coal mines, and then in all II degree gassy coal mines.

The water ampoules may be filled underground at any convenient point, where water is available, preferably near to the place of blasting so as to eliminate their transport cost. They can be filled by means of a foot operated valve, supplied by the manufacturers, or by a valve and filling tube which may be made in the colliery.

The use of water- or gel- filled ampoules as stemming material for explosives considerably reduces
(i) the risk of methane ignition, and
(ii) the amount of dust and fumes from blasting, thereby creating safer and better environmental conditions in the mine.

It is also claimed that this type of stemming:
(i) reduces the possibility of deflagration,
(ii) is more efficacious than the conventional stemming, and
(iii) brings down the degree of projection of fragments.

The three types of water-ampoules and one type of gel-ampoule, available in the country, are discussed in brief in Appendix-39.

In general, the stemming should:
(i) extend along the entire length of the shothole,
(ii) fill the cross-section of the shothole over its entire length, and
(iii) as far as practicable, exceed 200 mm in length.

In charging or stemming a shothole, no metallic tool, scraper, or rod shall be used, and no explosive shall be **forcibly pressed** into a hole of insufficient size.

In case the water ampoules of certain types (Types (b) and (c) of Appendix-39] are to be used as stemming, necessary exemption has to be obtained from the Chief Inspector from the above provision.

Forcing a cartridge of explosives down a shothole is always fraught with danger, particularly when it is stuck up. It is equally dangerous when attempts are made to press or force a cartridge, stuck up in a shothole of bigger size, either due to some obstruction in the shothole, or due to the cartridge having fallen diagonally. Such a shothole should always be dealt with in the manner laid down in the Regulations for misfires.

No shot shall be fired except in a properly drilled, charged, and [Hemmed shothole. As far as practicable, a shot shall be fired by the same shot firer/blaster who charged it.

The shotfirer/blasler should himself attach the detonator leads to ie firing circuit, and should be the last person to leave the face where the lot is to be fired.

In any mine, in which explosives other than gunpowder are used, *f* shot shall, if required by the Regional Inspector, be fired electrically.

In metalliferous mines, not more than 10 holes shall be fired in one round unless they are fired electrically or by means of an ignitor cord. In coal mines, except in a stone drift or a sinking shaft, not more than 10 shots shall be fired in one round. Where more than 6 shots are to be fired in one round, they shall be fired electrically. In case of opencast coal mines, any number of shots can be fired in one round if they are fired electrically by an exploder of adequate capacity.

No shothole shall be charged except those which are to be fired in (hat round; and all shotholes, which have been charged, shall be fired in one round.

Where a large number of shots have to be fired, the shot firing shall, as far as practicable, be carried out between shifts. No person shall:
(i) Remove, or attempt to remove, any stemming;
    (In metalliferous mines, stemming may be removed by water under pressure, or other approved device, such as compressed air.)
(ii) pull out any detonator lead;
(iii) remove any explosive from any charged shothole, either before firing or after a misfire;
(iv) bore out a hole that has once been charged; or
(v) deepen or tamper with empty holes or sockets.

All surplus explosives shall be removed from the vicinity of the shot-holes before the commencement of shot firing operations.

Fuse Blasting

No shot shall be fired by a fuse less than 1.2 m in length. In many cases, long lengths of fuse are inserted into the gunpowder cartridges with the result that the length of the fuse outside the cartridge becomes much less than 1.2m. Thus the shotfirer/blaster does not get sufficient time to *get* to the shelter after he has lighted the fuse. Hence it recommended that the length of the fuse outside the cartridge-should not less than 1.2 m.

Blasting gelatine or other high explosives shall not be lighted I order to set fire to fuses. In metalliferous mines, however, specially prepared 'kai piece' of such explosives may be so used. Such kai pieces shall be prepared in the magazine, and a correct record of the issue, use and return of such kai pieces shall be maintained in:

(i) the register of issue and return of explosives -by the magazine incharge; and

(ii) the blaster's record at the end of his shift — by the blaster.

The average burning rate of the safety fuse used at a mine should be determined by burning not less than three one metre lengths of such fuse] in open air. No safety fuse, which varies more than 10% from the average burning rate, should be used.

No fuse, which has been hammered or injured, should be used since such injury may affect the rate of burning, and may cause a hang fire. The hanging of a fuse on nails or other projections may cause a sharp bend lo be formed thus again injuring it,

The use of oil or grease to waterproof joints between the detonator and the safety fuse may injure the fuse and cause a misfire. A water-proof crimp or a compound specially prepared for water-proofing may be used.

In capping a safety fuse, at least 25mm should be cut from the end of each coil of the fuse to be used so as to prevent damp fuse ends from getting into the cap/detonator.

Any practice of attaching the capped safety fuse to a primer cartridge, which tends to kink, distort, cut, sharply bend, or otherwise damage the safety fuse, before or during loading, should be avoided as it may possibly cause a misfire.

The so-called "drop fuse" method of dropping or pushing a primer or any explosive with a lighted fuse attached to it must be forbidden. When lighting fuses in a round —

(i) they should be so timed that no charge will explode until at least 2 minutes after the last fuse in the blast area has been ignited;

(ii) consideration should be given to the length and burning rate of the fuse, condition of the shotfirer's travelling way, and the distance to the place of safety;

(iii) where more than 3 fuses are to be ignited at one time in the working face, no person should ignite a fuse until another person is sufficiently near him to be able to assist him in case of accident or emergency.

Electric Shot firing.

No shot shall be fired electrically except by means of a suitable shot firing apparatus (exploder); and the number of shots, fired at any one time by the exploder, shall not exceed the number for which it is designed.

Every exploder shall be so constructed and used that:

(i) it can only be operated by a removable handle or plug;

(ii) the plug or handle is not placed in position until a shot is about to be fired; and

(iii) the firing circuit is made and broken either automatically or by means of a push-button switch.

No defective exploder shall be used. If the exploder fails to fire all I he shots in a properly connected circuit, the shotfirer/blaster shall return the exploder to the manager/assistant manager as soon as possible and the same shall not be used again unless it has been tested on the surface and found to be in safe working order.

Every exploder shall, once at least in every three months, be cleaned and thoroughly overhauled by a competent person. The result of every overhaul, test, or repair shall be recorded in a bound paged book, kept for the purpose, and shall be signed and dated by the person making the overhaul, test or repair.

Exploders must **never** be repaired by unauthorised agencies. Only the work of maintenance of exploders is to be carried out at the mine level and any servicing and repair of an approved exploder must be carried out only by the manufacturer of the exploder or by the agency authorised by the manufacturer and approved by the Chief Inspector. In this context, the Inspectorate has brought out a list of the agencies where repair work of the various types of exploders can be carried out.

It is suggested that, in the **Exploder Maintenance Book**, a few pages should be ear-marked for each exploder. A complete history of maintenance, tests, repairs, overhauls, etc., of every exploder in use, since the date of its introduction, should be kept recorded on these pages, and every entry in this book should be countersigned by the engineer.

The duration of current in the firing circuit should **never** exceed **4 milli-seconds,** because there could be post-firing sparks caused between the ends of the shotfiring cables or the detonator wires due to the violent disturbance at or near the face after a round of shots is fired; and if the exploder output current has

not ceased by that time, this may cause (ignition of any methane which might have been liberated by the blasting round.

No current from a signalling, lighting, or power circuit shall be used for firing shots. The possible reasons for this provision may be:

a) The voltage of the electric supply may not be as per requirement of the firing circuit from the safety point of view. It may be too high or too low, thus increasing the possibility of stray current effects as well as an increase in the chance of misfire,
b) Persons firing shots, at the time of making connection, may get electric shock if the line voltage is high, specially when the connection of the firing line to the power line is not effected through a circuit-breaker.
c) Whereas an exploder is provided with all sorts of safety devices, **including the detachable key,** which should always be in the possession of the shotfirer/blaster, such safety devices are entirely lacking in case of Firing from the signalling, lighting or power lines.

Nevertheless, shotfiring in sinking shafts, and heavy blasting in slopes, may be permitted to be carried out from the power mains. Appendix-40 suggests some conditions that may be followed while firing from the power mains.

The following specifications have been notified for the various types of shotfiring cables:

(A) CABLE FOR SINGLE SHOTFIRING

Two-core cable, each core consisting of a conductor of at least four copper wires of not less than 0.018 inch (0.45 mm) in diameter, with insulation and further protection against mechanical wear and damage not less than that of P.V.C. (polyvinyl chloride) 0.025 inch (0.65 mm) in thickness with a figure of eight construction, or of vulcanised rubber or P.V.C., 0.020 inch (0,5 mm) in thickness, the two cores twisted, wormed and covered with a sheath of cotton braid, tough rubber or P.V.C.

(B) CABLE FOR MULTKSHOTFIRING

Single-core cable, consisting of a conductor of at least three copper wires of not less than 0.036 inch (0.9 mm) in diameter, insulated to withstand at least 250 volts, and further protected against mechnical wear and damage.

(C) CABLE FOR SHOTFIRING IN SHAFTS

Two-core cable, each core consisting of a conductor of at least •-even copper wires of not less than 0.029 inch (0.74 mm) in diameter, insulated to withstand at least 250 volts, and adequately protected against mechanical wear and damage.

Note: - The following are the methods of insulation and protection for multi-shotfiring cables which are regarded as suitable:

1. insulated by vulcanised rubber or P.V.C., protected by taping, braiding and fire-resisting compounding;
2. insulated by vulcanised rubber protected by a tough rubber sheath or P.C.P. (Polychloroprene) sheath; or
3. Insulated by P.V.C., protected by a P.C.P. sheath.

The shotfiring cable shall be well insulated, and of sufficient length, in no case less than 18 m, (not less than 20 m in metalliferous mines), so as to permit the shotfirer/blaster to lake proper shelter.

(The minimum length of shotfiring cable should be specified the same in both Coal and Metalliferous Mines Regulations).

The insulating material should be capable of withstanding 1500 V for 30 seconds.

The shotfiring cable must not be used for any purpose other than shotfiring.

The shotfiring cable should be short-circuited at the blasting end, until it is ready to be attached to the blasting unit. The cables for different locations should be staggered as to length, and kept well separated until attached to the detonator leading wires.

The part of the shotfiring circuit leading from the firing apparatus to the blasting area should not be earthed, and it should be provided with a bar for short circuiting the leading wires when the switch is in the "off position.

Before coupling it to the exploder, the shotfirer/blaster shall couple the cable himself to the detonator leads. He shall take care to prevent the cable from coming in contact with any power or lighting cable, or other electrical apparatus. The cable to the exploder shall be connected last, by the shotfirer/blaster himself, because, whenever this connection is made, firing may be effected by the operation of the key/switch by anybody, either by mistake or deliberately, ,when perhaps somebody might have been engaged in some other work in the face, or in the shot-firing circuit, etc. Before doing so, he shall see that all persons, in the vicinity, have taken proper shelter. After firing the shots, and before entering the place of firing, he shall himself disconnect the cable from the shotfiring apparatus.
The shotfirer/blaster shall take adequate precautions to protect electrical conductors and apparatus from injury.

The manager may specify the minimum distance to be maintained between any electric detonator, being used, and the following installations:

(a) overhead electrical power transmission lines,
(b) energised electric trailing cables,

(c) electric earthing systems, and
(d) any metallic part connected with electrical earthing system.

No person should carry out blasting operations by means of an electric detonator when the detonator is closer than the distance specified in respect to that installation. No power should be restored to an installation which is closer than the specified distance to any electric detonator being used in blasting operations.

All electric detonators should have their leading wires twisted together or **shunted** until the holes have been charged, to avoid any possibility of premature explosion due to any stray electric current. For the same purpose, the ends of the leading wires, after being brought to the face, should be touched together before they are connected to the shotfiring cables, when any current in the wires will be indicated by a spark.

All electric power should be cut off from the equipment at the face before explosives are taken, and during charging and firing of shots.

The part of the blasting circuit leading from the exploder to the blast area should not be earthed. In extremely wet working places, all electric connections should be well taped and made waterproof.

The shotfiring cables should be kept clear of pipe lines, tracks, and other sources of active or stray currents.

Immediately after firing the charge of explosives and disconnecting the shotfiring cable from the exploder, the shotfirer should replace the short circuit on the cables by joining the wires together. In case of simultaneous shotfiring:

(i) care shall be taken that all connections are properly made
(ii) if fired belowground, all shots shall be connected in series;

(Any discontinuity in any detonator circuit will cause non-firing, and the detection of the defective detonator becomes easy by elimination. It is not the case with parallel connections.)

(There is an impression that, when a round of shotholes is connected in series, either all the holes will fail to blast or all of them will blast, and that there is no chance of a **single misfired hole.** Due to varying characteristics of electric detonators, possibility of one or more holes in a round of shotholes failing to detonate cannot be ruled out. Therefore, before drilling a fresh round of shotholes, all coal from the face should be cleaned and the face checked for any misfire/socket **by the shotfirer.)**

(iii) the circuit shall be tested, either for continuity or for electrical resistance, before connecting it to the exploder; such a test shall be made with an apparatus specifically designed for the purpose, and after all the persons, including the shotfirer/blaster and his helpers, if any, in the vicinity have taken adequate shelter; it has to be ensured that there is no open or short circuit by the passage of a limited testing current (not exceeding 50 mA), so that there is no possibility of an accidental explosion of a detonator; the mine management should periodically verify the resistance of the electric detonators, indicated on their wrappers, this verification being carried out **once at least in every 3 months; and**
(iv) in coal mines, only detonators of the **same electrical resistance** shall be used.

The ILO Code (1986) recommends that, in mines liable to **sudden outbursts** of gas, all shots should be connected **only in parallel.** Also, where delay detonators are used in coal, the Regulations should specify the **maximum period of delay** between the firing of the first and the last shot in the round. In series firing, current of at least 1.5 A strength should be used.

Deep-Hole Blasting in Opencast Mines

The manner of carrying out deep-hole blasting in the opencast mines is described in Appendix-19.

Solid Blasting/Blasting-off-solid/ (B.O.S.) in Coal Mines

Solid blasting may be carried out with the help of Soligex (P5) explosives with Carrick (non-incendive) detonators in the I and II degree gassy seams, subject to certain restrictions regarding ventilation. P3 type explosives may be used in I degree gassy mines, with short delay detonators and without any undercut, overcut, or sidecut.

Soligex (P5) can be used with delay detonators with copper tube and approved type of exploder,

Splitting of Pillars without Providing an Additional Free Face

(i) In I and II degree gassy coal mines, splitting may be done without providing an additional free face, provided wetting arrangements are really satisfactory.
(ii) In III degree gassy coal mines, splitting of pillars, without providing an additional free face, may not be permitted. However, special permission may be sought from the Inspectorate for the B.O.S., with P5 explosives and non-incentive milli-second delay detonators.

It would be a useful precaution to use water ampoules in solid blasting faces, in addition to the proper wetting arrangements.

The conditions for trials with solid blasting in the I and II degree gassy mines have been given in Appendix—41.

In general, solid blasting will not be permitted in the III degree gassy mines. However, in horizon mining, in drivage of coal laterals or chimneys, in the working of longwall faces, etc., it may be permitted with the following provisions:

(A) For horizon **mining,** solid blasting maybe recommended if, in coal laterals or chimneys, at least 300-600 m/minute (10,000-20,000 cft/min) of air, depending upon the dimensions of the drivage and the rate of emission of the gas, can be ensured at the face.

(B) For a longwall face, solid blasting may be recommended if, in the stables, at least 300 m^3/min (10,000 cft/min), and at the face, at least 1,000 m^3/min (30,000 cft/min) of air can be ensured.

In addition, for both (A) and (B):

(i) the total delay interval between the first and the last shot in a round should not exceed 100 ms (0.1 s);

(ii) the arrangements for treatment of coal dust **at and within** 90 **m** of the site of blasting should be as per statute, and stone dust barriers should be in position; and

(iii) standard of supervision should be satisfactory.

(C) For **bord** and pillar workings, solid blasting may not normally be permitted.

Consequent upon the introduction of solid blasting in coal, there have been some incidents of drilling into sockets containing remnant charges of explosives, or misfired charges. To guard against such incidents, the following precautions may be observed:

1. The provisions in the Coal Mines Regulations regarding:
   (i) the charge in any shothole shall consist of one or more complete cartridges of the same diameter and the same type of explosive;
   (ii) in case of simultaneous blasting, the testing of the electrical blasting circuit and the provision of the detonators of the same electrical resistance shall be made; and
   (iii) special precautions applicable to stone drifts shall be ensured; shall be strictly complied with.
2. Every case of misfire shall be enquired into as a statutory duty; on the part of the manager, either by himself or, on his instructions, by an assistant manager, etc.,
3. The 'misfire record' shall be more specific. It shall mention the details of the type of explosives and detonator used in the misfired hole.
4. A general pattern of shotholes shall be worked out to give most satisfactory results, and the shotfirer should always adopt the same in day-to-day blasting operations.
5. Any tendency on the part of the shotfirer to rush through the blasting operations **must** be severely dealt with. The overmen and mining sirdars should ensure that the shotfirers carry out their duties under the Regulations, particularly those relating to **Inspections after** Shotfiring and **Misfires, in** a conscientious and thorough manner. The manager and supervisory staff shall ensure that control, management and direction are su'ch as to ensure proper compliance of law by the shotfirers and other officials and workers. The coal cutters and loaders must be disciplined so as not to interfere with the legal and safe practices.
6. As statutorily required, the shotfirers shall test for inflammable gas in the prescribed manner.
7. Only approved types of exploders, and cables in good order, shall be used. Any serious defect in any approved exploder, cable and explosives shall be brought to the notice of the Inspectorate **forthwith.**

Ring Hole Blasting with Special Explosives. Detonating Cord, etc.

Appendix-42 gives the conditions for the above special type of blasting in the sub-level caving method of extraction of pillars.

Precautions While Blasting in Hot Strata in Overburden or Coal in Opencast Coal Mines.

While blasting in hot strata, where fire is active, the following precautionary measures should be adopted:

1) No explosive other than slurry explosive should be used.
2) Blasting should be done with detonating fuse down the hole.
3) Temperature inside the blast holes should be measured before filling them with water, and, if the temperature exceeds 80 C in any hole, such hole should not be charged. Records of measurements of temperature in each hole should be maintained in a bound paged book.
4) All blast holes should be kept filled with water. 'Where any hole is traversed by cracks and fissures, such a hole should not be charged unless it is lined with an asbestos pipe and the hole filled with water. In addition, bentonite should be used for sealing any cracks at the bottom of the holes.
5) The detonating fuse should **not be laid** on hot ground without **taking** suitable precautions which will prevent it from coming in contact **with the** hot strata.
6) The charging and firing of the holes in any one round should be completed expeditiously, and in any case **within 2 hours,**
7) Blasting operations should be carried out under the direct supervision of an assistant manager.

Water Infusion Shotfiring in Coal Mines

The ILO Code (1986) recommends that:

(i) **No** shot should be fired by the water infusion method **unless the** explosives and the detonators are approved by the **Chief** Inspector.

(ii) The shotfirer should satisfy himself immediately before he **fires** the shot that the shothole is **filled with water.**

(iii) The infusion apparatus should be so **constructed that it holds secure in the shothole** and is **not ejected by the** shot.

Shotfiring in Stone Drifts

The ILO Code (1986) recommends **that:**

(i) It should be lawful for a shotfirer, engaged in a cross-measure drift, to prime the cartridges at a place at least 45 m from the face of the heading, provided that —
  (a) the place is fixed by the manager;
  (b) immediately he has removed a detonator from its case to prime a cartridge, the shotfircr short-circuits the detonator leads; and
  (c) immediately each cartridge has been primed, the shotfirer places it in a specially constructed box which is kept securely locked; only primed cartridges should be placed in or taken out of the box, which should be divided into separate compartments.

(ii) Detonators of different delays should not be placed in the same compartment of the box,

(iii) Priming of cartridges should not begin until the shotfircr has established that the shothole can be charged immediately after he has completed priming.

Shot firing in Sinking Shafts/Winzes

The ILO Code (1986) recommends that:

(i) The primers should be prepared only in a special place fixed by the manager.

(ii) The explosives should be brought to the bottom of the shaft/winze/ in closed containers and only when they are immediately required for use.

(iii) No shotfirer should couple a shotfiring cable to a detonator m a shaft provided with a winding apparatus unless —
  (a) the bucket is conveniently placed for persons in the shaft/winze to enter it;
  (b) he has satisfied himself that the person operating the winding apparatus is ready to raise.

(iv) The shot firer/blaster should notify to the winding engine driver, by a special signal, that blasting is about to take place; and the driver may reply by raising and lowering the bucket, etc., a few metres a number of times.

(v) While connections are being made to the shotfiring line, **only** (hose persons needed for the operation, in addition to the shot firer, should be present.

(vi) The cable should not be coupled **to the** shotfiring apparatus until all persons are in a place of safety.

(vii) The shot firer should be the **last** to leave the bottom of the shaft/winze.

Sometimes it becomes necessary to blast a **"hung up"** raise. **In such** cases, warning should be given **on both** levels and all entrances guarded.

Chamber/Coyote/Sprung-Hole Blasting

The chamber, coyote, or sprung-hole blasting should be carried out according to a design worked out for each case. In chamber blasting, after the drivage of the headings is completed, the actual position of the drifts and the chamber must be determined by the surveyor, and located on a plan, to ascertain that they have been driven exactly as planned. Thus it would be possible to correctly and precisely calculate the weight of each charge.

The cross-section of the drift connecting the chamber **with** the surface should be **not less than *12 m*** (i.e., 1.5 m high x 1.2 m wide), while the shaft should be **not less than 1 m** in cross-section.

Since a long time is required to charge the chamber, etc., persons not connected with work may remain within the danger **zone** until the insertion of the priming charge is started, provided that these persons are **not closer than** 50 **m** from the nearest charge, and that only ANFO, slurries, or nitro-glycerine explosives, containing a maximum of 15% nitro-glycerine, are used. The shot firer/blaster should not have any detonator on his person during charging, until just prior to the insertion of the priming cartridge into the shothole.

To avoid the formation of a large charge of static electricity during the charging operations, the explosive should be poured in small quantities, **with pauses in between.** It is best to use a metal pipe for the purpose. Deep boreholes may be charged with the help of a chute so that the men pouring the charge can stand at a distance of 1.5-2 m away from the shothole.

All work in the chamber/coyote should be .stopped and all equipment/tools not needed for loading the explosives should be removed. The area being loaded should be **clearly marked** and kept free of all obstructions. For transporting explosives in such blasting areas, only vehicles with rubber tyres should be used.

A place, **not closer than 3m** from the mouth of the drift/shaft, should be prepared for holding the explosives required for charging the chamber.

It is permissible to light the working of the chamber with a lighting circuit of 250 volts, only upto the moment the priming cartridge is to be inserted in the chamber, etc. When the priming operations commence, all the circuits should be switched off, and all further lighting should be furnished by means of approved safety lamps.

A shaft chamber must never be charged by freely dropping the explosives into it. It should be lowered into the chamber by means of a suitable mechanism fitted with brakes, or rope.

In case the chambers are charged with ammonium nitrate explosives, it is permissible to fill the chamber with the aid of special drop pipes.

If an electrically driven pump is used in the shaft, both the pump and the electric power supply circuit should be removed before the priming cartridge is lowered into the chamber.

The electric firing circuit should be checked both after the charging is completed, and after the stemming is in place (in order to make sure that the circ6it has not been damaged during the stemming operation).

Firing in the chamber, etc., should be carried out only with the help of detonating fuse and electric detonators. When the depth exceeds 6 m, the firing circuit should be duplicated.

The official in charge of blasting should not give the order to check the results of the chamber blasts until 30 minutes have elapsed after the blast.

In opencast mines, no springing/bulling should be carried out in coal, but only in rock. The hole springing should be so arranged that none of the other holes contain charge when the sprung charge is fired in a given shothole. Thus all the shotholes of a particular round should be sprung before placing of the main charge.

When a sprung charge has been fired, no person should load into the hole any further charge unless

(i) the sprung hole has been filled with water; or;

(ii) the sprung hole has been allowed to stand unloaded for two hours and then washed out with water jets; or

(iii) the sprung hole has been allowed to stand unloaded for 30 minutes, and thereafter a copper rod has been inserted in the hole for at least 5 minutes and, on withdrawal, has been found to be sufficiently cool to enable the back of the hand to be held against it.

Controlled Blasting Technique

Controlled blasting is used to reduce over break and minimise fracturing of the rock at the boundary of an excavation. The blast dimensions for a specific job are usually arrived at by trial and error. The four basic controlled blasting techniques are:

(i) line drilling,

(ii) pre-splitting,

(iii) cushion blasting, and

(iv) smooth blasting.

(i) Line Drilling. This is the earliest method and involves drilling a row of closely spaced holes along the final excavation line, providing a plane of weakness along which to break. Line drill holes, 50-75 mm in diameter, are usually spaced *2-4* diameters apart and contain no explosives. The blast holes, adjacent to the line drill holes, are normally loaded lighter, and are on closer spacing, than the other blast holes. The maximum depth for line drilling is about 9 m. Drill hole deviation is the limiting factor. Line drilling involves no blasting in the final row of holes, and thus minimises damage to the final wall. The chief disadvantage is the high drilling cost.

(ii) Pre-splitting. Pre-splitting, sometimes called pro-shearing, involves a single row of holes, usually 50-100 mm in diameter, drilled along the final excavation at spacing of 6-12 borehole diameters. Dynamite cartridges, 50-60 mnrin size, on 0.3-0.6 m centres, are usually spring-loaded on detonating cord. Special small diameter cartridges with special couplers are also available for total column loading. In unconsolidated formations, closer spacings with lighter powder loads are required. The bottom 0,6-0.9 m of the borehole is usually loaded somewhat heavier than the remainder. Stemming between and around the individual charges is optional. The top 0.6-0.9 m of the borehole is not loaded, but is stemmed. The depth that can be pre-split is limited by hole alignment, with 15 m being the maximum. The pre-split holes are fired before the adjacent primary holes to provide a fracture plane to which the primary blast can break. Pre-splitting too far in advance is not recommended. It is seldom done underground.

(iii) Cushion Blasting. Cushion blasting involves drilling a row of 50-150 mm diameter boreholes along the final excavation line, loading with a light well-distributed charge, and after the main blasting, rather than before, as in pre-splitting. The burden on the holes is slightly larger than the spacing. Wedges may be used to abut the charges to the excavation side of the borehole, and minimise the damage to the final wall. Explosive loading is similar to that in pre-splitting. Cushion blasting has been done to depths near 30m in a single lift with the large diameter boreholes because alignment is more easily retained. Cushion blasting is seldom done underground.

(iv) Smooth Blasting. Smooth blasting is the underground counterpart of cushion blasting. At the perimeter of the tunnel or drift, closely spaced holes, with a burden-to-spacing ratio near 1½ : 1 are loaded with light well-distributed charges. Smooth blasting differs from cushion blasting in that (a) except at collar, the charge are not stemmed, and (b) the perimeter holes are fired on the last delay in the same round as the primary blast. Total column loading is most common, although spacers may be used. The back to the borehole is loaded somewhat more heavily. The holes are stemmed to prevent the charges from being pulled out by the detonation of the previous delayed holes. Smooth blasting reduces overbreak in a drift, and also provides a more competent roof/back, requiring less support. It involves more perimeter holes than does normal blasting,

Pre-blasting Survey and Blast Design

In USA, the Regulating Authority (Office of Surface Mining— < >SM) may require a mine management to conduct a pre-blasting survey i 'I a dwelling/structure on a complaint made to them by the

owner of that dwelling/structure, and submit a report thereon. The survey report may include recommendations of any special conditions or proposed adjustments in the **blast design** to prevent damage to the concerned dwelling or structure.

The OSM also requires the mine managements to submit a blast design if any blasting operations are to be conducted within —

(i) 1000' of any public building, school, or other important dwelling/structure not belonging to the owner, or,

(ii) 500' of an active or abandoned underground mine.

The blast design may contain sketches of the drill pattern, delay periods, and decking, and indicate the type and amount of explosives to be used, location and general description of the structures to be protected, and applicable fly rock, air blast, and ground-vibration standards.

Taking Shelter

The shot firer/blaster shall ensure that, before a shot is charged, stemmed, or fired, all persons, other than his assistant, if any, in the vicinity have taken proper shelter. He shall also take suitable steps to prevent any person from approaching the shot and shall himself take adequate shelter, along with his assistants, if any, before firing shots. The inadvertent entry may be prevented by

(i) posting guards at all possible entrances, and

(ii) fencing them. In opencast workings, he shall not charge or fire shots unless he has taken the above precautions.

Danger Zone. In opencast workings, the shotfirer/blaster shall not charge or fire a shot unless:

(a) sufficient warning, by efficient signals or other means, approved by the manager, is given over the entire area falling within a radius of 300 m from the place of firing, called 'Danger Zone';

(Recently, the Inspectorate has advised the raising of the limit of the danger zone from 300 m to at least 500 m, and prescribing that all those, who must remain within the danger zone at the time of blasting, should take shelter in a substantially built shelter. Where the entire danger zone, and a distance of at least 20 m beyond, cannot be got vacated, the shots should be fired by controlled blasting technique with mini-second delay detonators, or be muffled, as described later in the Chapter, so that flying fragments (fly rock) cannot project beyond a distance of 10 m from the place of firing. In either case the technique] should be got approved by the concerned Regional Inspector.)

(b) he has ensured that all persons within the danger zone have taken proper shelter; and

(c) where any part of a public road or railway line falls within the danger zone, 2 persons are posted, one each in either direction, at the two extreme points of such road or railway. These 'guards' shall, by an efficient system of telephonic communication, or hooter, or loudspeakers, or .other means, approved by the Chief Inspector, or| Regional Inspector, indicate clearance of traffic to the shotfirer/blaster, and also warn the passers-by and, whenever possible, the vehicles also, if any, which have passed by such road or railway.

The warning siren/hooter should be sounded for a minimum period of 2 minutes and the shotfirer should fire the shot/round of shots only at the end of that time.

If blasting is done in such a manner, approved, in writing, by the Chief Inspector or the Regional Inspector, that the flying fragments from blasting cannot project beyond a distance of 10 m from the place of firing *(e.g.,* muffle blasting), the above provisions, *viz.,* (a), (b), and (c), need not be complied with.

A good way of 'muffing' the shots is to use a carpet of inter-linked chains/ropes at each hole, adequately weighted down by sand-bags. Sheet covers are not so satisfactory, and they should not be used.

In case of the opencast workings where any permanent building or structure of permanent nature, not belonging to the owner, lies within the danger zone, the aggregate maximum charge in all the holes, fired at one time, shall not exceed 2 kg, unless permitted, in writing, by the Chief or Regional Inspector, and subject to such conditions as he may specify therein. If blasting is done with delay detonators, or other means, and there is a delay of at least half a second between successive shots fired, a maximum charge of 2 kg can be used in each hole.

However, if the shortest distance from the place of firing to any part of such building or structure is less than 50 m, irrespective of the amount of charge, no blasting shall be done except with the permission, in writing, from the Chief or Regional Inspector, and subject to such conditions as he may specify therein.

In general, the Chief Inspector may, by an order in writing, and subject to such conditions as he may specify, exempt any mine, or part thereof, from the above provision on the ground that its observance is not necessary or reasonably practicable on account of the special conditions existing therein.

It is dangerous to carry out blasting operations in opencast mines during the whole shift, when other work is also being done in the area. Under such circumstances it is difficult to ensure that all persons within the danger zone have taken adequate shelter. It is, therefore, desirable that all blasting operations (including carrying of explosives into the working area, preparation of priming cartridges, soaking LOX cartridges, if used, charging, stemming and firing of shotholes) in opencast working should be restricted to the periods when the workings are generally clear of other work persons, *i.e.*, the period between the adjacent shifts, or at the beginning or end of a working shift. Where blasting is carried on in adjacent blocks/areas, the minimum distance between such blocks/areas should be not less than 300 m.

In many opencast mines, a number of shotfirers/blasters are engaged side by side for simultaneous blasting operations. As shots fired by all such shotfirers/blasters are likely to go off together, it is difficult to count them for ascertaining whether there has been any misfire or not. In case there is a slight time stagger in blasting operations, some of the shotfirers/blasters may be injured by missiles thrown off by other blasting in the neighbourhood, as they may not be able to take proper shelter in time. It is, therefore, desirable that, where a number of shotfirers/blasters are employed in proximity to each other, *i.e.*, within 300 m, only one shotfirer/blaster at a time may fire shots and the interval between two shotfirers/blasters firing shots should be not less than 30 minutes.

When the blasting operations are carried out beyond daylight hours, it may not be possible to ensure that all persons in the danger zone have taken shelter. There is also the possibility of some inadvertent entry into the danger zone by workers, or even outsiders. Possibility of persons remaining unprotected in the danger zone, therefore, cannot be ruled out. It is hence felt that shots, if fired after daylight hours, should be muffled so that the flying fragments from blasting cannot project beyond a distance of 10 m from the place of blasting.

Where the workings, either above or below- ground, offer insufficient protection against flying fragments or missiles, adequate shelter or other protection shall be provided.

In view of the diversity in the nature of coal, the manager of each underground coal mine should determine, for his mine, the zone likely to be affected by blasting, depending upon the nature of roof, method of work, etc.

In metalliferous mines, where shots are to be fired in 2 or more adjoining stopes, the blasters shall so arrange to time the firing of shots that shots in only one of the stopes are fired at a time.

Apart from compliance with the prescribed statutory precaution-it is considered desirable to devise a system which would further aid such endeavours. One step could be to put up notices prohibiting entry *into (all* dangerous areas. These notices may be in the form of a pedestal boar or a horizontal bar across the gallery, etc. The notice could bear *the* inscription (in red colour) —

"DANGER: BLASTING GOING ON-NO ENTRY"

preferably in the language understood by the workers in the mine.

Such obstacles could be positioned at all entrances and approaches to the blasting area by the shotfirer/blaster, or his helpers, and would be removed by them only after the completion of blasting, and after making the area safe. However, these precautions are to be in addition to the positioning of the guards, etc., as stipulated in the statute, and not a j substitute or replacement.

Where two workings belowground have approached, within 3 m in metalliferous mines, and within 4.5 m in coal mines, of each other, the shotfirer/blaster shall not fire shot in any one of the said workings unless all the persons have been withdrawn from the other working places, and the same have been so fenced off as to prevent persons inadvertently coming in direct line of the shot. (Danger of 'blown-through' shots).

One right-angle bend, by itself, may be inadequate in preventing injuries from the flying pieces of coal/stone. Depending upon the size of pillars in the mine, a sufficient length of cable should be issued to the shotfirer/blaster so that he is able to fire shots from a place beyond the reach of the flying fragments of coal/stone. *In* deciding the place, from where the shots should be fired and other persons should lake shelter, it may be borne in mind that negotiating *2* right-angle bends would keep the people out of danger.

It is suggested that, when blasting has to be carried out in a face which has approached within 3 m, in metalliferous mines, and within 4.5 m in coal mines, of other workings, the mining sirdar/male should also be made responsible for the supervision of blasting in such faces.

It is emphasised that notices should be put up, arid portable fences with caution boards erected, in all approach galleries to the place of firing, as well as in a face that has come within 4.5 m/3 m, in coal and metalliferous mines respectively, of the same.

In several instances there might have been some inaccuracy on the pan of the surveyor, who may fail to mark accurately the relative positions of the approaching working places/galleries. Thus the shot-firer/blaster is misled to believe that the stipulated safe parting is in existence, which gives him a false sense of security. In such cases the surveyor cannot waive off his responsibility. It would be better if all the approaching galleries are precisely surveyed so that adequate precautions can be taken at the right time. Of course it would he best if, whenever two galleries approach each other within 9 m/ 6 m of each other, in case of coal and metalliferous mines respectively, only one should be worked and the other kept stopped. The entrance of the temporarily stopped face should be fenced off.

The overman/foreman incharge of the district, who carries a hand plan of the district, should give instructions in writing to the concerned shotfirer/blaster when any two galleries or workings approach within 4,5 m (3 m in metalliferous mines) of each other in the district under his, charge. Such a step may even be taken by him when they approach within 10 m of each other, so as to cover up any inaccuracies in the hand plan available with him. Thus the shot fire r/blaster would become aware of the existence of the danger on this account, and would take all necessary steps to the danger on this account, and would take all necessary steps to withdraw persons from the vulnerable places.

When a face is temporarily discontinued as above, it should be ensured that the stopped face is always kept dry by providing drains, siphon, or pump, as may be necessary.

In some cases, a working face may be approaching a gallery/ roadway. In such cases, it shall be ensured that, when the parting between the side of gallery/roadway and the face is 9 m (6 m in

metalliferous mines) or less, all approaches to such gallery/roadway shall be fenced off before charging, stemming, or firing of shots at the face so as to prevent persons approaching the place where connection is likely to be established.

The projectiles, resulting from blasting, can travel even through long boreholes, and can cause accidents. In order to avert such accidents, the following precautions may be taken:

1) The boreholes, drilled for exploration or for tapping water, etc., shall be shown on the plan or tracing of the workings provided to the supervisory officials.
2) The approach to the end of a borehole shall be fenced off before blasting to prevent any person from coming in direct line of the borehole
3) No shothole shall be drilled within 0.6 m of any borehole.
4) The supervisory officials (assistant manager, etc, overman/foreman) shall, where applicable, personally brief the mining sirdar; mate and the shotfirer/blaster on the necessity of taking the precautions (2) and (3) above.

The precautions to be taken for the prevention of a 'blown through' shot, and the occurrence of the resultant fire or coal dust explosion, while extracting coal pillars by opencast method, have been discussed in Chapter VI.

Inspections after Blasting

After a shot has been fired, no person other than the shot-firer/blaster (or, in metalliferous mines, any other competent person holding a manager's/foreman's certificate appointed for the purpose by the manager) shall enter, or allow any other person to enter, the place until the atmosphere in the area is free from dust, smoke, or fumes. The shotfirer/blaster, or other competent person, shall, before any other person enters the place, make a careful examination, and with his assistants, if any, make the place safe (by dressing/scaling—for details please see chapter VI.) No other person shall enter the place, and where guards have been posted, they shall not be withdrawn, until the examination has been made and the place has been declared safe in all respects. In case of opencast workings, an all-clear signal shall be given, except in case of a misfire.

In metalliferous mines, after shots have been fired, all persons engaged in clearing mineral, rock or debris shall look for the unexploded cartridges and detonators. If such a cartridge and detonator is found, it shall be removed and shall, as soon as possible, be handed over to a blaster or other official.

Some accidents have occurred due to careless examination of the places of firing after shots have been fired. When (he-working places and the galleries in the vicinity are not properly examined and dressed after shotfiring, falls of roof and sides may occur resulting in casualties.

Although the zone, within which the workings may be examined and made secure after blasting at any working place, has not been stipulated in the Regulations, it is obviously desirable lo secure all places within such distance of the place of firing which are likely to be disturbed because of the shotfiring operations. In each case, therefore, the manager should determine the zone likely to be affected according to the local conditions of the roof and the nature of work.

Sometimes the shotfirers/blasters and their helpers are involved in the accidents due to falls of roof/sides in the course of connecting detonator leads to the shotfiring cable in between two rounds of blasting. In such cases, apparently the above statutory provisions are not applicable, for the shotfirer / blaster had not allowed anybody else to enter the face after the completion of the earlier round of firing. It is, however, clear that the conditions of roof and sides deteriorate due to blasting as well as the dislodgement of the supports, already set, by the blasting operations. So, when the shotfirer/blaster enters the place for a subsequent round, he exposes himself to danger unless he checks and makes the roof/sides secure before attempting to attach the detonator leads to the shotfiring cable in between the two rounds of blasting.

There can be no two opinions about the need for careful checking of roof/sides by the shotfirer/blaster while coming to the faces in between two rounds of shots. Hence the importance of periodical examination of working faces by the shotfirer/blaster in between two rounds of blasting can never be over-emphasised.

In the stone drifts of coal mines, and in metalliferous mines, after the shots have been fired, and before the commencement of drilling in any place, all loose rock shall be removed from the face, and the area lying within a distance of 1.2 m, in coal mines, and within a radius of 2 m in metalliferous mines, from the face, shall be thoroughly cleaned or washed down with water, and carefully examined for the presence of misfires or sockets.

In metalliferous mines, the vicarious responsibility of ensuring this provision has been assigned to the mining mate in charge of the place. Where any special conditions exist, the Chief Inspector may, by an order in writing, and subject to such conditions as he may specify therein, grant a relaxation from the above provisions.

No person should drill a shot hole in any place in a shaft/winze in the course of being sunk or deepened unless all loose material in the vicinity has been so cleared away that the position of any sockets or shot holes already in that place can be seen easily.

It is advisable that search for sockets is made in every big boulder, whether above- or below-ground, before attempting to break it. For the purpose, the boulders should be thoroughly cleaned or

washed down with water, and a careful examination made, by a competent person, for the presence of misfires/sockets.

If any socket is found, it shall be treated in the manner prescribe (for dealing with misfires (described below).

Ventilation of Workings after Blasting

The manager should determine and specify the waiting period] after blasting at any place belowground in any one round taking all precautions. This waiting period should be such that the proportion of j nitrous fumes and CO in the air at the end of such period at the working place does not exceed 5 ppm and 50 ppm respectively.

The manager should issue written instructions *so* as to ensure that no person enters, or remains at, the place of blasting during the waiting period, and in the return air from the place of blasting during the blasting operations and the waiting period. In metallifeous mines —

(i) where blasting is done in a raise/slope, proper precautions should be taken to prevent closing of the entrance to the working place, or interference with the effective circulation of air by the broken material produced by the blast; and

(ii) in case of a single-compartment raise or boxhole, where material from the blast may block the entrance, proper precautions should be taken to ensure adequate ventilation of the working place before workmen enter it.

Misfire

In coal mines, unless the shots are fired electrically, their number shall be counted by the shotfirer and another competent person authorised for the purpose. In metalliferous mines, unless the shots are fired electrically or by ignitor cord, their number shall be counted by blaster only. Since there may be a mistake in counting the number, it is suggested that, in metalliferous mines too, the number should be counted also by another competent person authorised for the purpose.

Unless it is certain that all the shots have been exploded, no person shall re-enter, or be permitted to re-enter, the place until 30 minutes after the firing of shots. Where shots are fired electrically, this interval may be reduced to not less than 5 minutes after the source of electricity has been disconnected from the cable.

In the event of a misfire, the entrance/entrances to the working place shall be fenced so as to prevent the inadvertent access; and no work other than that of locating or relieving the misfire shall be done therein until the misfire has been located and relieved. In opencast workings,, it shall be sufficient to mark the place of the misfire with a red flag.

In coal mines, a second charge shall not be placed in the misfired hole. In metalliferous mines, the tamping may be sludged out with the compressed air, or water under pressure, or removed by such other means as may be approved, in writing, by the Chief Inspector, and subject to such conditions as he may specify therein. The hole shall thereafter be re-primed and fired.

If the misfire contains a detonator, the leads or fuse thereof shall be attached by a string to the shotfiring cable or some distinctive marker like timber or some other large object. An iron wire, about 4 m long, may also be used. On his return to the face after the misfire the shotfirer/blaster should follow the marker and carefully remove the detonator attached to it, if it has not already exploded. He should take immediate steps to deliver it to the surface for its destruction.

Except where the misfire is due to a faulty cable, or a faulty connection, and the shot is fired as soon as practicable, after the defect is remedied, or, in metalliferous mines, the shot has been re-primed and fired, another shot (relieving shot) shall be fired in a relieving hole, which shall be so placed, and drilled in such a direction, that, at no point shall it be nearer than 30 cm from the misfired hole.

The relieving hole should not be closer than

(i) 3 m in case of large diameter blasting in opencast mines, and

(ii) 50 cm in case of sprung-holes.

The relieving hole shall be, so far as practicable, parallel, and of equal depth, to the misfired hole. It shall be drilled in the presence of the shotfirer/blaster, preferably the same person who fired the shot.

After a relieving shot has been fired, a careful search for cartridges and detonators, if any, shall be made in the presence of the shotfirer/blaster (or, in metalliferous mines, other competent person, holding manager's / foreman's certificate, appointed for the purpose, by the manager), amongst the material brought down by the shot. In case of workings belowground, if the cartridge or detonator is not recovered, the tubs, into which the material is loaded, shall be marked, and a further search made on the surface. As far as possible, the search for the detonators and cartridges, and the loading of any coal/ore/stone/debris, which may contain a detonator, shall be carried out without the aid of tools.

If a misfired hole is not dislodged by a relieving shot, the above procedure of drilling and blasting a relieving hole and searching for the explosives shall be repeated.

A misfired hole, which cannot be dealt with in the prescribed manner, shall be securely plugged with a wooden plug. No person, other than a shotfirer/blaster, an official, or a person authorised for the purpose, shall remove, or attempt to remove, the plug.

A sufficient number of wooden plugs should be made available in the vicinity of the site of blasting.

When a misfired shot is not found, or when a misfired shot is not relieved, the shotfirer/blaster shall, before leaving the mine, give the information of the failure to such shotfirer/blaster/official as may relieve or take over charge from him. He shall also record, in a bound paged book kept for the purpose, a report on every misfire, whether suspected, and whether the shothole has been relieved or not relieved. It shall be the responsibility of the relieving shotfirer/blaster/official also to sign the report and to record, in the Misfire Book, the action taken for relieving the misfired shothole.

The shot firer /blaster of the next shift shall locate and re-blast the misfired hole. However, if, after a thorough examination of the place where the misfire was reported to have occurred, he is satisfied that no misfire had actually occurred, he may permit drilling in the place.

A shot, being fired in a round, should be treated as a misfire if:

(i) by the individual tests on it, it is found to be faulty shot (misfire in a round by broken continuity), or

(ii) when the round is fired, it fails to explode (misfire in a round after firing).

In the event of any misfire in a round no person shall attempt to remove any part of the charge from the shothole.

In the event of a misfire in a round by broken continuity;

a. the stemming should be removed with water or with an approved device, an additional primer inserted in the shothole with proper stemming, and the round properly connected up, tested and fired; or

b. the lead of the detonator should be connected to the shotfiring cable or some other distinctive marker by a string, the other shots in the round (excluding, where delay detonators are used, any shot having a higher period of delay) shall be duly connected up, tested and fired: if the detonator has been dislodged, steps shall be taken for the recovery and disposal of the detonator and the charge; and any shots having a higher period of delay shall thereafter be connected up, tested and fired; if it has not been dislodged:

(i) if there were any shots having a higher period of delay, they shall be fired in turn, in ascending order of delay (in each delay, the shot nearest to the misfire being fired first), so however that, if it is dislodged before all shots have been fired, immediate steps shall be taken for the recovery and disposal of the detonator and the charge; and

(ii) in the other case, it shall be treated as a single-shot misfire.

In the event of a misfire in a round after firing, if there were more than one misfire, the shotfirer/blaster shall coned them in series, and fire them as a round, but if there was one misfire only, or if one or more misfires, fired in series as mentioned above fails or fail to explode, it shall be treated as a single-shot misfire.

When a misfire occurs with ANFO explosives, the following procedure may be adopted:

(a) an attempt should be made to wash out the stemming and explosive from the hole;

(b) if the attempt to wash out the hole is successful, the hole may be re-charged and fired;

(c) if the attempt to wash out the hole is unsuccessful, and electric shotfiring has been used, the hole shall be re-primed and an attempt made to explode the original charge;

(d) if the attempt to wash out the hole is unsuccessful, and fuse firing has been used, or if the re-firing as in (c) above, fails, the normal procedure of dealing with a misfire is adopted.

Following guidelines may be considered when working with misfired holes in opencast mines:

(a) Guard the area and admit only a select team of blasters to investigate the amount and extent of misfired explosives. If electric caps are involved, wait 30 minutes to allow the holes to cool off and stabilize before approaching the blast area.

(b) Remove any exposed and loose undetonated explosive material from the work area and inspect the product for any remaining unfired blasting caps.

(c) Removal of stemming must be done with air or water using plastic or rubber hose pipes.

(d) Complete physical removal of misfired explosives, when legal, can only be safely done using a water jet with rubber or plastic hose probes.

(e) Hang-fire conditions-are extremely hazardous and can result from explosive charges which burn (deflagrate) in the drill hole due to partial column separation or the heat effects from adjacent holes or misfired holes. Electric cap "arching" can also cause hang-fires and is possible with parallel circuits and power line firing systems. **Wait one hour** (60 minutes) before returning to any suspected hang-fire area. Be alert for the noxious and toxic fumes that are common with burning explosives.

(f) Wait 30 minute after firing the misfire before returning to the area.

Appendix—43 deals with the manner of relieving of large quantities of explosives in case of a sinking shaft.

PRECAUTIONS REGARDING EXPLOSIVES AND BLASTING

The general precautions to be observed-by the persons **employed in** the mines are described in Chapter IV.

Precautions against Fire

Precautions against fire, while using the liquid oxygen explosives, are described in detail in Appendix-34.

The Metalliferous Mines Regulations stipulate that:

(a) no person shall place, or throw, or cause or permit to be placed or thrown, any 'cheesa stick' or 'kai piece' on or near any timber, wooden structure, or other combustible material; and

(b) where explosives are used in blasting any timber, forming part of stulls, sets, and chutes, sufficient water shall be applied to the timber, both before and after firing a shot.

The best advice to the persons handling and transporting explosives is "never to fight explosives fires", but immediately evacuate the general area. Explosives are very unpredictable when heated to high temperatures, and the risk of detonation is too great to warrant any fire-fighting attempts. ;

Precautions against Dust

After blasting, the working places shall not be entered, unless sufficient time has elapsed for dust, smoke, and fumes to be cleared by a current of air, and the broken material, ore, or rock shall not be moved unless it has been thoroughly wetted with water.

Precautions in Gassy Mines

If, in a ventilating district, presence of inflammable gas is detected in any place, no shothole shall be charged, stemmed, or fired in that place, or in any other place situated on its return side, **till** such place has been cleared of gas and **declared safe.**

Immediately before charging a shothole, or a round of shotholes, and again before firing the shots, the shotfirer/blaster shall carefully test for inflammable gas at all places within a radius of 18 m in coal mines, and 20 m in metalliferous mines, of the place of firing. (This difference in radius in coal and metalliferous mines is not understandable.)

In particular, the shotfirer/blaster should test carefully for the inflammable gas at the mouth of the shothole/holes, roof cavities, and the space between laggings above supports.

In coal mines, no shothole shall be charged if any break is found therein, or if inflammable gas is found issuing there from. A plug of stemming may be placed at the back of every shothole before it is charged. This provides an added precaution against the danger arising from the presence of a-crack at the back of the hole, as such cracks are not easy to detect.

If, after charging a shothole, inflammable gas is found in any place within the prescribed radius, no shot shall be fired until the place has been cleared 01 gas and declared safe.

Where stone dust barriers are statutorily required, the shotfirer should not begin firing until he has satisfied himself that the same are in place and in good order.

No delay-action detonator shall be used, except with the previous permission, in writing, of the Chief Inspector, and subject to such conditions as he may specify therein. The manager may give the following details in his application for permission to the Inspectorate:

(i) the point at which the drivage is to commence, and the distance, direction, and inclination it is expected to be driven;

(ii) the direction and amount of the ventilation current, the percentage of CH_4 if any, and the necessary information with respect to the auxiliary ventilation for the proposed work;

(iii) location of ah[1] seams of coal adjacent to, and expected to penetrate, the drivage;

(iv) dimensions of the drivage to be driven;

(v) nature of strata to be penetrated;

(vi) maximum number of shots to be fired in a round, and the pattern of blasting;

(vii) the kind and amount of explosives to be used for each shothole; etc.

Permission may also be sought to take into the mine a larger amount of explosives per container and per explosives carrier.

The shotfiring cable should be not less than 90 m in length, and all persons should take refuge in a manhole, or be out of the direct line of the blast.

The gas detector readings should be taken with an approved gas detector, in addition to the flame safety lamp test, immediately before firing any shots. If the examination shows the presence of \V<\% or more of CH4 in the general body of air at the face, or the roadway leading to it, no shot should be fired. A report should also be made to the Regional Inspector forthwith.

The conductors in the shotfiring cable should be insulated for voltages up to 300 V.

The shotfiring and testing devices should be tested daily.

Appendix—44 describes the conditions for blasting with delay detonators in drifts.

Special attention should be paid to the practice of shotfiring to ensure that, where the shots are fired singly, the shotfirers/blasters check for gas before each shot is fired. The number of shots being fired by each shotfirer/blaster, in such a case, may also be reviewed. This number may be reduced if it is found, by actual observations, that the shotfirer/blaster cannot fire all the shots, already fixed, after taking all due precautions, laid down for blasting, in the II and III degree gassy seams.

The practice of blasting in the afternoon and night shifts is generally lax, and the shotfirers/ blasters tend to fire the shots without taking all the necessary precautions. The manager should (a) either himself check occasionally, or (b) specially depute an assistant manager to pay particular attention to ensure safe practice of blasting in the back-shifts in gassy mines.

The following precautions should be taken in all coal mines to guard against the danger of accumulation of CH_4:

1) No machine cut should be made unless the arrangements for wet cutting are functioning properly.
2) After making an undercut, drilling of shotholes should not be commenced until a competent person has found the place free from inflammable gas.
3) No shothole should be charged until a careful check has been made for the presence of cracks, etc.

In very highly gassy seams, and the seams liable to outbursts, the following precautions may be taken:

(i) Shots shall only be fired when there are no persons at all in the various roads and connections of the return airway of the working in question, upto and including the upcast shaft.

(ii) When the shot is fired from the surface, two multi-pole switches shall be placed on the line, one at the bottom landing, and the other at the surface. The two switches shall not be closed until the moment of firing, and the one underground shall be closed before the one on the surface. Precautions shall be taken to prevent the switches being closed prematurely or accidentally.

(iii) When the shot is fired from underground, the person firing the shot shall take shelter in the roads by which the intake air current reaches the working in question. The cage shall be kept at the bottom landing, which shall be connected to the surface by telephone. Further, rescue apparatus may be available within immediate reach of these rescue-trained shot-fires/blasters.

(iv) After each round of shots, at least one hour should elapse before anyone returns to the face.

(v) In any blind heading, no person should blast, or be permitted to blast, except between shifts.

Precautions against Vibrations and Airblast

Put in simply, vibration is earth movement, and airblast is noise from the blast.

When an explosive is detonated within a rock mass, the bulk of the energy is consumed by fragmentation, but some of the left-over energy is dissipated in the form of waves travelling outward from the blast through the ground, producing movements in rock that are within its elastic limits.

After the energy is passed, the rock recovers completely from any displacements to which it is subjected, and returns to its original position. However, these low energy elastic waves, as a bye-product of an explosion, can cause human discomfort and damage to surface structures in their paths.

Particle velocity is the best criterion for evaluating blast vibrations in terms of its potential to cause damage. The frequency of the ground vibrations is also important since it may induce sympathetic resonance in the receiving building structures, most of which have natural frequencies between 5 & 40 Hz.

The ground motion is calculated as the vector sum of the three components (transverse, longitudinal, and vertical) at the same instant, and the largest value of this is termed **peak particle** velocity— (ppv).

A sealed person will feel a vibration with a peak particle velocity of only ½ or even ¼ mm/sec, if it has a frequency in the range 5 to 20 cycles per second (Hertz). It has been shown that structural damage is unlikely to occur at levels below 100 mm/sec, and cracking of plaster below 25 mm/sec. The natural frequency of the human body is between 7 and 15 Hertz, depending on the build of the person. Vibrations as small as 5 to 10 mm/sec at a person's natural frequency will feel very uncomfortable, especially if they occur regularly and have durations of several seconds. Some of the recommended blast vibration limits in the different countries have been given in Table 7.3.

TABLE-7.3

RECOMMENDED SAFE BUST VIBRATION LIMITS

Country	p.p.v. mm / s	Frequency relation Hz	Type of structure	Remarks
Germany	3	10	Sensitive structure	
	3-8	10-50	Domestic houses	
	8-10	50-100	Industrial Structure	
U.K.	10	-	Densely built-up areas	In tunnel blasting
	25	-	Sparsely built-up areas	
	12	< 12	All buildings	in surface coal mining
U.S.A.	13	< 40	Older houses	
	19	< 40	Modern houses	
	50	≥ 40	All structures	
Czechoslovakia	10	-		
Switzerland	8	10-60	Sensitive structure	
	8-13	60-90		

Sweden	18	-		In sand, gravel, clay
	35	-		In slate, moraine, soft limestone
	70	-		in granite, hard limestone
Australia	2	-	Historical buildings and monuments	p.p.v. is the vector sum of three
	10	-	House & low-rise residential buildings	velocity components measured
	25	-	Commercial and industrial buildings or structures of reinforced concrete or steel con-struction	at the same instant

The Indian Standards IS: 6922, recommend a maximum ppv limit of 70 mm/s for soil and weathered and soft rocks, and 110 mm/s for hard rocks. However, for design purposes, ppv may be limited to 50 mm/s.

In UK, the Department of Environment (DOE) has published a Circular 'Minerals Planning Guidance: Applications, Permissions and Conditions', which prescribes general guidance on types of conditions which are desirable to control blast vibrations. They recommend regulations of the blast times, warnings, ground vibration and airblast limits, and other specific blasting restrictions as approapriate.

The limits can be based upon safe criteria to prevent damage to buildings and structures, or, more conservatively, upon the human tolerance to whole body vibrations. Stringent vibration limits can sometimes necessitate very small explosive charges (Low Maximum Instantaneous Charge — MIC), which can result in operational difficulties and a potential for the likelihood of accidents to increase. The use of small charges may also increase the vibration levels. Restrictive blasting times can also create problems when delays or misfires occur, and there is insufficient time to take corrective action to deal with them safely.

The application of limits can be undertaken in a number of ways ranging from the definition of an absolute limit, design limit, to a statistical limit with a defined percentage of occurrences that are allowed beyond it. Multiple limits, which vary at different facilities or times of the day or night, are some times applied. Separate limits are sometimes imposed for specific structures, such as impoundments or gas pipelines.

A significantly lower limit is sometimes specified for the night time in order to avoid sleep disturbance. The Mines (Explosives) Regulations, 1959, UK, specifically prohibit quarry blasting between one hour after sunset and one hour before sunrise.

About 94% of the blasting restrictions imposed by the MPA's include restrictions on the times and frequency of blasting, with at least 47% allowing it from Monday to Friday. The times during the week are usually in the range of 8 am to 6 pm, with one or two limited time periods in this range specified. At least 22% of time conditions allow Saturday blasting, but it is usually restricted to the range from 8 am to 1 pm. In several cases the number of blasts (frequency) is limited between 2 and 5 per week for surface mining and 3 times per day for underground mining.

The other conditions predominantly relate to notification/warning, monitoring requirements, and control of blasting practices.

In order to control vibrations, a blasting **schedule** should be prepared based on initial test blast investigations. The dimensions in blast geometry are burden, spacing, and depth. When properly designed, the required degree of fragmentation is obtained coupled with the maximum reduction in the environmental effects of the blasting vibrations. Regular and constant monitoring of blasting may also be carried out. Buildings likely to be affected due to-vibrations should be identified and protected by trenching or other appropriate measures to minimise vibration effects.

Airblast is that portion of the explosion energy which travels through the air and not through the earth as with seismic vibrations. Most complaints are caused by the airblast. Rattling of windows and shaking of dishes are mainly due to the low frequency airblast (concussion) that hits homes in the area. A specific limit of 120dBA has been imposed in UK. The control of vibrations commonly also controls the airblast. Sometimes blasting restrictions are applied to the operations by specifying that "no secondary blasting **shall** take place".

In the USA, airblast has to be controlled so that it does not exceed the maximum limits listed below at any building, etc., not belonging to the owner.

TABLE 7.4 AIRBLAST LIMITS

Lower frequency limit of measuring system Hz(±3dB)	*Max. level (dB)*
0.1 Hz—flat response	134 Peak
2 Hz or lower-flat response	133 peaks
6 Hz or lower-flat response	129 peaks

The management has to conduct periodic monitoring, at locations specified by Office of Surface Mining (OSM), to ensure compliance with the airblast standards.

If a shot is overloaded, with respect to the amount of rock burden to be broken, the result will be higher airblast and fly rock, but with somewhat lower vibration, due to the fact that the heavy explosive loading will easily shatter the rock burden and then cast the rock and the high temperature gases into the air, creating much noise and visible violence.

If a shot is under-loaded$_7$then explosive loading cannot efficiently break the rock burden and the explosive energy is contained in the rock formation and causes excessive seismic vibration with lower levels of airblast.

Correct blast design will reduce both vibrations and airblast, and give the best breakage also. The following checklist may aid the blaster in trouble-shooting for airblast problems:

(a) The sharp report of the high energy detonating cord is the culprit in many bad blasts. All exposed cord should be covered with minimum 150 mm of dirt, or the initiation system should be changed,

(b) Inversion weather, with its attendant smog/fog, will greatly aggravate the airblast problem. Inversion "bends" the sound waves back toward the earth, causing louder noise in the ears of the neighbours. Blasting should be avoided on such days.

(c) When the blast design has a large number of 'O' delays, the effect on airblast is detrimental, these "openers" tending to "spike" the airblast giving a sharp initial sound, quite noticeable to the casual listener. The delay system may have to be re-designed.

(d) Judicious decking of the charge effectively controls the problem.

(e) The trend toward larger drills and larger loading and hauling equipment is detrimental to the problem, and proper loading limits are important.

(f) Wind direction is important. Airblast will travel downwind and will cause increased complaints from the neighbours in that direction from the blast.

Precautions against Lightning

In considering the dangers of lightning, it is necessary to distinguish between —

(i) direct stroke of lightning, accompanied by a considerable heat release and mechanical effect that may cause fires and lead to detonation of explosives, and

(ii) secondary action of the lightning discharges, that strike at a point some distance away from the structure and may cause sparking through electro-static and electro-magnetic induction, thus leading to the explosion of the material sensitive to sparks.

Any stroke of lightning also presents a danger of electrocution to any person standing close to a lightning conductor.

Protection against a direct stroke of lightning is based on the property of the lightning to strike the highest object having the least electrical resistance to earth.

For the above purpose, lightning rods are provided adjacent to the magazine, etc., raised higher than the magazine roof so that they receive the strokes of lightning and safely drain the discharge current to earth.

Protection from indirect action of lightning discharges is ensured by reliable earthing of the metallic elements of the structure (roofing steel, piping, etc.) or by providing the structure with metal screening in the form of a wire mesh laid over the roof covering (if it is not metallic).

The lightning discharges in opencast mines may also cause premature firing of the electric detonating devices. Therefore, during a thunderstorm, no blasting operation, including charging, should be carried out. If, in case of electrical shot-firing, the firing circuit has been set up before the thunderstorm came on, the blast should be fired off immediately, or the branch lines should be disconnected from the trunk line, and thoroughly insulated with tape. At the same time, all persons must be withdrawn from the danger zone.

In underground workings also, specially in drift mines and shallow mines, there is a hazard of premature discharge of detonators, due to lightning currents. The high potential differences, caused by the energy liberated by lightning, occur at discontinuities in the lines of current in the ground, *e.g.*, at the faces of headings. These are precisely the points where the detonators are generally used. The low energy required to set off these detonators, and the possibility of an earth fault m the shotfiring line, constitute the conditions which favour the premature discharge of the detonators by reason of the local potential differences. The necessary energy can also be induced into the shotfiring lines by the intermediary of the metallic structures which are conducting the current caused by the lightning stroke.

In the event of a lightning strike on the surface close to a working area, lightning currents could penetrate into this area through direct conduction in the intervening soil and rock media. Any large conductive structures underground (e.g., conveyor units or power cables), as well as the mine excavations, cause local distortion of the current distribution in the underground strata. Local disturbances, such as boreholes, dykes, faults, etc., could either increase the penetration depth of the lightning current, or locally modify the distribution.

Lightning surges could also enter the mine through direct strikes to the structures at a shaft entrance, or at ventilation shafts. The local injection of the lightning current into the earth via the earth electrodes would cause a potential rise of these structures in relation to earth, thus propagating a voltage surge down into the mine via power cables, armouring, water pipes, conveyors, etc. The cables or equipment are often operated in dose proximity lo the exploders and detonator circuits, thereby enhancing the possibility of inducing disturbance currents therein.

Protection of Shot firing Lines in Underground Workings

1. For gassy mines, or non-gassy mines with a depth of less than 100 m, very careful insulation of shotfiring lines, detonator wires, and all connections, with respect to the ground and the metallic masses, should be ensured.
2. Use of detonators of very low sensitivity *(i.e.*, high intensity) is recommended.

The above solution, however, is severely limited in coal mines and gassy metalliferous mines, because of the risk that high energy exploders could ignite methane. Also, sometimes a large number of detonators has to be fired simultaneously (typically 30-40). The amount of energy available per detonator is limited, and thus very high energy detonators seem impractical.

Some special detonators *(e.g.*, Type 0 and Type 1 Carrick Short Period Delay—SPD)are provided with electrostatic protection through an insulation sleeve placed over the fuse head and coordinated spark gap which ensures that any electrical discharges (sparks) take place between the detonator tube and detonator wires, rather than through the fuse head itself.

A range of "torroid" electric detonators has been recently "permitted" in the British coal mines. Each detonator is coupled, via its own transformer or torroid, to a special high frequency a.c. exploder. The torroid, being frequency selective, can be activated only by a high frequency signal in the range of 15-30 kHz.

The "torroid" electric detonators have the additional advantage that, should lightning current enter one detonator, this current will not necessarily affect other detonators in the same circuit,

3. All metallic conductive elements entering the underground should be connected to a low impedance earth electrode at the mine entrance. This will minimise the injection of surge currents into the mine in the event of direct strikes in close proximity to such conductive elements.
4. AH conductive metallic services, such as cable armouring, water pipes, conveyors, and rails, should be cross-bonded at regular intervals, not exceeding 600 m.
5. Removal of all earthed metal (*i.e.*, rails, cable armourings, water pipes, etc.) from the vicinity of workings (preferably 100 m or more away) would be effective, specially just before the onset of a storm.
6. The use of an efficient lightning warning system on an area basis is recommended. For the purpose a pre-programmed decision-making electronic module has been developed, which monitors variations in flashing rate within each of the three effective ranges, *viz.*, 5,10,or 20 km, and translates them into "risk factors" which in turn trigger alarm signals.

The alarm signal takes the form of a parallel system of flashing lights and audible tones, one for each of the three alarm levels, each representing an increasing degree of hazard. As the lightning hazard increases, the light progresses from a green "alert", through an amber "warning", to a red "hazard" condition, with both the flashing rates and audible tone levels increasing in frequency, as an indication of a developing lightning hazard.

7. "STORM WARNING" notices (painted in red) for opencast mines, shallow mines, and drift mines are very effective, but should be considered only as an additional precaution, supplemented by the protective measures already described.

ACCIDENTS FROM EXPLOSIVES

The accidents from explosives may be due to the following causes;

1. Flying material from the blast — specially in opencast mines. (Fly rock Hazard)

The major factors are-

(i) staying too long at the face when fuse-blasting;
(ii) unguarded shots, improper warning methods, and not taking proper shelter in spite of being warned;
(iii) not posting guards at all points of entry into the danger zone;
(iv) not warning all concerned within the danger zone;
(v) not muffling the shots when statutorily required;
(vi) returning too soon after the blast;
(vii) failure of the structures to provide adequate shelter within the danger zone; and

(viii) short fusing.

On the surface, within the danger zone, people often take shelter under a tree or behind big boulders. Many a times a proper shelter is not provided.

In underground workings also, accidents have occurred when persons have unknowingly strayed into the danger zone. In a few cases the persons, engaged in blasting, have themselves been injured as they did not take proper shelter. They were either in the direct line of the blast, or they did not take proper shelter after two right angle bends.

The largest number of accidents has occurred due to the persons returning too soon after blasting, either to charge and fire more shots, or to start loading.

In case of fuse blasting, there may be too many shotholes for one person to light within the safe time, or, if there are two persons lighting the fuse, there may sometimes be a lack of coordination between them. In one instance, the lamp of one person got extinguished and he could not get out. Sometimes a person, lighting fuse, slipped in watery places, and as a result took more time than usual to light the shots. Again, in watery places, there may be difficulty in lighting the fuse properly and quickly.

Quite often there is a mistake in counting the number of shots that have gone off, and persons do not wait long enough before going in.

Establishing a safe radius from fly rock might save damage to the equipment, but the only complete safeguard for the personnel is shelter *(e.g.*, special fly rock shelter),

2. Premature detonation of shots. The usual factors producing accidents of this type are-

(i) detonation of charge while loading of the shothole due to the impact of the tamping rod;

(ii) in electrical shotfiring,

a. by making inadvertent connection to the electrically charged lines,
b. by the application of current while the men are still at the face,
c. by accidental contact of the detonator leads with the charged conductors,
d. by stray currents, etc.; and

(iii) short fusing.

3. Electrical blasting. Such accidents may occur due to

(a) poorly installed blasting circuits,
(b) insufficient or too high current,
(c) poor connections at the face,
(d) use of wrong delays or wrong blasting sequence,
(e) overloading of the shotfiring devices, and
(f) accidental contact with charged lines, charged surfaces, and stray currents.

4. Missed holes. This cause is more common in underground, than in opencast mines. Majority of such accidents is due to the dangerous practice of drilling hi a socket or too near a misfired hole.

5. Asphyxiation from noxious gases. Asphyxiation from the fumes of the explosives (mostly nitrous fumes) in underground mines occurs when persons return too soon after blasting, or, through some mishap or injury, they are overcome by the fumes, before reaching a place with good ventilation.

The effect of inhalation of the nitrous fumes on the workers does not appear to have received adequate attention. In many cases, death was apparently taken to be due to broncho-pneumonia, whereas, in fact, it was due to the broncho-spasm due to inhalation of the noxious nitrous fumes, Had the patients been treated for noxious fumes, by the provision of oxygen, etc., it is likely that their lives could have been saved.

The effect of inhalation of nitrous fumes on different individuals maybe different, depending upon

(i) the concentration of the noxious fumes in the general body of air,
(ii) degree of exposure, and
(iii) the constitution of the individual.

The mine managements should bring the above occupational hazard to the attention of particularly the mine hospital doctors, emphasising the dire necessity of treating such patients MORE for inhalation of the nitrous fumes than for bronchitis.

The asphyxiation can be minimised to a great extent by using suitable explosives, which emit small amounts of nitrous fumes after blasting, and better ventilation.

The presence of fumes is most likely when using ANFO products that have lost oil content due to prolonged exposure to high storage temperatures. When oil content in ANFO falls below the oxygen balance of 6% by weight, a fume hazard is possible. Water in the drill hole with ANFO, or undersized or underweight primers can also result in such fumes.

In order to guard against accidents due to exposure to blasting fumes on the return side of underground workings, the following precautions may be taken:

(a) No plaster shooting with ANFO should be done belowground.
(b) As already discussed earlier in the Chapter, the manager should determine and specify the waiting period after blasting at any place belowground. The determination may be made by having at least two blasts of usual strength in each working district, and determining peak concentration of the nitrous fumes, and the time taken for this concentration to fall to the 5 ppm level.

In case peak concentration is more than 50 ppm, and 5 ppm level is not reached within 5 minutes:

(i) before engaging persons after blasting, the determination of nitrous fumes by a supervisor should be made mandatory like that for CH_4 and CO;

(ii) a detailed exercise should be taken up, to determine the amount of nitrous fumes produced per kg of explosives. Then the weight of explosives to give 5 ppm concentration within 5 minutes can be calculated. Only this quantity of explosives should be used.

Weight of explosives per round could be increased by increasing the waiting period.

(c) During blasting operations —

(i) the blaster may position himself on the intake side of the blasting site;

(ii) before blasting, all persons from the places situated on the return side of the place of basting may also be withdrawn;

(iii) where blasting is to be carried out at a number of places in one district, blasting may be done first at the place situated on the return-most point and progressively towards the intake side; during the complete operation, persons may be withdrawn and may remain so upto the waiting period as decided by the manager,

(iv) where heavy blasts are required, it is ideal to have an exclusive shift (usually the night shift) only for blasting.

(d) All bronchitis and pneumonia deaths of underground workers may be closely monitored, and thoroughly investigated if there is evidence that the deceased, within 3 weeks of his death, was in underground employment where he was likely to be exposed to blasting fumes.

(e) While treating bronchitis and pneumonia cases of the mining areas, the medical officers concerned may also take into account the history of the patients, particularly the designation, nature of work, and whether the patient was exposed to blasting fumes before falling sick.

(f) The mandatory 5-year medical examination of underground workers may also be utilised to detect disorders which may potentiate the action of nitrous fumes, such as chronic bronchitis, allergic diseases of respiratory tract, pulmonary emphysema and pulmonary sclerosis.

6. Handling, storage, transport, and destruction of explosives. The storage of explosives has much deeper relation to safety in their use than is commonly realised. Improper storage of the explosives and detonators leads directly to misfires and incomplete detonation and incomplete burning of charges, giving off a greater percentage of noxious gases.

The above cause can be avoided if the Explosives Rules and the Regulations about the storage, transport and destruction are strictly followed.

7. Sudden *break-through* due to insufficient parting (discussed in detail earlier in the Chapter).
8. Sparks and flame from explosives igniting any methane, if present.
9. Dislodgement of supports after a blast in the underground workings,
10. Hang fires in defective fuses and subsequent sudden blast.
11. Presence of high electrostatic charges during storms and heavy clouds in opencast mines.

Most of the accidents from explosives occur, not due to the faulty nature of the explosives, but due to the ignorance and carelessness of the shotfirer/blaster and his assistants, and therefore, proper training of the personnel who use them is essential.

Prevention of Accidents from Explosives

The following three important points need careful attention with a view to prevent accidents from explosives:

(a) Before any shot is fired, all concerned, including the shotfirer/blaster and his assistants, must take proper and adequate shelter.

(b) The shotfirer/blaster must not return too soon after blasting, and the roof and sides must be made safe, by dressing and supporting, before any person is allowed to return to the face after blasting.

(c) Adequate precautions must be taken to prevent a 'blow through' shot (already discussed earlier in the Chapter), specially when there may be a gas-filled caved goaf in the vicinity.

Other points, which may help in preventing the accidents, are:

1. Explosives should be stored in dry, well ventilated magazines. If, for example, the fuse is stored in a damp place, it is likely to absorb enough moisture to delay, or even prevent, its burning. Even if it is dried before use, its normal burning speed may be slowed. Worse still, burning may become irregular which would tend to increase the chances of misfires and spoil the blasting rounds due to the charges exploding out of the intended sequence. The latter condition may result in the cutting off of the shotholes, leaving unexploded explosives at their bottom and possibly in muck pile.

   The ideal storage temperature may be considered as 8 C-30 C for surface magazines, and 8 C-40 C for underground magazines.

2. If the explosive is contaminated with dirt or grit, its sensitiveness to deterioration increases greatly. Hence, in the magazines, overshoes, etc., should be worn and the floor kept clean so

that, if by any chance the explosive gets to the floor, it is not mixed with grit or carried out by the boots of the magazine in charge / explosives carriers.

3. The spilled ANFO explosive and cement may together form ammonia. If the gas becomes annoying, it shall be removed.
4. On deterioration, the explosives will pick up moisture, and a liquid will be formed at the ends of the cartridges, staining the explosives cases or the magazine floor. This liquid may also contain some nitro-glycerine, and it should be treated as dangerous. For this reason the explosives cases should never be slid across each other, but should be lifted and placed in position. Where exudation occurs, the liquid should be absorbed by sawdust and any stained surfaces cleaned up with methylated spirit, followed by washing with hot water.
5. The high explosives and detonators should be handled with care to avoid shock and friction; must be protected from Fame, sparks or extreme heat, and kept dry from moisture.
6. The explosives should remain in the workings no longer than absolutely necessary. The explosives, detonators, or capped fuses, left over at the end of the shift, should be returned to the magazine. Any explosives, left lying around, are likely to absorb moisture and become unreliable.
7. The detonator leads, if not short-circuited, should be kept away from contact with stray electric currents and the electrically charged surfaces. In opencast mines and shallow mines, specially drift mines, blasting should not be carried out **during** thunderstorms **and heavy** clouds.
8. Before blasting, the site should be examined for overhangs, supports and CH_4 (in underground mines), etc.
9. Only one case/canister of explosives should be opened at a time. The cartridges should always be inserted into the shotholes one at a time. The wrappings from the cartridges should never be removed.
10. The shotholes should be thoroughly cleaned out before charging them. If any cuttings are trapped between the cartridges, the unprimed cartridges may not detonate completely.
11. The pricker should make a hole **of sufficient** depth in the centre of the priming cartridge so that the full length of the detonator is embedded in it. Also, sand grains should not remain either on the pricker or the cartridges, otherwise frictional sparks may be caused.
12. If a cartridge becomes jammed in a shothole, it should not be dislodged with a drill rod or any other metal rod. If it proves impossible to relieve a jammed cartridge with a wooden rod, the hole may be loaded to allow the normal amount of stemming. If possible, **slightly** heavier **charges** may be used in the neighbouring holes.
13. Any kinks should be avoided in the detonator leads.
14. During charging and stemming, care should be taken to avoid damage to the covering of the detonator leads, detonating fuse, and safety fuse. Damaged insulation is a possible cause pf misfires.
15. In gassy coal mines, a plug of stemming may be placed at the back of every shothole before it is charged. This provides an added precaution against the danger arising out of the presence of a crack at the back of the hole, as such a crack would be very difficult to detect.
16. In electric shot firing —
    (a) The leading wires should be long enough to enable the shots to be connected up with as few joints as possible. Each additional **joint is a** potential **source of current leakage.**
    (b) In damp conditions, all connections should be covered with insulating tape or joint insulators.
    (c) The shot firing cable should never be dragged along the ground, as this would damage the insulation.
17. A careful search should be made for misfires, cut-off holes, and any explosives left in sockets. No subsequent drilling should be done in or near a socket.