

C O N T E N T S

	PAGE
CHAPTER I -- GENERAL	
1 Definition	1
2 Classification of explosives	1
3 Explosion	1
4 Detonation	2
CHAPTER II -- CLASS I: PROPELLANTS	
5 Burning of a propellant	3
6 Properties of the ideal propellant	6
7 Modern propellants	7
8 Propellant manufacture	8
9 Table of propellants	9
10 Cordites	11
11 Types of cordite	13
12 Nitrocellulose cannon powders	15
13 Mortar and S.A.A. propellants (other than cordites)	16
14 Methods of indicating shape and size of propellant	17
15 Propellant code letters	18
CHAPTER III -- CLASS II: HIGH EXPLOSIVES	
16 Definition	18
17 Properties of the ideal high explosive	18
18 Initiators	19
19 Disruptive initiators	20
20 Igniferous initiators	21
21 Intermediaries	22
22 Bursting charges	24
23 Miscellaneous high explosives	28
CHAPTER IV--CLASS III: MISCELLANEOUS EXPLOSIVES -- GUNPOWDER, PYROTECHNIC AND OTHER COMPOSITIONS, WHICH CANNOT USUALLY BE DETONATED	
24 Gunpowder	29
25 Sulphurless gunpowder	30
26 Time-fuze compositions	31
27 Pyrotechnic compositions	32
28 Illuminating compositions	32
29 Signal compositions	32
30 Incendiary compositions	33
31 Smoke producers	33
32 Priming compositions	35
33 Tracing compositions	35
INDEX	37

C H A P T E R I

GENERAL

1. DEFINITION.

An explosive is a substance which, on being suitably initiated, is capable of exerting a sudden and intense pressure on its surroundings.

2. CLASSIFICATION OF EXPLOSIVES.

Explosives may be grouped in various ways: --

- (a) THE EXPLOSIVES ACT, 1875, which embodies the Home Office Regulations for the licensing and manufacture of explosives and for the protection of the public and workers from accidents. It subdivides explosives into seven classes in relation to their handling, storage and transport.
- (b) MAGAZINE REGULATIONS, which adapt the relevant principles of the Home Office Regulations to service conditions. Explosives and ammunition are classified into thirteen groups for storage purposes, according to the relative fire risks and risks of sympathetic detonation of the various types of explosive and ammunition.
- (c) CHEMICAL CLASSIFICATION, which groups explosives into two classes: --
 - Explosive chemical compounds;
 - Explosive mixtures.
- (d) SERVICE CLASSIFICATION, which groups explosives according to the uses to which the explosives are put. They are three main groups: --
 - (i) PROPELLANTS. These normally function at explosive rates only.
 - (ii) HIGH EXPLOSIVES. These are materials which can be detonated and are normally used to produce a detonation.
 - For convenience they are arranged in sub-groups: --
 - Initiators.
 - Intermediaries.
 - Bursting charges.
 - Disruptives used in mining and demolition.
 - (iii) MISCELLANEOUS. This group comprises gunpowder; and the various pyrotechnic and other compositions which cannot usually be detonated.

The essential differences between groups (i) and (ii) above depend on the differences between the phenomena of explosion and detonation.

3. EXPLOSION. [British textbook of Explosives www.ssrichardmontgomery.com](http://www.ssrichardmontgomery.com)

Explosion may be regarded as a rapid combustion, which occurs in the absence of atmospheric oxygen, and is characterized by the evolution of heat, flash, and sound, and by the rapid decomposition of the substance, forming large quantities of gas. For example, in the 0.303-inch cartridge, the volume of cordite is about 0.11 cu. ins. Whereas the volume of gases formed at normal temperature and pressure is 136 cu. ins., at the explosion temperature of 2,700 degrees centigrade this volume is increased to approximately 1,400 cu. ins. at atmospheric pressure, which gives rise to a chamber pressure in the rifle of about 19 tons per sq. in.

The velocity of propagation of an explosion may be between 0.3 and 300 metres per second and depends to a great extent on the surrounding temperature and pressure. When an explosive such as cordite is ignited it burns from the surface inwards in parallel layers with a velocity which depends on the pressure, but which, even under several thousand atmospheres, never exceeds a few

metres per second. The ignition is communicated from layer to layer by the heat generated.

Temperature also plays a big part. The charge temperature of a gun cartridge affects the rate of explosion and corrections have to be applied in the range tables for this factor. The hotter the explosive is before ignition, the less heat is required to ignite it and the less time it takes to burn from layer to layer.

4. DETONATION.

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This must not be regarded as a higher rate of explosion. What happens is an almost instantaneous disruption of the molecule, followed usually by a recombination of the elements in a different way. In a substance such as nitroglycerine there is metastable molecular equilibrium. The nitroglycerine on detonation breaks down into its components, which re-combine to give stable compounds with a credit balance of heat.

A detonation travels through the material as a wave and not as a flash. It is essentially a dynamic effect, which produces molecular disintegration with the emission of energy. Some form of stress is necessary to initiate the change, and in each case there is a critical value of this stress which must be reached before the detonation occurs. When a flame is applied to mercury fulminate, at first it burns with a velocity of about 10 metres per second only, but the reaction becomes more and more rapid, and within an interval of time probably not more than 1/3,000 sec., detonation sets in. Certain azides develop their full effect even when not confined, but mercury fulminate requires a small degree of confinement, such as that given by the thin copper shell of a detonator. In these cases, it would appear that the initial blow needed to cause detonation is provided by the explosion of the first part of the material. This will not occur unless the acceleration of burning is sufficiently great, and it is only in the initiator class that such rapid acceleration can be anticipated with any degree of certainty. Even here the rates vary considerably. For instance, mercury fulminate reaches detonation less rapidly than silver fulminate, while silver azide reaches detonation more rapidly than silver fulminate.

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EFFECT OF AN AIR GAP. -- If an air gap is introduced in a detonation system the detonation wave, in jumping the gap, loses energy, and the amplitude of the wave falls off in proportion to the size of the gap. If the falling off is great enough, the detonation wave may fade out altogether; and even if the gap is so small that the wave passes over, it may have lost so much of its energy that complete detonation of the remainder of the explosive will not occur, and a 'partial detonation' or "explosion only" will result.

It is therefore very important to avoid air gaps in a detonation system and to maintain the stress supplied by the initial detonation above the necessary critical value, since detonation breaks down when the amplitude of the wave falls below this critical value. Air gaps are unimportant in an explosion, as the flash crosses the gap easily. Slight gaps between the components of initiating systems are unavoidable, and therefore initiating and intermediary fillings should have an ample margin of power.

VELOCITY OF DETONATION -- The velocity of detonation varies from 3,000 metres/sec. to over 8,000 metres/sec. with service high explosives. Rates for some of the commoner H.E.s are given below: --

Fulminate of mercury	4,500 metres/sec.
Lead azide	4,500 " "
Ammonium nitrate	2,500 " "
Amatol 80/20	4,620 " "
Guncotton, wet	5,500 " "
T.N.T.	6,950 " "
Picric Acid	7,250 " "
Guncotton, dry	7,300 " "
C.E.	7,520 " "
Nitroglycerine	7,500-8,000 metres/sec.

The velocity of detonation is not greatly affected by external conditions unless these are extreme. Air temperature has little or no effect. Increase of confinement has a slight effect only, provided that the confinement is sufficient to ensure complete detonation. In very insensitive explosives, however, the propagation of detonation may not be maintained under light confinement.

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The chief factor affecting velocity of detonation is the density of the explosive. Up to a maximum limit increase in density means increase in velocity.

e.g., Picric acid. Density 1.3, rate 5,980 metres/sec.

" 1.5, " 7,110 " "

" 1.6, " 7,250 " "

This is the limit for picric acid and further increase in density will not affect the rate of detonation.

It should be noted that increase in density produces also a decrease in sensitivity, e.g., T.N.T. crystals are used as an intermediary, while cast T.N.T. is used as a bursting charge.

It has been found that the effect of detonation is most violent in the direction in which the detonating wave is traveling. It follows therefore that both in the design and use of detonators this point should be borne in mind. The most effective part of a detonator is the closed end.

THE "HOLLOW CHARGE" PRINCIPLE. -- It has been known for many years that a cavity, preferably in the shape of a cone or paraboloid, at the end of a charge of high explosive remote from the detonator, tends to concentrate the main detonative effect in that direction. This fact has been utilized in the design of certain types of ammunition in order to obtain greatly increased penetration of armourplate.

CHAPTER II

CLASS I -- PROPELLANTS

5. BURNING OF A PROPELLANT, British textbook of Explosives www.ssrichardmontgomery.com

1. The main characteristics of the burning of a propellant are: --

- (a) burning is purely on the surface and normal to the surface;
- (b) the rate of burning increases with pressure on the surface. It is practically proportional to pressure, though it departs from linearity at high pressures.

The efficiency of the gun as a heat engine for a given nature and size of propellant is determined by the calorific value of the propellant and the specific rate of burning of the propellant (ins. per sec./tons per sq. in.). Two propellants of the same calorific value may have widely different rates of burning.

2. As the propellant starts to burn, gas is generated and the pressure in the chamber of the gun rises until the projectile starts to move. After this, pressure continues to rise until the rate at which the volume behind the projectile increases counterbalances the rise of pressure caused by the evolution of gas. At this stage we get the point of maximum pressure, after which the pressure falls off slowly until all the propellant has been consumed. The pressure will then fall more rapidly because of expansion and heat losses. (See Fig. 1)

3. It should be noticed that the greatest acceleration of the projectile will occur at the point of maximum pressure. This does not mean that the

projectile ceases to accelerate at this position. The velocity will continue to increase until the pressure of the gases has ceased to act on the base of the projectile, i.e., shortly after it has left the muzzle of the gun.

4. Notice, too, that the point of maximum pressure is reached very quickly. The maximum acceleration of the projectile results in very great "set-back" effect on the projectile. This effect is important in the design of shells and fuzes.

5. ALL BURNT POSITION. -- The position reached in the bore of the gun by the projectile at the moment when all the propellant charge has been consumed is known as the "all-burnt" point. British textbook of Explosives www.ssrichardmontgomery.com

6. The gun is capable of producing its maximum muzzle velocity when the optimum powder is used and this usually means a large size of propellant, large charge weight, a forward position of "all-burnt," and higher muzzle pressures. The propellant, however, is used most efficiently when "all-burnt" is well back and there is a large adiabatic expansion. If the "all-burnt" point is too near the muzzle, irregular ballistics are caused. The "all-burnt" position is therefore arranged to be fairly well back in the bore.

7. It should be noted that if the "all-burnt" position is brought outside the bore, we not only waste propellant, i.e., pressure, but also increase the risk of burning particles igniting material near the gun. Further, irregular ballistics are caused by the loss of control over the amount of propellant consumed while the projectile is in the bore of the gun.

8. CONTROLLABILITY. -- One of the essential properties of a propellant is that it should be controllable. That is to say, the total time of burning should be capable of alteration in order to keep the "all-burnt" point in the desired place. Provision has to be made, among other points, for different calibres, various lengths of bore and more than one charge for the same equipment.

Control can be achieved by altering the shapes and sizes of the propellants. One of the great advantages of the cordites is that they can be made in various shapes and forms, e.g., sticks, tubes.

9. The following list gives the general effects of the various shapes, when made up into a charge. The effects do not refer to one stick only but to the comparative effects of the different shapes when made up into complete charges.

- (a) POWDER FORM.--Initially very large surface area, followed by a rapid decrease in surface during burning. This results in quick rise in pressure, but a rapid falling off, i.e., not well sustained. Suitable for mortars and small arms.
- (b) CORD FORM.-- Surface area and therefore time to "all-burnt" will depend on the diameter of the cord. During burning the diameter and hence the surface area will decrease, but less rapidly than with powder, and the pressure is therefore better sustained. Large sticks are sometimes used with catapults for launching aircraft, where a very rapid pressure rise is undesirable. Cord is commonly used for full charges in most guns except those of very small calibre.
- (c) TUBE FORM.--The surface area during burning remains practically constant and therefore the pressure is better sustained than with cord. Large tubes are used with catapults for launching aircraft and with rocket weapons, etc. Small tubes are commonly used with howitzer and reduced charges. They are also used for the full charges of certain very small calibre guns.
- (d) MULTI-TUBE FORM.--The surface area increases during burning. Pressure is therefore still better sustained. Used with nitrocellulose cannon powders, which are cooler burning and rather less powerful than ordinary cordites.

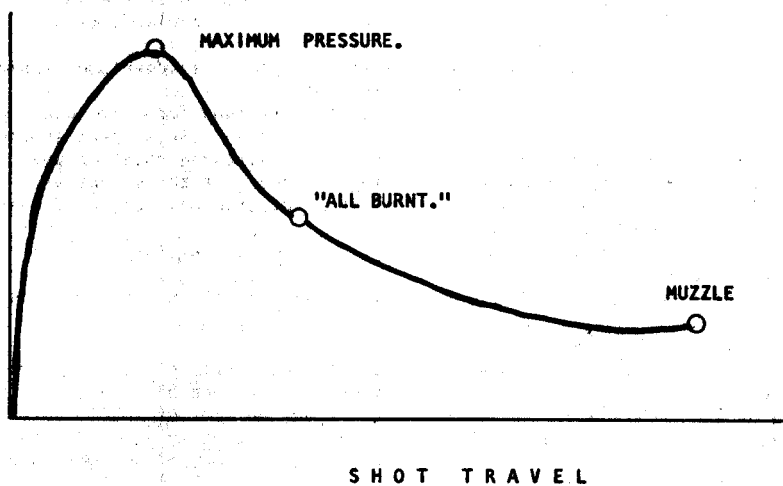


Fig. 1

- (e) **SLOTTED TUBE FORM.**--Behaves ballistically similarly to ordinary tube, i.e., produces an approximately constant burning surface. With ordinary tube, as the inside burns, an excessive pressure is developed in the tube itself, causing irregular burning. Further, if the physical strength of the propellant is low, the internal pressure may burst the tube and cause a sudden rise in the burning surface, with irregularities of pressure and muzzle velocity. Slotted tube overcomes these defects in that the gases developed inside the tube can escape freely through the slot.
- (f) **STRIP OR RIBBON FORM.**--Ballistically similar to tube form. It does not pack so satisfactorily inside a rigid cartridge and the surface should be rough to a certain extent to avoid the strips sticking together and thereby completely altering the burning surface. If the strips are roughened it is almost impossible to get a satisfactory method of measurement through routine inspection.
- (g) **FLAKE FORM.**--Used for mortars, and is very similar ballistically to powder form. British textbook of Explosives www.ssrichardmontgomery.com
Graphited to increase slip between flakes and to act as waterproofing.

6. PROPERTIES OF THE IDEAL PROPELLANT.

1. A propellant is an explosive which, by its regularity of burning, produces moderately high and sustained gas pressure in the bore of a gun, thereby imparting an acceleration to the projectile. It may be made of ingredients some or all of which are capable of being detonated, but it is essential that there should be no tendency to detonate on the part of a propellant when used under the conditions for which it is intended.

2. The following are the chief properties which an ideal propellant should possess:--

- (a) **ITS RATE OF BURNING SHOULD BE REGULAR AND THE TIME TO "ALL-BURN'T" READILY CONTROLLABLE.**

This regularity ensures ballistic regularity, and a steady development of pressure. The propellant must: (i) be uniform in composition; (ii) not break up, giving a sudden change in surface area during combustion; (iii) burn at the surface only and at a regular rate from layer to layer. If these three conditions are satisfied, the rate of pressure development depends upon the ratio:--

$$\frac{\text{Surface area of the propellant}}{\text{Volume of propellant}}$$

which can be adjusted by varying the size and shape of the propellant to give the rate of burning required.

- (b) **IT SHOULD BE SMOKELESS.**

Smoke is mainly caused by solid products of combustion. It is undesirable from the tactical point of view as it discloses the gun position; and also it may mask the target temporarily and therefore make gun-laying more difficult and slow up the rate of fire.

Smoke and flash are to a great extent interconnected problems, and it can be taken roughly that one can diminish the flash at the cost of increasing the smoke, and vice versa.

- (c) **IT SHOULD LEAVE NO SOLID RESIDUE.**

Solid residue may cause fouling of the bore and increased erosion. Furthermore, smouldering fragments remaining in the bore of a gun may cause pre-ignition of the following charge.

- (d) **IT SHOULD BE FLASHLESS.** British textbook of Explosives www.ssrichardmontgomery.com

Muzzle flash and back flash are both caused by the ignition of the combustible gases formed by the explosion on contact with the air. The former is bad tactically, especially at night, while the latter may

be a source of danger to the gun detachment or to cartridges and other inflammable material in the vicinity of the breech. Unfortunately, most flash-reducing substances tend to increase the smoke.

(e) IT SHOULD BE FREE FROM POISONOUS FUMES.

Poisonous fumes are particularly dangerous to the gun detachments in turrets and tanks. Most propellants produce carbon monoxide on firing.

(f) IT SHOULD GIVE AS LITTLE EROSION AS POSSIBLE IN THE GUN.

(g) IT SHOULD BE EASY TO IGNITE.

Most modern propellants are not easy to ignite, and the use of gun-powder igniters is almost universal.

(h) IT SHOULD BE STABLE IN STORAGE AND TRANSPORT.

This factor is more particularly important under peace conditions. It avoids the necessity for replacements at frequent intervals, alteration of ballistics with age, and spontaneous combustion. The explosives used in modern propellants undergo a continuous though slow process of decomposition. Direct sunlight, heat, and damp accelerate the rate of decomposition. The decomposition is accompanied by an evolution of heat and the formation of free acids. If the heat is not dissipated and the acids are not neutralized, decomposition is accelerated and may eventually become so pronounced as to result in spontaneous ignition.

(i) IT SHOULD BE INSENSITIVE TO SHOCK AND FRICTION.

This factor is of particular importance with storage in the magazines of warships. In general, the nitrocellulose propellants are more sensitive to impact than are the cordites.

(j) IT SHOULD BE UNAFFECTED BY MOISTURE.

The general effect of absorption of moisture by a propellant is to reduce the energy available for useful work when fired, because of the high latent heat of vaporization of the water absorbed, thereby reducing the muzzle velocity of the projectile. In addition, damp will accelerate the decomposition of the propellant and its interaction with its surroundings.

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Hygroscopic explosives necessitate extra trouble in providing air and water-tight packages.

(k) IT SHOULD NOT BE AFFECTED BY TEMPERATURE.

Exposure to extreme temperatures may lead to physical changes in the propellant. Changes in temperature may also cause variation in ballistics which necessitate the application of charge temperature corrections. Increase in temperature generally means increase in range with the same charge.

(l) IT SHOULD BE CAPABLE OF RAPID AND EASY MANUFACTURE.

Raw materials should be indigenous, easily procurable, and cheap. The processes of manufacture should not be complicated and should not require large and expensive plants.

(m) IT SHOULD INVOLVE A MINIMUM OF FOODSTUFFS IN ITS PRODUCTION.

Fats, sugar, and grain are used in the manufacture of nitroglycerine, ether and alcohol.

(n) IT SHOULD BE SAFE TO MANUFACTURE.

(o) IT SHOULD GIVE THE MAXIMUM POWER FOR THE MINIMUM BULK.

The propellant effect depends partly on the volume of gas and the quantity of heat evolved by the explosion of unit mass of the propellant. It also depends upon the specific rate of burning.

7. MODERN PROPELLANTS.

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All modern propellants are based on nitrocellulose, and when based on this alone, they are known as "single-base" types. "Double-base" type propellants contain nitroglycerine as well.

Until the beginning of World War II, practically all the propellants in the British service were of the double-base type; but it has been found necessary, owing to the big increase in requirements, to purchase single-base propellants from the U.S.A. Certain single-base propellants are manufactured in this country for special purposes, such as for S.A.A. and mortar ammunition.

The relative advantages and disadvantages of the two types are summarized below: --

Nitrocellulose propellant in general have the following objections compared with the double-base types:--

- (a) They are in general more hygroscopic and therefore more subject to ballistic change from differences in atmospheric conditions. This defect is reduced to a considerable extent in the modern American powders by the use of nitro-cellulose of high nitration and of a substantial proportion of water-repellent ingredients (dinitrotoluene and dibutylphthalate). British textbook of Explosives www.ssrichardmontgomery.com
- (b) They are less easy to ignite than all cordites except Flashless.
- (c) They are less powerful than ordinary cordites.
- (d) They require a solvent process for their manufacture in which the consumption of solvent is high.
- (e) They are liable to give sporadic high pressures when used in the higher pressure guns if ignition is defective.
- (f) The finished product contains a certain amount of residual solvent which, if the propellant is not in air-tight containers, is slowly lost during storage, with a consequent change in ballistics and in the physical condition of the propellant.
- (g) They are too brittle to use in cord form.
- (h) The granular form in which it is necessary to manufacture them makes B.L. cartridges so filled objectionably non-rigid.

The advantages of the nitrocellulose propellants compared with the double-base types are: --

- (a) They are cooler burning, and therefore less erosive than the majority of double-base propellants.
- (b) They give considerably less flash than ordinary cordites.
- (c) Their ballistics are less affected by changes in charge temperature.
- (d) They require less fats or oils or other food stuffs, as nitroglycerine is not used. British textbook of Explosives www.ssrichardmontgomery.com
- (e) The granular form in which it is necessary to manufacture them is easier to fill into Q.F. cartridges than the stick forms in which cordites are made.

8. PROPELLANT MANUFACTURE.

It is essential to bring about the gelatinization of the nitrocellulose. The methods adopted are: --

- (a) SINGLE-BASE TYPES. (Nitrocellulose powders.)
Volatile solvents such as ether and alcohol have to be used.
- (b) DOUBLE-BASE TYPES.
 - (i) By the action of a volatile solvent, such as acetone or ether-alcohol. (Cordites Mk. I M.D., R.D.B, W., W.M., N, NQ.)
 - (ii) By the action of heat in the presence of a gelatinizer such as carbanite. (Cordites S.C. and H.S.C.)

CELLULOSE. -- This is obtainable from many plant sources such as cotton, soft woods, rushes, straw, etc. Celluloses derived from cotton and wood are used in service propellants. The source of the cellulose and the processes necessary to obtain cellulose of the requisite purity from such sources have a considerable effect on the properties of the nitrocelluloses produced, e.g., viscosity.

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The following nitrocelluloses are at present used in the British service:--

Nitrocellulose, Cotton, Type A	Nitrogen, 12.2 per cent
" " " " Type B	" 13.1 " "
" " " " Wood (nitrated paper), Type A	" 12.2 " "
" " " " " " " " Type B	" 12.9 " "
" " " " " (nitrated pulp), Type A	" 12.2 " "
" " " " " " " " Type B	" 13.1 " "

The terms soluble and "insoluble" applied to nitrocellulose refer to solubility in ether-alcohol, 2 : 1 by volume. Solubility depends upon the nitrogen content thus:

11.1-12.6 per cent N	soluble in ether-alcohol
12.8-13.1 per cent N	insoluble in ether-alcohol

All forms of nitrocellulose are soluble in acetone and insoluble in water.

Nitrocellulose made from cotton and containing more than 13 per cent. nitrogen is called guncotton.

STABILIZERS. -- Both nitrocellulose and nitroglycerine are unstable substances. The decomposition products are positive catalysts which accelerate the rate of decomposition. Stabilizers are substances which will combine with and so render inactive these decomposition products. It is clear that the stabilizer must not itself react with nitrocellulose and nitroglycerine, although it must be so well incorporated with the other constituents of the propellant as to give a homogenous colloid.

An ideal stabilizer must have the following properties: --

- must absorb oxides of nitrogen;
- must be capable of neutralizing any acid in the propellant;
- must form a colloidal solution with the nitrocellulose or nitroglycerine;
- must be inert towards the nitrocellulose and nitroglycerine, as must also be the compounds formed by the union of the stabilizer with the decomposition products.

The chief stabilizers in use are: --

1. MINERAL JELLY, which is used in cordites Mk. I, M.D., R.D.B., and W.M.; and "cracked" mineral jelly in cordite M.C. It only satisfies properties (a) and (d) above.

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2. DIPHONYLAMINE, which is used in certain nitrocellulose powders, such as N.C.T., N.H., and F.N.H. It fails to satisfy condition (c) above and tends to accumulate in spots on the surface of the nitrocellulose.

3. CARBAMITE, which is used in cordites S.C., H.S.C., W., and W.M. It agrees with all the above conditions.

4. METHYL CENTRALITE, which is used in Bofors cordite and many single-base propellants, besides being a good stabilizer with properties very similar to those of carbamite, is also useful in acting as a moderant in nitrocellulose propellants. In this connection its high melting point (121° C, as against 72.5° C, for carbamite) is advantageous.

9. TABLE OF PROPELLANTS.

The following table gives the compositions and some of the properties of propellants: --

Name	COMPOSITION			Per cent N. in N.C.	Igni- tion Temp.	Temp. of explo- sion, °K*	Cal. val. (W.L.)
	Per cent N.G.	Per cent N.C.	Stabilizer, etc.				
Cordite Mk. I.	58	37	5 Mineral Jelly	13.1	160°C.	3676	1225
" M.D.	30	65	5 Mineral Jelly	13.1	160°C.	3217	1025
" R.D.B.	42	52	6 Mineral Jelly	12.2	155°C.	3128	1000
" M.C.	30	65	5 'Cracked' M.J.	13.1	160°C.	3217	1025
" W.	29	65	6 Carbamite 0.2 Chalk	13.1	153°C.	3304	1025
" W.M.	29.5	65	2 Carbamite 3.5 Mineral Jelly 0.4 Chalk	13.1	163°C.	3292	1010
" S.C.	41.5	49.5	9 Carbamite 0.15 Chalk	12.2	154°C.	3090	970
" H.S.C.	47	49.5	3.5 Carbamite 0.15 Chalk	12.2	164°C.	3625	1175
" N	18.7	19	7.3 Carbamite 54.7 Pierite 0.3 Cryolite 0.2 Chalk	13.1	c.165°C.	2426	755
" NQ	20	21.5	3.5 Carbamite 54.7 Pierite 0.3 Cryolite 0.15 Chalk	13.1	c.165°C.	2797	880
Ballistite A	39.5	60.5	---	12.65	165°C.	3782	1250
Ballistite B	38	60	0.5 Carbamite 1.5 Pot. Nitrate 0.6 Graphite	12.65	---	--	--
N.C. (Y)	--	83	5 Camphor 12.0 Barium Nitrate	12.25	171°C.	--	765
N.C.T.	--	99.5	0.5 Diphenylamine	12.6	178°C.	3014	865
NH (Dupont)	-- Nil	86	1 Diphenylamine 3 Dibutylphthalate 10 Dinitrotoluene	13.15	170°C.	2681	770
NH (Hercules)	Nil	82	0.9 Diphenylamine 17 Dinitrotoluene	13.15	167°C.	2753	795
FNH (Dupont)	Nil	84	1 Diphenylamine 5 Dibutylphthalate 10 Dinitrotoluene	13.15	165°C.	2511	750
FNH/P.	Nil	83	1 Diphenylamine 5 Dibutylphthalate 10 Dinitrotoluene 1 Pot. Sulphate	13.15			
M.4.X. (Dupont)	32	66.15	0.6 Diphenylamine 0.25 Pot. sulphate 1 Graphite	13.0			
Nobel's 'Superim'			Carbamite Sod. sulphate				
Hercules 81. mm. Mortar powder	40	57.75	0.75 Diphenylamine 1.5 Pot. nitrate				

* A 4000 atmospheres.

10. CORDITES.

Cordite is the name given to a group of propellants consisting essentially of a uniform colloidal mixture of nitroglycerine and nitrocellulose with the addition of some substance to act as a stabilizer. The name is derived from the fact that the usual form in which cordite is used is sticks or cords.

The original composition, evolved by Sir Frederick Abel and Professor James Dewar, was introduced into the Service in 1891, and later known as Cordite Mk. 1.

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SOLVENTS. -- Some of the cordites, especially the older types, employ volatile solvents for dissolving the nitroglycerine and nitrocellulose. Acetone is used for this purpose in cordites Mk. 1, M.D., M.C., W., W.M., N, and NQ. Cordite R.D.B. employed ether-alcohol.

The so-called "solventless" cordites (S.C. and H.S.C.) use carbamite, which acts as a stabilizer and at the same time does away with the necessity for a volatile solvent. Manufacturing time is greatly reduced as the lengthy process of evaporating out the solvent is eliminated.

Although cordites W and W.M. use carbamite as a stabilizer, they are made by a solvent process in order to utilize plant originally designed for the manufacture of earlier types.

STABILIZERS. -- The earlier varieties of cordite (Mk. 1, M.D., M.C., R.D.B. employ mineral jelly as a stabilizer, while the more modern types (S.C., H.S.C. W, N and NQ) use carbamite.

Cordite W.M. ("Modified" cordite W) introduced during the present war in order to economize in carbamite, employs mineral jelly in addition to a reduced percentage of carbamite.

Properties of the cordites: --

- (a) **REGULARITY OF BURNING AND CONTROLLABILITY.**--Cordite is good in both these requirements.
- (b) **SMOKELESSNESS.**--Cordite gives very little smoke. The flashless types are not altogether satisfactory in this respect, but this fact may be due in part to the extra gunpowder required for their satisfactory ignition.
- (c) **RESIDUE.**-- Cordite gives little residue on firing.
- (d) **FLASHLESSNESS.**-- Except for the flashless types, all cordites give considerable flash. British textbook of Explosives www.ssrichardmontgomery.com
- (e) **POISONOUS FUMES.**--Carbon monoxide is produced by all cordites.
- (f) **EASE OF IGNITION.**-- Propellants cannot be ignited satisfactorily direct from a cap except in small cartridges: it is necessary to employ gunpowder to secure proper ignition. Flashless cordite resembles nitrocellulose powders in being more difficult to ignite than ordinary cordite.
- (g) **EROSION.**--Cordite gives considerable erosion, owing to the high temperature of explosion. The presence of nitroglycerine is chiefly responsible and cordite Mk. 1 is about three times as erosive as cordite M.D., which has a smaller nitroglycerine content. The erosion is very greatly reduced with flashless cordite.
- (h) **STABILITY.**-- Cordite deteriorates from the day it is made, although the carbamite cordites last better than the mineral jelly types.
The chief factors which affect stability are: --
 - (i) High storage temperatures. The rate of decomposition reaction increases approximately 1.8 times for every 100° F. rise in temperature.
 - (ii) Effect of catalysts. Introduced catalysts, mainly in the form of impurities such as particles of iron pyrites, lower the stability of the cordite. Wood and sulphur also have a bad effect. The decomposition products themselves act as catalysts and speed up the rate of decomposition still further. The use of imperfectly stabilized nitrocellulose is also very harmful because of the acid products it introduces.

- (iii) Low heat conductivity. Cordite has a thermal conductivity about equal to that of porcelain. The heat produced by the decomposition is therefore not easily dissipated, and a vicious circle is set up which may eventually result in the spontaneous ignition of the cordite.

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Chemical decomposition of cordite at low temperatures is very slow, and advantage might be taken of this fact to increase the life of cordite if the separation of the nitroglycerine could be avoided. This separation is known as "low temperature sweating." At temperatures below approximately 56° F. pure nitroglycerine freezes if sufficient time be given. It has, however, a marked tendency to remain supercooled, and this tendency is accentuated if the nitroglycerine be enclosed in a gelatinous colloid, as in cordite. In the process of freezing, the nitroglycerine crystallizes out, and becomes, more or less separated from the colloid mixture. On thawing it exudes to the surface of the sticks, giving rise to "sweating." If the temperature remains above the melting point, a gradual re-absorption occurs. If the exudation has not been too pronounced, no permanent ill effects result; but there is always the possibility of irregular re-absorption, and also the absorption of the nitroglycerine by absorbent materials such as cloth or paper, which would give a very sensitive and dangerous substance.

Exudation thus depends on the temperature, the duration of the cooling, the percentage of nitroglycerine in the cordite, and the ease with which it can separate from the other constituents. This last effect is conditioned partly by the chemical composition, but partly also by physical differences in the colloidal structure, as evidenced by the fact that certain cordites have a far greater tendency to exude than others of the same composition. Cordite Mk. I has the highest nitroglycerine content, and may exude after cooling to any temperature below about 45° F. for a moderate length of time. Exudation can be avoided with certainty only by keeping the temperature above 45° F. M.D. is in general very free from the tendency to exude under climatic conditions existing in this country. The figure of 32° F. is usually quoted for this cordite, as also for W and M.C. R.D.B. is usually classed with Mk. I in this respect.

Trials at the Research Department have shown that S.C., although it contains more nitroglycerine than M.D. cordite, is very free from the tendency to exude, probably because the carbamate present helps to prevent the separation.

At temperatures above 80° F. another form of "sweating" may occur, due to the partial liquefaction and exudation of the mineral jelly. Here again, no ill effects will follow provided there is nothing in contact to absorb the mineral jelly, otherwise there is a loss of stabilizer, and the stability is affected in consequence.

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- (i) EFFECT OF MOISTURE.--Cordite is unaffected by moisture under normal service conditions. It may deteriorate during very prolonged storage under conditions of extremely high humidity.
- (j) EASE OF MANUFACTURE.--The volatile solvent types are not easy or quick to make. They also make use of foodstuffs. The solventless types are better in both these respects.
- (k) SAFETY IN MANUFACTURE.--The manufacture of propellants is attended with a certain amount of danger, the most dangerous parts of the process being: --
 - (i) the manufacture of nitroglycerine;
 - (ii) the drying of nitrocellulose;
 - (iii) the stoving of solvent types;
 - (iv) the rolling and pressing of solventless types.

11. TYPES OF CORDITE.

Compositions of the undermentioned cordites are given in para. 9.

- (a) Cordite Mk. I.--This was the original type of cordite, and it is still often referred to as "Cordite" without any further designation. It is soft and plastic; golden in colour; greasy to the touch. Smokeless, but owing to its high nitroglycerine content, is hot burning and therefore very erosive. It gives considerable flash. Stability not very good. More liable to sulphur infection than later types. Now used only in certain S.A.A. (e.g., proof rounds, pistol ammunition). and cordite cylinders.

- (b) Cordite M.D. British textbook of Explosives www.ssrichardmontgomery.com

Cordite Mk. I proved so erosive during the South African war that the production of a cooler burning propellant was found necessary. Experiment led to the adoption in 1905 of a modified cordite known as cordite M.D. Compared with cordite Mk. I it is cooler-burning, less erosive, darker in colour, harder, and more brittle.

Because it is harder than Mk. I, the decomposition products cannot escape so readily from it, and so in spite of its smaller nitroglycerine content, it is less stable.

The only extensive use for M.D. now is in tubular form for S.A.A., and when used for this purpose a small percentage of carbamite is now added to improve its stability. It is then known as CORDITE C.D.T.

- (c) Cordite M.C.

Similar to cordite M.D. except that "cracked" mineral jelly is used as stabilizer, with a view to prolonging the life of the cordite.

- (d) Cordite M.D.C.

This is simply cordite M.D. broken down and reworked with carbamite as stabilizer.

- (e) Cordite R.D.B.

Introduced during the 1914-18 war because of acetone shortage, since by the use of nitrocellulose of lower nitration it was possible to use ether-alcohol as solvent. Somewhat tougher and less brittle than cordite M.D., but not so pliable as Mark I.

Ballistic properties similar to M.D.: cooler burning.

Note.--All the above cordites are absolescent except for minor uses. Certain cartridges were filled during World War II with cordites Mk. I, M.D., M.C., or R.D.B. of World War I manufacture. These cordites were given an extension of their official life and the cartridges and packages are distinguished by special markings. For fuller details see "Limits of Life" and Disposal Instructions for Cordites Mark I, M.D., M.C., and R.D.B. in Cartridges, 1941." (57/Ammunition /3425.)

- (f) Cordite S.C.

The first solventless type of cordite. Golden colour, but darkens with age. Good ballistically. Uniform thickness of cords and tubes, i.e., no shrinkage. Very good stability.

Cannot be passed through small dies for S.A.A., charges as the friction set up is too great.

The type of plant is different from that for solvent cordites and manufacture is therefore not interchangeable.

Cooler burning than M.D. Too cool for certain small calibre guns.

Cordite S.C. is the standard naval propellant but it is also used for certain land service equipments.

- (g) Cordite S.U.

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This is cordite S.C. used for Rockets "U" 2 in., 3 in., and 5 in. It is employed in the form of large tubes, which may be slotted, drilled, or grooved.

- (h) Cordite H.S.C.
A hotter burning form of S.C. Used in tubular form of Q.F. 2-pr. Mk. VIII gun.
- (i) Cordite W.
Properties similar to cordite M.D. but more stable owing to carbamite being used as stabilizer.
Standard propellant for land service until Flashless was produced in large enough quantities.
- (j) Cordite W.M. British textbook of Explosives www.ssrichardmontgomery.com
Approved as a war time alternative to cordite W in order to economize in carbamite. Properties similar to cordite W. Requires a slightly larger size of stick in order to give the same ballistics as W.
- (k) Cordite, Bofors (Boforite).
A Swedish propellant introduced for the Q.F. 40 mm. gun. It is now replaced by cordite W.M.T.
It is supplied in strips 9.4 in. x 0.47 in. x 0.033 in.
Hard, Rather brittle.
Greenish colour, due to interaction between the diphenylamine and the nitroglycerine.
Local deterioration is revealed by reddish-brown discoloration, which may bleach to a light patch, sometimes accompanied by exudation.
- (l) Flashless Cordites.
Cordite N.
Cordite NQ.
A propellant may be considered "flashless" when its flash is unlikely to attract attention of the naked eye at 4,000 yards. This result is achieved by the elimination of the bright flash (secondary flash) caused by the ignition of the inflammable gases on contact with the air. It has not been found possible to eliminate the dull red glow (muzzle glow) due to the incandescent gases in the bore, but this glow, being of very short duration, is of relatively small importance.

NOMENCLATURE.-- Several different types of "flashless" cordite have been evolved. They are of two main classes which differ in calorimetric value.

- (i) Flashless cordite of 775 cal/gram, designed for guns which are used in open situations and which have sufficient chamber capacity to accommodate the charge required for service ballistics.
Cordite N belongs to this class.
- (ii) Flashless cordite of 880 cal/gram, designed for guns used in enclosed situations or for guns, the chambers of which are too small to accommodate the charge necessary with cordites of Class (i).
Cordite NQ belongs to this class.

Variations in the nomenclature are also made to denote the source of the cellulose and its degree of nitration, but two varieties only are now actually employed in the U.S.: -- British textbook of Explosives www.ssrichardmontgomery.com

- (a) Cordite N, which is made from guncotton and is based on the cordite formerly known as RDN/AQ. (Cordite N/P is Cordite N with the addition of a small amount of potassium sulphate to improve flashlessness.)
- (b) Cordite NQ, which is made from guncotton and is based on a cordite formerly known as Cordite RDQ.

PROPERTIES OF THE FLASHLESS CORDITES.--

- (a) ADVANTAGES: --
- (i) Cooler burning and therefore less erosive than other propellants.
- (ii) Requirements of nitroglycerine, nitrocellulose, and acetone, are greatly reduced.

- (iii) Use the same manufacturing plant as cordite W.
- (iv) Drying time shorter than for cordite W.
- (v) Produce less carbon monoxide inside the gun than other cordites and so the gases escaping on opening the breech are less toxic than when flashing cordites are used (but see (B) (v) below).
- (B) DISADVANTAGES: -- British textbook of Explosives www.ssrichardmontgomery.com
 - (i) Bulkier than cordite W. An increase of about 15 per cent in charge weight is necessary to obtain the same ballistics as with cordite W.
 - (ii) Harder and more brittle than other cordites.
 - (iii) Produce rather more smoke than other cordites.
 - (iv) Require more gunpowder for satisfactory ignition.
 - (v) Give more carbon monoxide in the vicinity of the muzzle of the gun, since although the carbon monoxide produced inside the gun is smaller in amount than with other cordites, there is no secondary flash to burn it to the more innocuous carbon dioxide.

Later the use of potassium cryolite in small proportions in both flashing and flashless cordites was introduced. Its purpose is to reduce flash in the case of flashing cordites (e.g. H.S.C.T/K.) and to improve flashlessness in the case of the flashless cordites. Its presence may be indicated in the nomenclature by the use of the letter K, but this indication is omitted with some cordites.

NOTE -- All land service cordites containing carbamite employ a dye in the manufacture to ensure that the carbamite has been included.

12. NITROCELLULOSE CANNON POWDERS.

The development of these single-base propellants has been carried out mainly in other countries, particularly in America, France, and Germany.

The disadvantages and advantages of this type of propellant as compared with the cordites have already been discussed.

Nitrocellulose cannon powders, developed in the U.S.A., have now been adopted as service propellants. These propellants vary in colour from a light amber to a dark brown or black. They are made in the form of short cylindrical grains, with a length of about twice the diameter, and pierced with one or seven holes longitudinally. The size of grain, diameter, length, and web thickness are carefully designed to produce the required rate of burning in the gun for which the propellant charge is intended. The critical dimension in this respect is the web size or thickness of propellant between the perforation

Diphenylamine is used as a stabilizer in these propellants.

It is necessary to leave a certain amount of residual solvent in these propellants, as otherwise the grains are far too brittle. Evaporation of the solvent during storage, particularly in high temperatures, causes alterations in ballistic. To guard against such changes these propellants are packed in air-tight package, or with Q.F. ammunition of the fixed type, the joints between the shell and cartridge case, and at the primer hole, are carefully sealed.

These propellants are cooler, less erosive, and give less flash than ordinary cordites. In general, they require more gunpowder for satisfactory ignition than most cordites.

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The natures which may be met with are: --

(a) N.C.T. powder

This is the name given to a propellant of American design which was made during the 1914-18 war, and of which large quantities were made. The main disadvantage of this type of propellant is that it is very hygroscopic.

(b) NH. (non-hygroscopic.) powders.

The term NH covers the modern propellants made by the American firms of Dupont and Hercules. They differ essentially from N.C.T., in

the addition of dinitrotoluene and also dibutylphthalate (in the case of the Dupont powder) to reduce the hygroscopicity. Although very much less hygroscopic than N.C.T., they are not entirely free from this disadvantage.

(c) FNH ("flashless non-hygroscopic") powders.

FNH/P powders.

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The "flashless" powders differ essentially from the NH powders in the addition of more dibutylphthalate. They may also contain a small percentage of potassium sulphate which reduces the flash still further, but which gives rather more smoke. When potassium sulphate is present, the nomenclature becomes FNH/P.

The rate of burning is rather slower with these propellants than with the NH powders. They are also cooler burning.

13. MORTAR AND S.A.A. PROPELLANTS (OTHER THAN CORDITES).

(a) BALLISTITE.

One of the earliest smokeless propellants.

General properties similar to those of the cordites, but burns more quickly and regularly at low pressures, and is easier to ignite.

It is very erosive and not very stable, particularly in hot climates.

It is therefore only used when no other propellant is suitable, e.g., in primary cartridges for mortars, and in rifle grenade cartridges, where in both cases the low pressures would make the use of cordite impracticable. Used in flake form.

Ballistite A is used in rifle grenade cartridges.

Ballistite B, which is used in mortar bomb primaries, contains a small percentage of carbamite and is therefore rather more stable. It is also made slightly porous in order to increase its rate of burning and ease of ignition.

(b) NEONITES.

These are modern nitrocellulose propellants made by Messrs. I.C.I. Ltd., mainly for S.A.A. The name covers a series of nitrocellulose powders of different but related compositions.

Used in the form of flakes or small tubes.

The ballistics are adjusted by the use of surface moderants such as methyl centralite and dibutylphthalate, and also to some extent by altering the grain size.

They give less erosion than cordite, and less barrel wear, especially with steel enveloped bullets. They are therefore of particular value in S.A.A. for machine guns where long barrel life and maintained accuracy are essential.

The grains are graphited as a protection against damp and to prevent them from sticking together.

(c) N.C. (Y).

Developed from the sporting gun propellant E.C.3.

Quick burning and burns regularly at low pressures. Hence used for augmenting charges for 3-in. mortars.

Normally in the form of small rounded grains coloured orange with aurine. If aurine is not available, dyeing may be omitted.

(d) N.C.Z.

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Introduced during the 1914-18 war to augment supplies of S.A.A. propellants.

Based on the American powder, Dupont No. 16.

Dinitrotoluene, used as a surface moderant, also helps to waterproof.

Graphite coating for waterproofing and to prevent sticking.

Less smoke than cordite and very little flash.

Cool burning, so little erosion.

Hygroscopic. Ballistics affected when damp.

- (e) DUPONT M.4.X.
Irregular flattish grains, graphited.
Comparatively slow rate of burning. Therefore not suitable for replacing Ballistite B in mortar primaries without modification of the cartridge assembly.
Stability satisfactory, but not as good as ballistite containing carbamate. Used as an alternative to N.C.(Y) in augmenting charges for mortar bombs. Also used in artillery ammunition for burst short charges with heavy A.A. equipments.
- (f) NOBEL'S "SUPERIM".
Flattened spheres, graphited.
Diameter, 0.08 c.m.
Thickness, 0.006 c.m.
Stability satisfactory.
It has been introduced as an alternative to ballistite in rifle grenade cartridges. British textbook of Explosives www.ssrichardmontgomery.com
- (g) HERCULES 81 mm. MORTAR POWDER.
Practically identical with ballistite B.16, but non-porous.
Two thicknesses, 0.01 in. and 0.005 in.
Approved as alternative fillings for primary and secondary cartridges for 3-in. M.L. mortar; also for 0.303-in. rifle grenade cartridges.

14. METHODS OF INDICATING SHAPE AND SIZE OF PROPELLANT.

Propellants are made in various shapes and sizes in order to vary the rate of burning, and thereby obtain the required ballistics.

The SHAPE is indicated in the Service by appropriate letters added to the propellant nomenclature, thus: --

SHAPE	Letter	Example
Cord	None	Cordite M.D.
Tube	T	Cordite M.D.T.
Square Flake	S.F.	Cordite R.D.B.S.F.
Slotted Tube	/S	Cordite N/S
Drilled tube	/D	Cordite S.U./D.
Grooved, slotted tube	/S/G	Cordite S.U./S/G.

The SIZE is indicated as follows: --

- (a) Dimensions of the earlier cordites (Mk. I, M.D., M.C., and R.D.B.) and also of ballistite are expressed in hundredths of an inch. These are die sizes, but owing to shrinkage of these propellants during stoving, the actual dimensions are less.

Tubular cordite is known by numbered sizes, which indicate the external and internal diameters of the tube as it leaves the die.

EXAMPLES: --

"M.D.8" represents cordite M.D. in cords formed by a die of 0.08 in. diameter.

"M.D.T.7-2" represents tubes of cordite M.D. which when pressed has an external diameter of 0.07-in. and an internal diameter of 0.02 in.

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- (b) Dimensions of the later types of cordite (S.C., H.S.C., W., W.M., N. and NQ) are expressed in thousandths of an inch.

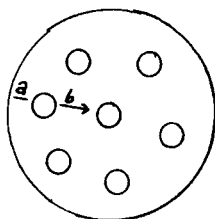
These are actual sizes.

EXAMPLES: --

"S.C. 048" represents cordite S.C. in cords of .048 in. diameter.

"H.S.C.T. 124-058" indicates cordite H.S.C. in tubular form of external and internal diameters 0.124 in. and 0.058 in. respectively.

- (c) The dimensions of the multi-tubular nitrocellulose cannon powders (N.C.T., NH; FNH) are expressed in thousandths of an inch. The average websize is used to indicate the size of the propellant. This is the mean of the distances from centre to outer hole, and from outer hole to periphery. For example, in the diagram the mean web-size is equal to $\frac{a+b}{2}$



"N.C.T. 065" implies that $\frac{a+b}{2} = 0.065$ inches.

15. PROPELLANT CODE LETTERS. British textbook of Explosives www.ssrichardmontgomery.com

Artillery cartridges, ammunition boxes and containers are stencilled with a letter, in a rectangle, indicating the class of propellant.

These indicating letters are as follows: --

A	.....	Cordites N and NQ
B	.....	Ballistite
C	.....	Cordite R.D.B. in cord or tube
D	.....	Cordite M.D. in cord or tube
E	.....	Cordites W and W.M.
F	.....	Cordites M.D. or R.D.B. in flake
H	.....	Cordite H.S.C.
HK	.....	Cordite H.S.C.T./K.
J	.....	Cordite Bofors
K	.....	FNH/DB
L	.....	FNH and FNH/P
M	.....	M.4.X.
N	.....	N.C.T.
O	.....	NH
S	.....	Cordites S.C. and S.U.

The letter "D" in a circle denotes drilled cordite.

The letter "G" in a circle denotes grooved cordite. These last two markings apply to cordite S.U. for Rocket weapons.

CHAPTER III

CLASS II. HIGH EXPLOSIVES

16. DEFINITION.

A high explosive may be defined as a material which can be detonated and is normally used to give detonation.

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17. PROPERTIES OF THE IDEAL HIGH EXPLOSIVE.

- (a) It should possess power and violence.

Power is the ability of the explosive to do work and is obviously dependent on the volume of gases formed at the temperature of explosion. The arbitrary figure of 100 has been given to lyddite as a basis of comparing the power of high explosives.

The time required for the explosive to develop its maximum pressure is not taken into account when determining the power, but the time factor is of the very greatest importance where violent blast and disruptive effect are required.

The violence of a high explosive will therefore depend very largely on the rate of detonation. British textbook of Explosives www.ssrichardmontgomery.com

(b) IT SHOULD BE INSENSITIVE TO ORDINARY SHOCKS.

It has to withstand handling, transport, shock of discharge and, with armour piercing shell, the shock of impact.

Sensitiveness to impact and to friction is not always similar in the same explosive, although explosives which are very sensitive to the one are usually sensitive to the other.

Sensitiveness to friction is difficult to measure scientifically. Comparative figures of insensitiveness to impact, using picric acid as a standard of 100, can be obtained experimentally.

A rise in temperature of an explosive generally increases its sensitiveness, as does a decrease in its density.

(c) IT SHOULD BE FREE FROM A TENDENCY TO DETONATE SYMPATHETICALLY.

Some high explosives are found to be more liable than others to detonate when stored in a dump in which an isolated detonation takes place. All high explosives have this tendency in some degree, and although it is more pronounced in some cases, e.g., lyddite, it is never absent.

(d) IT SHOULD BE STABLE IN STORAGE.

This is more important than with propellants, as the interior of a filled shell is very difficult to inspect.

(e) IT SHOULD BE UNAFFECTED BY DAMP AND EXTREMES OF TEMPERATURE.

Moisture may affect the volume of the substance, thereby forcing out some of the filling; or it may partially dissolve one of the constituents; or it may give rise to chemical reactions.

High temperatures may result in partial liquefaction of the filling.

Low temperatures, although usually harmless, may decrease the sensitivity of the explosive.

(f) IT SHOULD NOT FORM UNSTABLE OR SENSITIVE COMPOUNDS WITH METALS.

(g) IT SHOULD BE EASILY LOADED TO A HIGH DENSITY.

This feature is important for the following reasons; --

(i) In order to attain the maximum rate of detonation;

(ii) In order to maintain the continuity of the explosive system against "set-back" on firing.

(iii) In order to decrease the sensitiveness and thereby reduce the risk of premature firing of the high explosive.

(h) IT SHOULD PROVIDE SMOKE FOR OBSERVATION.

This property is of importance in connection with bursting charges.

18. INITIATORS.

DEFINITION.-- An initiator may be defined as an explosive which is used for starting the action of combustion, or explosion, or detonation.

We require some means of initiating: --

(a) EXPLOSION OF THE PROPELLANT CHARGE. -- The propellant is normally ignited by gunpowder, which is itself usually ignited by the flash from a cap containing some explosive which is sensitive to the friction and impact of the striker of the firing mechanism. Only a flash is required for this type of initiation. British textbook of Explosives www.ssrichardmontgomery.com

(b) Detonation of the H.E. filling of a shell. -- Here it is necessary to ensure detonation. But the main filling of a shell must not be sensitive.

otherwise it may detonate through rough handling or through shock of discharge. The principle adopted therefore is to have a relatively insensitive mass of bursting charge, and a very small quantity of highly sensitive explosive to initiate the detonation. The impulse from the initiator will be small owing to the very small amount of explosive used. An intermediary is therefore used to build up the impulse. Initiation of this type demands a detonation wave.

- (c) Ignition of certain other types of shell filling and also of the fillings of powder fuzes.-- To ignite the gunpowder in shrapnel, base ejection smoke, star, etc., shell, and in the magazines of powder fuzes, a flash is required.

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A flash is also required to ignite the fuze powder in a combustion time fuze. This type of initiation is therefore comparable to (a) above. It follows that two classes of initiators are needed; --

Igniferous initiators to produce flash.

Disruptive initiators to produce detonation.

It should be noted that disruptive initiators may also produce a flash, but this flash is normally small and of very short duration. Similarly igniferous initiators may detonate in certain circumstances, but they are designed to give a flash only, and detonation is undesirable.

Initiators are always used in small quantities and compressed. Compression prevents friction between the particles, and enables the cap or detonator to stand up to normal service conditions.

19. DISRUPTIVE INITIATORS.

- (a) FULMINATE OF MERCURY. -- Consists of grey or brownish-grey crystals, having in bulk the appearance of fine sand.

Safe when wet, so always stored in bulk under water.

Non-hygroscopic. Insoluble in water.

Very poisonous.

Soluble in a solution of sodium thiosulphate ("hypo"), which destroys it by decomposition.

Fairly stable if kept dry. If damp, it reacts with metals. Must not be used with aluminium or its alloys.

Very sensitive to impact and friction. Figure of insensitiveness (picric acid = 100) is 10.

Rendered inert by: -- British textbook of Explosives www.ssrichardmontgomery.com

- (i) HOT DRY STORAGE. Four months dry storage at 120° F. has been found sufficient to render fulminate detonators inoperative; and
(ii) OVER-COMPRESSION ("dead-pressed").

Uses: -- Because of its instability in hot climates and its liability to over-compression, fulminate has been largely replaced as a detonator filling by other substances such as lead azide.

Its main use is as an ingredient of certain igniferous compositions, e.g., compositions for caps and ignitory detonators.

- (b) LEAD AZIDE. -- White or grey prismatic crystals. Said to be more dangerous wet than dry, as it tends to form larger crystals with increased sensitivity. It is more sensitive to friction than fulminate but somewhat less sensitive to blows and to the pricking of a needle. When used in detonators, therefore a sensitizing layer of a more sensitive composition may be required on top of the azide.

Figure of insensitiveness (picric acid = 100) is between 15 and 25.

Compared with fulminate, it is unaffected by hot storage; it cannot be over-compressed; it requires less material for the same result, as its rate of acceleration of detonating speed is far greater.

Moisture alone will not affect it, but carbon dioxide in the presence of moisture may attack it, liberating hydrazoic acid which will attack the metallic case of the detonator. In any case, waterproofing precautions

taken in the make-up of azide-filled detonators should eliminate the possibility of chemical reaction of this nature.
To destroy azide, a solution of sodium nitrite in 4 per cent, nitric acid is used.

USES. -- Used extensively as a disruptive detonator filling for fuzes and gaines. It is normally provided with a sensitizing layer of detonator composition.

Also used as an ingredient of A.S.A.

A less sensitive form of lead azide is obtained by incorporating with the azide a small proportion of dextrine. This mixture is known as dextrinated lead azide.

- (c) LEAD STYPHNATE. -- A bright orange yellow powder, formed as a crystalline precipitate when solutions of lead acetate and magnesium stypnate are mixed.

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Similar properties to fulminate of mercury, but more stable under hot conditions of storage, and rather less sensitive to friction and impact. Figure of Insensitiveness (picric acid = 100) is 18.

Must not be allowed to come into contact with acids, oxidizing agents, sulphur, sulphides, or grit.

USES.--It is not used alone. Its chief use is as a constituent of A.S.A.

- (d) A.S.A. detonating composition. -- This composition is a mixture of Lead Azide 65 per cent. Lead Styphnate 32.5 per cent. Aluminium Powder 2.5 per cent.

It very readily picks up a flash and passes on a detonating impulse.

USES:--Often used as a filling for the lower disruptive detonator in graze-action percussion fuzes in order to convert the flash from the upper igniferous detonator to detonation.

- (e) FULMINATE COMPOSITION.-- A mixture of fulminate of mercury (80 per cent.) and potassium chlorate (20 per cent).

Formerly used in detonators for Grenade, No. 36M.

Used mainly now in certain detonators of aircraft bombs.

20. IGNIFEROUS AS INITIATORS. British textbook of Explosives www.ssrichardmontgomery.com

- (a) DETONATOR COMPOSITIONS.--There are four different detonator compositions ("A", "B", "C" and "D" Mixture) all of which contain the same three ingredients. Fulminate of mercury is used to increase the sensitiveness; potassium chlorate to increase the heat of explosion; antimony sulphide to prolong the flame effect.

The following table gives the percentage compositions and the uses of these mixtures: --

Ingredients	Composition			
	'A' and 'A.I' mixture	'B' and 'B.I' mixture	'C' and 'C.I.' mixture	'D' and D.I mixture
Mercury fulminate . . .	37.5	11.0	32.0	25.0
Potassium chlorate. . .	37.5	52.5	45.0	40.0
Antimony sulphide . . .	25.0	36.5	23.0	35.0
General use	i. Igniferous fuze dets. ii. Sensitizing layer in azide dets.. iii. Caps of perc. primers and tubes, vent.			
	Detonators of certain time and T. and P. fuzes			

NOTE: -- (i) The difference between the two mixtures under each letter is one of degree of fineness of the particles.

(ii) "A" mixture has now been largely replaced by Q.F. composition for the caps of percussion primers.

(b) Q.F. COMPOSITION. --

Potassium chlorate	12 parts
Antimony sulphide	18 "
Mealed powder	1 part
Sulphur	1 "
Powdered glass	1 "

Between 1914 and 1924, Q.F. composition was used exclusively for filling caps of percussion primers. It was replaced by detonator composition "A" mixture owing to a reduction in striker blow and in order to avoid "anvil intrusion" by using a smaller quantity of a more sensitive composition in the primer cap. British textbook of Explosives www.ssrichardmontgomery.com The introduction of power-ramming with heavy anti-aircraft equipments led to accidents, due to premature firing of the sensitive detonator composition. To eliminate this danger, more recent policy is to revert to Q.F. composition for the majority of Land Service primers. Primers containing Q.F. composition have the letter "Q" stamped on the base, after the date of filling, and boxes of complete rounds have "Q" stencilled on each end and also after the batch number, in brackets. As a further means of identification, caps filled with detonator composition are lacquered red, and those filled with Q.F. composition are lacquered blue.

(c) CAP COMPOSITION.

Mercury fulminate	8 parts
Potassium chlorate	14 "
Antimony sulphide	18 "
Sulphur	1 part
Mealed powder	1 "

Used in the caps of 0.303 in. and 0.5. in. S.A. cartridges, and of tubes, percussion, small arms cartridge.

Owing to the reduced amount of fulminate and to the presence of gun-powder and sulphur, the violence of the explosion with cap composition is less than with detonator composition.

NOTE: -- Detonator composition "A" or related compositions are used in the caps of small arms cartridges other than 0.303 in. and 0.5 in. calibre.

21. INTERMEDIARIES. British textbook of Explosives www.ssrichardmontgomery.com

Intermediaries are high explosives which are used to pick up the small but concentrated shock given by the initiator and transform it into a sufficiently violent impulse to detonate the main shell filling. Their sensitiveness lies between that of initiators and that of bursting charges.

They are used in the magazines of disruptive fuzes and gaines, and also in the exploder system of shell filled with high explosive.

(a) PICRIC POWDER. -- This is a mixture of finely-ground ammonium picrate and potassium nitrate in the proportion of 43 to 57.

Figure of insensitiveness (picric acid = 100) is 85 to 87.

It is easily ignited and on ignition rapidly develops explosive violence. It is capable of initiating a violent explosion, usually somewhat less than complete detonation, in most high explosives. Its use is normally confined to the exploder system of certain shell filled with lyddite or shellite and fitted with a powder-filled fuze. Although this system does not give rise to true detonation of the main filling, it has the advantage of simplicity in doing away with the need for a gaine under a powder-filled fuze, and the further advantage of providing a slight delay which is desirable in the use of certain types of shell.

- Picric powder is stable when dry, but interaction of the ingredients occurs when wet, giving ammonium nitrate and potassium picrate. The former readily absorbs moisture, and when damp attacks metals.
- (b) **COMPOSITION EXPLODING (C.E.)**-- This is the service name for the explosive trinitrophenyl-methyl-nitramine. Its trade name is tetryl. It is used in the service in several grades, which differ slightly in their degree of purity and may be in the form of powder or "corned" grains. The latter form of the explosive is prepared from the powder by adding a small quantity of a solution of gym arabic, followed by rumbling in a mixing machine and drying. British textbook of Explosives www.ssrichardmontgomery.com
- PROPERTIES** -- C.E. is a pale yellow powder. It is practically insoluble in water and is non-hygroscopic. When heated it melts between 128-50C. and 129-10C. and at slightly higher temperatures it decomposes somewhat rapidly. On this account it is not used in the cast condition. Its figure of insensitiveness is 70.
- It is liable to produce dermatitis in certain individuals, and for this reason the corned varieties are preferred, since they give rise to less dust during the filling operations.
- Chemically, C.E. is a neutral substance, and does not readily react with materials likely to come into contact with it in the Service. Alkalies, however, decompose it, and picric acid lowers its stability. It is therefore not used in the exploder system of lyddite shell, except in those designs which employ a burster container filled with T.N.T.
- The detonating properties of C.E. are not seriously affected by T.N.T. exudation, and it is therefore very suitable for the exploders of shell fillings containing T.N.T., especially if the shells are likely to be stored in hot climates.
- USES**-- C.E. is the normal fillings for the magazines of detonating fuzes and gains. In these it is employed in the form of compressed pellets. It is also used for the exploders of shells and bombs. In this respect, it is especially useful in conjunction with bursting charges containing T.N.T., as its detonating properties are not seriously affected by T.N.T. exudation.
- (c) **T.N.T. CRYSTALS**--T.N.T. crystals are extensively used in exploder systems. The T.N.T. is of a very high grade of purity, and is known as "T.N.T. Grade 1 - Exploder Flake."
- In crystalline form the sensitiveness to detonation is greater than in cast form.
- Owing to their susceptibility to T.N.T. exudation from the main filling, T.N.T. crystals are less satisfactory than C.E. for the exploders of Shell fillings containing T.N.T., especially for storage in hot climates.
- (d) **PICRIC ACID** -- Picric acid is used in the exploder system of certain large armour-piercing shell, e.g., 15-in. A.P.C. shell filled shellite. It is also widely used as an intermediary in German shells and aircraft bombs.
- British textbook of Explosives www.ssrichardmontgomery.com
- (e) **P.E.T.N.**-- P.E.T.N., penta-erythritol-tetranitrate, or penthrite, is an extremely violent and powerful explosive. Its power (picric acid = 100) is 166, while its rate of detonation is 8,300 metres/second. It has a somewhat high melting point of 140C. Crude P.E.T.N. is unstable, but when purified by recrystallization, its stability is good. It is sparingly soluble in organic solvents and of the common solvents acetone is the only one which can be used for crystallization. It dissolves readily in molten T.N.T. It is too sensitive to be used in shell without a desensitizer, such as wax. Its figure of insensitiveness (picric acid=100) is 40.
- P.E.T.N./wax, 88/12, was approved as an alternative to C.E. for the magazines of disruptive fuzes and gains. This approval was later rescinded. Pentolite (see para. 22 (f) has since been approved as a filling for the magazines of fuzes and gains.

22. BURSTING CHARGES.

(a) LYDDITE OR PICRIC ACID

Picric acid or trinitrophenol was discovered in 1771, and was used in the dyeing industry for many years before its use as an explosive. It was first employed as a shell filling in 1893. It is used by most countries as a bursting charge although under different names, e.g., granatfullung 88 (Germany); pertite (Italy); shimose (Japan); melinite (France). The practice in this country is to refer to it as lyddite only when in the cast form. If used in the powder form, it is known as picric acid. PROPERTIES. -- Picric acid is a bright yellow crystalline powder of absolute density 1.76. It is slightly soluble in cold water, and readily soluble in benzene and other organic solvents. When pure, it melts at 121.6°C. to an amber-coloured liquid which on cooling sets to a mass of needle-shaped crystals. British textbook of Explosives www.ssrichardmontgomery.com

ADVANTAGES AS A BURSTING CHARGE.

- (i) Very powerful disruptive. Rate of detonation is 7,250 metres/second. Gives great distortion of shell fragments.
- (ii) Can be filled to a high density by pouring.
- (iii) Extremely stable under the most adverse conditions of temperature, and is therefore very suitable for hot climates.
- (iv) Complete detonation of lyddite is accompanied by a large cloud of black smoke. Additional smoke-producing substances are therefore unnecessary in lyddite fillings.

DISADVANTAGES AS A BURSTING CHARGE.

- (i) The melting point of 121.6°C. necessitates the use of heated oil baths to melt the picric acid before filling into the shell by pouring.
- (ii) Requires a powerful intermediary, but C.E. should not be used in the exploders of lyddite shell, as the stability of C.E. is lowered by the lyddite.
- (iii) Very liable to sympathetic detonation.
- (iv) Picric acid is not always sufficiently insensitive to withstand impact on armour, and it is therefore unsuitable for armour-piercing projectiles. British textbook of Explosives www.ssrichardmontgomery.com
- (v) When used with picric powder as an intermediary, interaction between lyddite and the potassium nitrate in the picric powder produces nitric acid which attacks the material of the exploder bags.
- (vi) The great disadvantage of picric acid is its tendency to form sensitive picrates with metals. Although very stable when dry, if it gets moist it reacts readily with metals. It is therefore essential to seal the shell against ingress of moisture. The metallic picrates which may be formed are sometimes very sensitive. This feature is particularly characteristic of lead picrate, which has a figure of insensitiveness of 18. Great care is therefore needed to prevent the formation of picrates by interposing a protective film of varnish between the acid and the surfaces of all metal containers, and by the use of lead-free materials. Shellac varnish is not suitable, as at the high temperature at which lyddite is poured, this varnish softens. So copal varnish, lead-free, is sprayed on to the inside of projectiles and components, and stoved in an oven for at least one hour at 300°F. This coating is somewhat elastic, and more resistant than shellac. As the empty shell manufacturer does not know what filling is to be used, all H.E. shell in the Service are varnished, and copal varnish is always used.

(b) SHELLITE.

Shellite is a mixture of trinitrophenol (picric acid) and dinitrophenol. It is generally similar in properties to picric acid, but it has a lower melting point, which gives it the great advantage that it can be melted on a water bath.

The same precautions as with picric acid have to be taken with shellite for avoiding contact with metals, especially lead; and special medical precautions are taken with persons employed on shellite, on account of its poisonous character.

It is rather more insensitive than picric acid (figure of insensitiveness 124. Picric acid=100), and is therefore more suitable for armour-piercing projectiles, but as it is less powerful, it is not normally used with other types of shell.

(c) T.N.T. British textbook of Explosives www.ssrichardmontgomery.com

T.N.T. or trinitrotoluene was discovered in 1863, but before 1914 was not used in the Service as a shell filling, though it had been employed by the Germans since 1902. Its development as a service bursting charge was handicapped by the difficulty that was experienced in the design of a suitable exploder system. T.N.T. was formerly known as trotyl.

T.N.T. is graded according to its degree of purity as determined by its setting point. The grades in order of purity are: --

Grade I	setting point 80.00C. to 80.90C.
Grade II	" " 79.50C. to 80.90C.
Grade IIA	" " 79.00C. to 80.90C.
Grade III	" " 76.00C. to 80.90C.

PROPERTIES. -- The crude product of the nitration of toluene after washing with water is used as Grade III. This material has a yellow reddish-brown colour, and contains from 4 to 7 per cent. of impurities, some of which may impart to it an irritating odour.

The other grades are prepared from Grade III by purification. They are paler in colour (Grade I being nearly white) and have no irritating odour.

T.N.T. is insoluble in water and is not hygroscopic. It is soluble in acetone. Inhalation of T.N.T. dust produces poisoning, and contact with the skin may cause dermatitis.

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ADVANTAGES OF T.N.T. AS A BURSTING CHARGE.

- (i) T.N.T. is a very violent and powerful high explosive, being in these respects only slightly inferior to picric acid. It has a fairly high rate of detonation (6,950 metres/second at a density of 1.57).
- (ii) It is less sensitive to shock and friction than picric acid.
- (iii) It is a very stable explosive and, when pure, is entirely unaffected by normal conditions of storage. It is unaffected by damp.
- (iv) It is a relatively non-reactive substance. Being free from acid properties, when pure, it has not the tendency to form sensitive salts as has picric acid. Alkalies, however, interact with T.N.T. and produce a substance which is much more sensitive to shock than ordinary T.N.T., and is more readily ignited. Contact with alkali is to be avoided in its manufacture and use.
- (v) The low melting point of T.N.T. renders it easy to melt by steam heating, and when used alone in shell it is normally poured.
- (vi) The visibility of the burst of shell filled with T.N.T. is similar to that obtained with lyddite.

DISADVANTAGES OF T.N.T. AS A BURSTING CHARGE.

- (i) The lower grades of T.N.T. contain impurities in the form of unsymmetrical isomers, which give mixture with comparatively low melting points. Under hot storage conditions, these mixtures melt and give rise to exudation. This exudation is an oily liquid which is an explosive and may cause trouble in the way of possible pre-matures by getting into the screw threads and other exits of the shell, and being nipped by the shock of discharge. It may also be absorbed by exploders, which may be made unserviceable by being "deadened." T.N.T. exploders are particularly affected by this exudation and consequently for hot climates C.E. exploders are preferable with bursting charges containing T.N.T. The exudation may also increase the fire risk when the T.N.T. is being stored in bulk by flowing to the outside of the packing cases. British textbook of Explosives www.ssrichardmontgomery.com
- Because of the above, shell filled with T.N.T. are specially marked if suitable for use in hot climates with a ring of red crosses in place of the usual red filling ring. A filling ring of alternate red crosses and dashes is used to indicate a limited life in hot climates. It is applied to those shells which require a top exploder of C.E. for unrestricted use in hot climates, but in which T.N.T. exploders have been inserted in order to economize in C.E.
- (ii) T.N.T. is not free from the tendency to detonate sympathetically.
- (iii) Although less sensitive than lyddite, T.N.T., is not always sufficiently insensitive to withstand impact on armour. The larger natures of piercing shell may therefore be filled with T.N.T./BW, i.e. T.N.T. desensitized by the addition of a small percentage of beeswax.

USES. -- T.N.T. is used as a filling for shells, bombs, and anti-tank mines. It is also used as an ingredient of amatol and baratol. Other uses are as fillings for exploders and fuzes instantaneous detonating (F.I.D.), for which purposes only the purest forms of T.N.T. are used, i.e., "Grade 1 for Exploders," and "Grade 1 Special" respectively.

(d) AMATOL.

Amatol is an intimate mixture of ammonium nitrate and T.N.T. It was first adopted in 1915 to augment the supplies of the service high explosives, lyddite and T.N.T., and to economize in T.N.T.

The amatols which have been used from time to time include 40/60, 50/50, 60/40, 70/30, and 80/20, these designations indicating the proportions of the ingredients, the first-named figure, or numerator, referring to the percentage of ammonium nitrate.

The ammonium nitrate, as well as the T.N.T. used in amatol is graded according to its purity. The lower grades of ammonium nitrate contain saline and other impurities which adversely affect the stability of the amatol, especially when lower grades of T.N.T. are used. Ammonium nitrate is easy to obtain. It is very insensitive and the higher the percentage of ammonium nitrate, the more difficult the amatol is to detonate. For this reason, amatol shell fillings may use a layer of T.N.T. between the exploder and the bursting charge in order to reinforce the detonative impulse from the exploder system. This "T.N.T. surround" is frequently used with amatol 80/20. British textbook of Explosives www.ssrichardmontgomery.com

Ammonium nitrate has a considerably lower rate of detonation and is therefore less violent than T.N.T. Due regard should be paid to this fact in the selection of an amatol as a filling for any particular ammunition store. Where violent blast and disruptive effects are required, amatols containing 50 or lower percentages of ammonium nitrate give results approximating to that of T.N.T. On the other hand, T.N.T. is

about 10 per cent superior to amatol 80/20 in this respect. Where a more prolonged effect is required, as for example in cratering earth, amatol 80/20 is superior to T.N.T. It should be noted, however, that these theoretical considerations may be influenced by the need for greater economy in T.N.T. British textbook of Explosives www.ssrichardmontgomery.com

The high T.N.T. amatols can be filled into H.E. munitions of almost any kind by a straightforward casting process. For gun ammunition, which must be filled to a density of loading sufficient to resist set-back stresses on firing, amatols containing up to 50 per cent ammonium nitrate can be filled in this manner, giving a density of 1.55 which approximates closely to that of cast T.N.T., 1.57. For certain other ammunition stores such as aircraft bombs, amatols containing slightly greater percentages of ammonium nitrate, e.g., amatol 60/40, can be poured. For cast fillings, the amatol is prepared by mixing the ingredients in steam-heated vessels.

Hot mixed amatols of 80/20 to 70/30 proportions are conveniently filled into shells, mortar bombs, and the smaller aircraft bombs by screw filling. In this method a worm, working in the mass of explosive, extrudes and packs the amatol into the shell or bomb. It is essential that the mixture should be of a suitable consistency, and screw filling is generally limited to amatols of these proportions.

Cold mixed amatols can be filled by direct pressing with power-operated presses. This old-pressed method is not dependent on the use of any particular proportion of ingredients. Although a rapid method of filling, it requires an elaborate plant and in addition cold mixed amatol is rather more hygroscopic than the hot mixed type. Cold pressing is normally employed with amatol of 60/40 or near proportions.

If screw filling or cold pressing machinery is not available, there remain at present only hand-stemming methods for filling amatols of the higher percentages of ammonium nitrate. Hand-stemming is often used for filling amatols 80/20 to 77/23 into the larger natures of G.P. type aircraft bombs.

ADVANTAGES AS A BURSTING CHARGE.

- (i) Compared with T.N.T., it is more powerful but less violent, and therefore gives better cratering effect. This effect is notably characteristic of amatols containing a high percentage of ammonium nitrate, e.g., amatol 80/20.
- (ii) It effects a considerable economy in T.N.T.
- (iii) The lower grades of T.N.T. may be used in amatols with less danger from exudation in hot climates. For example, while only Grade I T.N.T. is suitable for unrestricted use in all climates, amatols containing between 50 and 70 per cent. ammonium nitrate may use Grade II T.N.T., and amatol 80/20 may use Grade III T.N.T. with safety under these conditions.

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DISADVANTAGES AS A BURSTING CHARGE.

- (i) It is more insensitive than T.N.T. and a powerful exploder system is required to ensure detonation.
 - (ii) Owing to the presence of ammonium nitrate, amatol is very hygroscopic, and it is therefore essential to ensure that the shell is sealed against the ingress of moisture. Cold-mixed amatol is more hygroscopic than the hot-mixed variety as, in the latter, the crystals of ammonium nitrate have been more or less completely coated with a waterproofing layer of T.N.T.
- Ammonium nitrate in the presence of moisture attacks metals, the corrosion products being sometimes dangerously sensitive, and in any event may finally cause the destruction of or damage to metal components. Brass, and particularly tinned brass, is objectionable in this respect. With brass, blue and green coloured compounds

are produced which are somewhat unstable and sensitive, and have comparatively low ignition points. With tinned brass or bronze, ammonium nitrate produces a definitely sensitive compound (basic stannous nitrate). The copal varnish applied to the cavity protects the metal of the shell from the effects of amatol, while other metal parts in contact with the explosive -- such as the bases of fuzes and gages -- are normally coated with R.D. cement. British textbook of Explosives www.ssrichardmontgomery.com

- (iii) Although amatol compares favourable with T.N.T. for T.N.T. exudation, there is a possibility of exudation occurring under hot storage conditions with amatols containing low grade T.N.T.
- (iv) Amatol 80/20 yields little or no smoke as it is a "balanced" explosive, i.e., it contains sufficient oxygen for complete combustion. The amatols containing higher proportions of T.N.T. give a grey smoke on burst.

(e) BARATOL.

Baratol is an intimate mixture of barium nitrate and T.N.T., the usual proportions being 20/80 and 10/90.

ADVANTAGES: --

- (i) It is non-hygroscopic.
- (ii) It is unaffected by hot storage conditions.
- (iii) It does not react with metals to form sensitive compounds.

DISADVANTAGES: --

- (i) It is less powerful than picric acid, T.N.T., or amatol.
- (ii) It is comparatively heavy, with a filling density of about 2.4 (compared with 1.42 in the case of hot-mixed amatol). This would make about 3 lb. difference in the weight of a 4.5 in. howitzer shell.

USES. -- Baratol is not used as a filling for shell. Its main use is as a filling for munitions which are difficult to render completely waterproof and are likely to be subjected to very damp conditions in the Service. It is therefore used in certain grenades and mines.

(f) PENTOLITE.

Pentolite is a mixture of P.E.T.N. and T.N.T., the usual proportion being 50/50.

For particulars of P.E.T.N., see para. 21(e)

(g) R.D.X. British textbook of Explosives www.ssrichardmontgomery.com

R.D.X. is an extremely powerful and violent explosive. In these respects, it is about 40 per cent superior to lyddite. It is, however, too sensitive to be used as a bursting charge by itself and is normally desensitized by the addition of wax of T.N.T. It is a stable explosive and does not form sensitive compounds with metals.

It is rather expensive to manufacture.

In its desensitized forms, as used in bursting charges, it is less liable to sympathetic detonation than pentolite, and R.D.X. desensitized by beeswax (R.D.X./B.W.X) and R.D.X./T.N.T. are considered preferable to pentolite as a filling for shells and bombs in the Service.

3. MISCELLANEOUS HIGH EXPLOSIVES.

The most commonly used high explosives have been dealt with in preceding paragraphs. Brief details of certain other high explosives less frequently met with in the Service are given below.

- (a) **BURROWITE** -- This is essentially an amatol with the addition of aluminium. It is used as one of the alternative bursting charges for the No. 75 Grenade.
- (b) **EXPLOSIVE D.** -- The American name for Ammonium Picrate used as a bursting charge.
- (c) **TRIMONITE** -- A 70/30 mixture of picric acid and mono-nitronaphthalene, which is used in American H.E. mortar bombs as a bursting charge.
- (d) **TRIDITE** -- The American name for Shellite, i.e., mixture of picric acid and dinitrophenol. British textbook of Explosives www.ssrichardmontgomery.com
- (e) **NOBEL'S EXPLOSIVES.** -- These are high explosive mixtures which are designated by formula numbers. Some of the more widely used in ammunition stores are: --

704 and 704B -- These are used as bursting charges for grenades and for the 14-1b. H.F., bomb for the 29-mm. spigot mortar. They are similar in make-up to alumatol, with the addition in the case of 704B of small quantities of calcium stearate and paraffin wax.

808 -- This is used in the Service as a blasting explosive. It is also used as a bursting charge in the 20-1b. H.E. bomb for the 29-mm. spigot mortar. It contains nitro-cellulose, nitro-glycerine, mono-nitrotoluene, and a stabilizer.

823 -- A type of blasting explosive consisting of nitro-cellulose, and nitro-glycerine, plasticized by dibutyl phthalate. It has a consistency similar to that of vaseline. One of its uses is in the No. 74 (S.T.) Grenade.

831 -- The 20-1b. H.E. bomb for the 29 mm. spigot mortar uses this explosive in the exploder system. It is a mixture of C.E. and T.N.T.

CHAPTER IV

CLASS III. -- MISCELLANEOUS EXPLOSIVES -- GUNPOWDER, PYROTECHNIC AND OTHER COMPOSITIONS, WHICH CANNOT USUALLY BE DETONATED.

24. GUNPOWDER. British textbook of Explosives www.ssrichardmontgomery.com

Gunpowder is the oldest known explosive. Its origin is unknown. It remains an important explosive, but is now little used as a propellant, having been almost entirely superseded by the modern smokeless powders.

In this country, gunpowder usually consists of 75.5 parts by weight of potassium nitrate (salpetre), 14.5 of charcoal, and 10 of sulphur, the ingredients being ground together in a moist condition, compressed, granulated and dried.

It is manufactured in various sizes of grain, which determine the rate of burning. The most important grades are: --

Gunpowder	B.S. Mesh Sieve by which the Gunpowder must be	
	PASSED	RETAINED*
P. 3. (Pebble)	3/4-inch	3/8-inch
G. 7. (R.L.G. 2.)	1/4-inch	No. 8
G. 12. (R.F.G.2.)	No. 8	No. 16
G. 20. (R.P.P.)	No. 16	No. 25
G. 40.	No. 30	No. 52+
Healed	No. 150	No. 240±

Note: -- *The whole of the sample in the case of P. powder, and at least 95 per cent. in the case of G. powder (except G.40).
 +Not more than 12 1/2 per cent to pass.
 ±Not more than 25 per cent to pass.

PROPERTIES OF GUNPOWDER. -- Gunpowder consists of small polished grains, the grain size being determined by the dimensions of the mesh aperture through which it has been sieved. It varies in colour from black to brown according to the nature of the charcoal used. It is usually glazed, a little graphite being sometimes added for that purpose.

SENSITIVENESS. -- Gunpowder is relatively insensitive to shock, but it is somewhat readily ignited if a thin layer is nipped between hard surfaces. It has a fairly high ignition point (between 270° and 300°C.), but it is very susceptible to ignition by any flame or spark which may momentarily raise it locally to that temperature, and the ignition spreads throughout the whole mass with explosive violence. On this account it is a dangerous explosive to handle, and special precautions must be taken that any tools used with it are not liable to give rise to sparks. To this end all tools for working with gunpowder are made of copper or bronze. British textbook of Explosives www.ssrichardmontgomery.com

RATE OF COMBUSTION. -- The explosive properties of gunpowder are governed by the fact that it is a mixture of substances none of which is itself explosive, all interaction having to take place between particle and particle. Thus, fine grains, lack of glazing, and a porous nature, all tend to increase the rate of combustion, while an increase in the size of the grains, a glazed surface, and a greater density, all tend to diminish it.

As none of the ingredients of gunpowder is explosive, and as it is only a mechanical mixture, it cannot be detonated. Its rate of combustion, however, is rapid compared with smokeless propellants. Thus, in a gun it gave a high and very rapidly attained maximum pressure, but the pressure rapidly fell off and was not well sustained during the passage of the projectile down the bore.

More than half (56 per cent) of the products of combustion of gunpowder are solids at the ordinary temperature. These solid products were the source of two of the many disadvantages of gunpowder as a propellant, since they caused rapid fouling of the weapons, and produced large clouds of dense white smoke on discharge.

STABILITY AND STORAGE. -- Gunpowder can be stored indefinitely in any climate provided it is kept perfectly dry. When wet, gunpowder is difficult to ignite, and if allowed to remain damp, the potassium nitrate tends to segregate and may be absorbed from the gunpowder by paper unless this is varnished. Moreover, potassium nitrate will react readily with copper and other metals in the presence of moisture.

SERVICE USES. -- Although it has been almost entirely superseded as a propellant by the smokeless powders, gunpowder is still widely used in a number of other directions, e.g. --

- (i) Igniters for cartridges. British textbook of Explosives www.ssrichardmontgomery.com
- (ii) Magazines of tubes, primers, and igniferous fuzes.
- (iii) Bursting charges in certain types of projectile, e.g., shrapnel, star, and base ejection shell.
- (iv) Priming compositions for certain pyrotechnic stores.
- (v) Delay compositions.
- (vi) Blank charges.
- (vii) Propellant for certain pyrotechnic stores and for some smooth-bore weapons.
- (viii) Ingredient of certain combustible compositions such as cap composition, Q.F. compositions, etc.
- (ix) Safety fuze.

25. SULPHURLESS GUNPOWDER.

Sulphurless gunpowder consists of a mixture of 70.5 parts of potassium nitrate and 29.5 parts of charcoal. It was originally introduced for the igniters of cordite cartridges because the sulphur in ordinary gunpowder was liable to cause a reduction in the stability ("sulphur infection") of cordite Mk. I.

Its use in igniters is now obsolete, but it is used to a considerable extent in pyrotechnic stores, since many pyrotechnic compositions form sensitive or unstable mixtures with sulphur.

It is manufactured in several sizes of grains, the two following being the most widely used. British textbook of Explosives www.ssrichardmontgomery.com

- (a) **SULPHURLESS MEAL POWDER**, in which all the grains must pass B.S. Mesh Sieve No. 150 and not more than 25 per cent, must be retained on B.S. Mesh Sieve No. 240.
- (b) **S.F.G. 12**, in which all the grains must pass a B.S. Mesh Sieve No. 8, and at least 75 and 94 per cent, respectively must be retained on B.S. Mesh Sieves No. 16 and No. 18.

26. TIME-FUZE COMPOSITIONS.

Time-fuze powders are made in a similar manner to gunpowder, but great care is taken in the selection, manufacture and blending of the constituents. The powders are made in lots and carefully blended, so as to obtain the specified time of burning.

The time of burning of a fuze composition can be varied within limits, by three means: --

- (a) **CONTROL OF THE TIME OF INCORPORATION.** -- The rate of burning increases with the milling up to a maximum time. Milling for any longer period has no effect on the rate of burning, but may be slightly beneficial in other directions.
- (b) **TREATMENT AND BLENDING OF THE CHARCOAL.** -- Charcoal from different woods may be blended to give definite times of burning. For example, the charcoal from *lignum-vitae*, a hard wood, can be used as a slowing agent. Variations in the temperature and duration of the charring produces charcoals which vary in their effects on the rate of burning.
- (c) **BLENDING OF DIFFERENT POWDERS.** -- Powders which burn at different rates may be blended to produce a powder with the desired mean time of burning.

The factors affecting the successful operation of a time fuze are briefly these:

- (a) **External factors** including spin, pressure on the burning surface, temperature of the composition in the rings, humidity of the air.
- (b) **Internal factors**, which are those inherent in the fuze composition itself, e.g., formation and nature of slag. The fluidity of the slag of fuze powders of the gunpowder type is increased by the proportion of sulphur. Some of the fuze powders used in the service are given in the following table.

Fuze Powder	Composition	Remarks
22-sec. Powder and 30-sec. Powder	Potassium nitrate 75 per cent Sulphur 9 per cent Charcoal 16 per cent	
S.R. 227 and S.R. 227 A	Potassium nitrate 72 per cent Sulphur 7 per cent charcoal 21 per cent	S.R. 227 A is a finer grain- ed powder, made from the finer material obtained dur- ing manufacture of S.R. 227 Composition designed for A.A. time fuzes
R.D. 202	Ammonium perchlorate 77 per cent Charcoal 20 per cent Starch 3 per cent	Long-burning, slagless com- position.

27. PYROTECHNIC COMPOSITIONS.

Pyrotechnic compositions may be divided, according to their use, into the following classes: --

- (a) Illuminating compositions.
- (b) Signal compositions.
- (c) Incendiary compositions.
- (d) Smoke compositions. (Considered here for convenience.)
- (e) Priming compositions.
- (f) Tracing compositions.

Pyrotechnic compositions are combustibles which burn with an intense or with a distinctive flame. They are normally mixtures which will burn in the absence of air. They therefore require two main constituents, a combustible material and an oxygen producer. There may also be substances to produce colour, to alter sensitivity, to increase stability, or to regulate the burning. British textbook of Explosives www.ssrichardmontgomery.com

The combustible materials in common use are charcoal, metallic powders, lactose, woodmeal, sulphur, and antimony sulphide. Lactose and wood meal may also be used to assist in regulating the rate of burning.

Oxygen is provided by chlorates, perchlorates, or nitrates.

A binding material, such as paraffin wax, boiled linseed oil, shellac, or acaroid resin, may be included in the composition. These substances may also act as moderants, and have the properties of reducing sensitiveness, waterproofing, preserving metallic powders from oxidation, and assisting in regular burning.

28. ILLUMINATING COMPOSITIONS.

The majority of the compositions designed for illuminating purposes, such as those used in star-shells, tracers, etc., consist of mixtures of magnesium or aluminium powder with oxidizing agents such as barium nitrate or potassium nitrate. Other ingredients, such as strontium carbonate, are added if it is desired to modify the colour of the light, and others, such as paraffin wax or boiled linseed oil, are added to reduce the sensitiveness of the mixture and to prevent deterioration in the presence of moisture.

Illuminating compositions in general, when compressed, are not easily ignited, and it is necessary to prime them with some more easily ignited composition.

29. SIGNAL COMPOSITIONS.

These compositions are of two main types: --

- (a) Those which produce a coloured light. -- These are used for night signals, or for signals which may be used by day or night. The chief requirement of these compositions is a distinctive colour. The colour is obtained by the inclusion in the composition of an appropriate metallic salt, e.g. -- British textbook of Explosives www.ssrichardmontgomery.com

Metal	Flame colour
Sodium	Yellow
Barium	Green
Strontium	Red

The combustible material used in these compositions will depend on whether only night signals are required, or whether the signal should be visible by day and night. At night, sources of light of small intensity are visible from long distances and combustible materials such as charcoal, sulphur, shellac, lactose, etc., provide sufficient illumination. Metallic powders (e.g., aluminium and magnesium) are employed when a greater intensity of light is required to make the signal visible and capable of recognition by day.

The oxygen carrier in these compositions may be a chlorate, perchlorate, or nitrate. A disadvantage of chlorate compositions is that contact with sulphur gives rise to sensitive and unstable mixtures which, under

severe conditions of storage, may inflame spontaneously. The priming compositions used with mixtures containing chlorates should therefore be free from sulphur, e.g., sulphurless gunpowder should replace gunpowder.

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- (b) **THOSE WHICH PRODUCE A COLOURED SMOKE.** -- Coloured smoke compositions are sometimes used for daylight signalling. The resulting smokes consist of clouds of particles condensed from the vapour of an intensely coloured material, usually a dyestuff.

In the compositions the dyestuff is intimately mixed with a suitable combustible such as cane or milk sugar, and an oxygen carrier such as potassium chlorate. The heat produced by the composition must not be too great and must be sufficient to volatilize the dyestuff but not to burn it up.

30. INCENDIARY COMPOSITIONS.

Most illuminating compositions, on account of the high heat of combustion of magnesium and aluminium, are capable of exerting an incendiary effect. By modifying the proportions of the ingredients, this property can be accentuated, and the composition used for incendiary purposes.

An incendiary mixture should produce either a hot molten mass or a persistent flame effect. When ignited, it should be difficult to extinguish. The material to be ignited by the mixture will naturally influence the choice of ingredients.

Two typical incendiary compositions are: --

THERMIT		S.R. 306	
Hammer scale	76	Aluminium powder	20
Aluminium powder	24	Hammer scale	40
		Barium nitrate	35
		Boric acid	5

White phosphorus is sometimes used for incendiary purposes e.g., cartridges 303-in. B, Mk IV. Oil may also be employed to produce an incendiary effect.

31. SMOKE PRODUCERS.

Smoke-producing substances are used for two main purposes --

- (a) **SMOKE SCREENS.** -- Certain materials are employed in smoke generators, shells, bombs, and grenades, for screening objects. The smoke produced by these ammunition stores is almost invariably white. It is normally produced by dispersing substances which absorb, or react with, the moisture in the air. Consequently, they form a better screen in moist than in dry air. British textbook of Explosives www.ssrichardmontgomery.com

Until comparatively recently the standard smoke-producing substance was white phosphorus, which burns in air to form the hygroscopic phosphorus pentoxide, which is readily converted to phosphoric acid by absorption of atmospheric moisture.

Phosphorus has one advantage over other smoke compositions in that the oxygen necessary for combustion is obtained from the air, and not from an oxidizing agent mixed with it. The yield of smoke-producing substance from a given volume of filling is thus high, the air contributing more than half the weight of phosphorus pentoxide produced.

White phosphorus ignites in contact with the air and therefore does not require any igniting composition; but this advantage is outweighed by the added fire risks in storage and in transport.

Another disadvantage of phosphorus is its high temperature of combustion resulting in the formation of convection currents in the air which carry the smoke upwards with consequent loss of screening effect. This phenomenon is known as "pillaring."

Phosphorus is filled into shells, bombs, etc., which are arranged to burst on percussion at the point where the smoke screen is required.

Owing to the disadvantages of phosphorus, hexachlorethane mixtures are now used very extensively as fillings for smoke-screening stores. They depend for their action on the production of zinc chloride, which is produced by the interaction of zinc oxide and hexachlorethane. The zinc chloride is volatile and very hygroscopic, picking up moisture from the air to form a dense cloud. There is little heat in the reaction, and for this reason "pillaring," which is an objectionable feature of the white phosphorus types, does not occur. Calcium silicide is included in these hexachlorethane mixtures to keep the reaction going. Another advantage of the hexachlorethane mixtures over white phosphorus is that they do not ignite in contact with the air, and are therefore safer in storage and transport; but they entail the use of an igniting composition.

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- (b) SMOKE FOR OBSERVATION OF BURST. -- Where little or no smoke is produced by the burst of a projectile, or where the smoke produced is of an unsuitable colour for easy observation, it may be necessary to include a smoke-producing substance in the filling.

These smoke-producing substances can be considered under two headings:--

- (i) SUBSTANCES USED TO PRODUCE SMOKE ONLY. -- Of these, the most important is red phosphorus. The phosphorus, mixed with a small percentage of mineral jelly, is pressed into pellet form in a mould. The pellets are filled into a suitably shaped box of aluminium, steel, or plastic. The smoke boxes are inserted into the shell immediately below the exploder system. Particulars of red phosphorus smoke boxes used in the service are given in the following table: --

RED PHOSPHORUS SMOKE BOXES

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Smoke Box	Material of Box	Shape	Uses
Box, Smoke, 2- $\frac{1}{4}$ -oz.	Steel	Cylindrical	H.E. shell
Box, Smoke, 1- $\frac{1}{2}$ -oz.	Aluminium	Cylindrical	H.E. shell
Box, Smoke, 1- $\frac{1}{4}$ -oz.	Plastic	Cylindrical	H.E. shell
Box, Smoke, 1- $\frac{3}{4}$ -oz.	Plastic	Bowl-shaped	Chemical shell (base-ejection)
Box, Smoke, 1- $\frac{1}{4}$ -oz.	Plastic	Bowl-shaped	Chemical shell (base-ejection)

TITANIUM TETRACHLORIDE is sometimes used as a smoke filling, e.g. in certain smoke bombs for the 3 in. and 4.2 in. M.L. mortars. It is a volatile liquid which when scattered by a small explosive charge, interacts with the moisture in the air to produce a white smoke.

- (ii) SUBSTANCES USED TO PRODUCE A SMOKE AND EXPLOSIVE EFFECT. - Various compositions are used to produce a combined high explosive and smoke-producing effect. There are two main types of composition. -

- (1) MIXTURES, EXPLOSIVE AND SMOKE -- These compositions are used with certain H.E. shell fillings, such as amatol, in order to produce smoke for observation of burst and maintain the efficiency of the shell. These compositions are included in the actual bursting charge of the shell. There are three mixtures--
MIXTURE, EXPLOSIVE AND SMOKE, No. 4, which consists of
amatol 80/20, 25 per cent; aluminium powder 75 per cent.

MIXTURE, EXPLOSIVE AND SMOKE, No. 5, which consists of ammonium nitrate, 56 per cent; T.N.T., 14 per cent; ammonium chloride, 30 per cent.

MIXTURE, EXPLOSIVE AND SMOKE, No. 7, which consists of ammonium nitrate, 40 per cent; T.N.T., 20 per cent; ammonium chloride, 40 per cent.

- (2) FUMYL.--Fumyl is used with bursting types of chemical shell and certain old designs of bursting smoke shell. There are three Fumyl compositions.--

FUMYL MK. I, which consists of T.N.T., 60 per cent; ammonium chloride, 40 per cent.

FUMYL MK. II, which consists of T.N.T., 45 per cent; ammonium chloride, 40 per cent; ammonium nitrate, 15 per cent. British textbook of Explosives www.ssrichardmontgomery.com

FUMYL MK. III, which consists of composition exploding, 38 per cent; aluminium powder, 24 per cent; sodium chloride, 35 per cent; boiled linseed oil, lead free, 3 per cent.

Chlorsulphonic acid referred to as C.S.A. and a mixture of chlorsulphonic acid and sulphur trioxide referred to as C.S.A.M. are also used as smoke producing materials in certain bursting types of mortar bombs and grenades.

32. PRIMING COMPOSITIONS.

Most illuminating, signal, incendiary and smoke-screen compositions are difficult to ignite and it is therefore necessary to prime them with some more easily ignited material. Although gunpowder and sulphurless gunpowder are used very extensively for this purpose, there are also special priming compositions which normally contain gunpowder mixed with certain other ingredients. S.R.252 is a typical priming composition which is very extensively used.

S.R. 252

Potassium nitrate	40 parts
Silicon	40 parts
Gunpowder, sulphurless, mealed	20 parts

33. TRACING COMPOSITIONS. British textbook of Explosives www.ssrichardmontgomery.com
Tracing compositions, used in tracers or in tracer cavities of projectiles, are pyrotechnic mixtures which are normally ignited by the flash from the propellant gases, through an intermediate layer of priming composition to ensure a more reliable action. Tracing compositions are comparatively simple in their make up, containing a combustible such as magnesium powder, an oxygen producer -- generally a nitrate -- a colour producer (which may be the oxygen producer also e.g. strontium nitrate) and a binding material of the nature of shellac or beeswax. The composition may be varied to give a trace suitable either for day or for night use.

Typical compositions are:

Day tracer		Night tracer	
S.R. 372		S.R. 190	
Magnesium powder	40	Magnesium powder	23.5
Strontium nitrate	45	Barium nitrate	58.5
Beeswax	5	Graphite	6
Shellac	5	Chinese wax	7
Alloprene	5	Acaroid resin	5

A	Page	C-continued	Page
ABEL, Sir F	11	CHARCOAL	
ACETONE		In Gunpowder	29
Solvent for cordite	11	In sulphurless gunpowder	30
Solvent for T.N.T.	25	In pyrotechnic compositions	32
AIR GAP	2	In signal compositions	32
ALCOHOL		In time-fuze compositions	31
Solvent for propellant manuf.	8	CLASSIFICATION of EXPLOSIVES	1
ALKALIES		CODE LETTERS of PROPELLANTS	18
Reaction with C.	23	COLD PRESSING of AMATOL	27
Reaction with T.N.T.	25	CONFINEMENT & DETONATION	2
ALL BURNT POSITION	4	COMPOSITIONS	
ALLOPRENE in S.R. 372	35	Cap	22
ALUMINIUM		Detonator	21
In Burrowite	29	Q.F.	22
In illuminating compositions	32	COMPRESSION	
In incendiary compositions	33	Effect on sensitivity	20
In signal compositions	32	CORDITES -- see Propellants	
In smoke mixture	34, 35	Composition and Properties	10
Incompatible with fulminate.	20	General properties	11
AMATOL	26	Solventless	11
AMMONIUM CHLORIDE		Cool burning	14
In smoke mixtures	35	CORROSION -- see METALS	
AMMONIUM NITRATE		CRYOLITE	10
In amatol	26	C.S.A. (chlorsulphonic acid).	35
Effect on metals	27	C.S.A.M.	35
Formation from picric powder	23	D	
AMMONIUM PERCHLORATE	31	DANGER in cordite manufacture	12
AMMONIUM PICRATE	29	D.C.A. (Detonator Compositions A, B.C., and D)	21
ANTIMONY SULPHIDE		DEAD PRESSING of fulminate	
In cap composition	22	of mercury	20
In detonator compositions	21	DECOMPOSITION of CORDITE	12
In Q.F. composition	22	DENSITY of EXPLOSIVE	3
In pyrotechnic composition	32	DENSITY of FILLING	
A.S.A.	21	H.E. shell	19
AZIDE		Amatol	27
Lead	20	Baratol	28
Silver	2	DERMATITIS	
B		From C.E.	23
BALLISTITE	10	From T.N.T.	25
BARATOL	28	DESENSITIZER for P.E.T.N.	23
BARIUM NITRATE		DETONATION	
In baratol	28	Nature of	2
In illuminating compositions	32	Velocity of	2, 3
In incendiary compositions.	33	Velocity of (Table)	2
In N.C. (Y)	10	Velocity of in amatol	26
BOFORITE	14	Velocity of in lyddite	24
BORIC ACID	33	Velocity of in P.E.T.N.	23
BURNING OF PROPELLANTS	3	Velocity of in T.N.T.	25
BURROWITE	29	Sympathetic	19
BURSTING CHARGES	24	Sympathetic in lyddite	19, 24
C		Sympathetic in pentolite	28
CALCIUM SILICIDE	34	Sympathetic in R.D.X.	28
CALCIUM STEARATE	29	Sympathetic in T.N.T.	26
CAMPHOR	10	By impact on armour	24, 26
CANNON POWDERS		DETONATOR COMPOSITIONS	21
See Propellants	15	DEWAR, Prof. J.	11
CAP COMPOSITION	22	DEXTRINATED LEAD AZIDE	21
CARBAMITE		DIBUTYL PHTHALATE	
As gelatinizer	8	In propellants	10
As stabilizer	9	In 823	29
Per cent in propellants	10	DINITRO PHENOL	
CARBON MONOXIDE	11	In shellite	*25
CATALYSTS		In tridite	29
Cordite decomposition	11	DINITROTOLUENE	10
C.E. (Composition Exploding)	23	DIPHENYLAMINE	
CELLULOSE	9	In propellants	10
CHALK in propellants	10	In N.C.	15
CHAMBER PRESSURE	3, 4	DUPONT PROPELLANTS	10

1--continued	Page
LEAD	
Reaction with picric acid	24
Reaction with shellite	25
LEAD AZIDE	20
LEAD PICRATE	24
LEAD STYPHNATE	21
LINSEED OIL In pyrotechnics	32
LYDDITE	24
incompatibility with C.E.	23
M	
MAGNESIUM	32
MEALD POWDER	22, 29
MELINITE	24
MERCURY FULMINATE, see fulminate	
METHYL CENTRALITE	9
METALS	
reaction with amatol	27, 28
reaction with fulminate	20
reaction with gunpowder	30
reaction with lead azide	20
reaction with lyddite	24
MINERAL JELLY	
as stabilizer	9
per cent in propellants	10
in smoke producers	24
MOISTURE	
effect on amatol	27
effect on ammonium nitrate	27
effect on cordite	12
effect on fulminate	20
effect on lead azide	20
effect on gunpowder	30
effect on picric powder	23
MONONITROTOLUENE	29
MULTI-TUBULAR PROPEL- LANTS	18
N	
NITRIC ACID	24
NITROCELLULOSE PROPEL- LANTS see Propellants	8,9,10,15
NITROGLYCERINE	10
NOBLES EXPLOSIVES	29
NOBELS SUPERIM	10
O	
OBSERVATION of BURST, Smoke for	34
P	
PARAFFIN WAX	32
PENTOLITE	28
PERTITE	24
P.E.T.N. (PENTHRITE)	23
PHOSPHORUS RED	34
PHOSPHORUS WHITE	33
PICRATES	24
PICRIC ACID	23,24,25
PICRIC POWDER	22
PICRITE	10
PILLARING	34
POTASSIUM CHLORATE	
in coloured smoke	33
in cap composition	22
in detonator composition	21
in Q.F. composition	22

P--continued	Page
POTASSIUM NITRATE	
in gunpowder	29
reaction with copper	30
in gunpowder sulphurless	30
in illuminating compositions	32
in picric powder	22
in propellants	10
in time-fuze compositions	31
in S.R. 252	35
POTASSIUM PICRATE	23
POTASSIUM SULPHATE	10
POWER OF H.E.s	18,27
PRESSURE	
chamber with gunpowder	30
PRESSURE SPACE RELATIONSHIP	4
PRIMING COMPOSITIONS	35
PROPELLANTS	
burning	3
controllability	4
double based	8
form	4,17
ideal	6
table of compositions and prop- erties	10
ballistite	10,16
cordite-Bafors	9,14
H.S.C.	8,9,10,11,14
H.S.C.T./K.	15
M.C.	9,10,11,12,13
M.D.	8,9,10,11,12,13
M.D.C.	13
Mk. I	8,9,10,11,12,13
N	8,10,11,14
N/P	14
NQ	8,10,11,14
R.D.B.	8,9,10,11,12,13
RDN/AQ	14
RDQ	14
S.C.	8,9,10,11,12,13
S.U.	13
W	8,9,10,11,12,14
W.M.	8,9,10,11,14
N.C. powders--FNI	9,10,16
FNI/P	10,16
H.C.(Y)	10,16
N.C.T.	9,10,15
N.C.Z.	16
NH	9,10,15,16
Neonite	16
Superim	10,17
Hercules 81-mm.mortar powder	10,17
M,4X. (Dupont)	10,17
PYROTECHNIC COMPOSITIONS	32
Q	
Q.F. COMPOSITION	22
R	
R.D. 202	31
R.D.X.	28
RESIN acaroid	32
S	
SCREW FILLING	27
SENSITIVENESS	
see Figure of Insensitiveness	
SHELLAC	32
SHELLITE	25
SHIMOSE	24
SIGNAL COMPOSITIONS	32
SILICON in S.R. 252	35
SILVER AZIDE	2
SILVER FULMINATE	2

S--continued	Page
SIZE OF PROPELLANTS	17
SLAG in TIME-FUZE	
COMPOSITIONS	31
SMOKE	
for observation	19
boxes	24
amatol burst	28
lyddite burst	24
coloured	33
mixtures explosive and smoke	34
producers	33
SODIUM compounds in signal compositions	32
SODIUM CHLORIDE in smoke mixtures	35
SODIUM NITRITE	21
SODIUM SULPHATE	10
SODIUM THISULPHATE	20
SOLVENTS	
propellant manufacture	8
residual in propellants	15
SPONTANEOUS IGNITION	7
S.R. 190	35
S.R. 227	31
S.R. 252	35
S.R. 306	33
S.R. 372	35
STABILITY	
cordite	11
fulminate of mercury	20
lead azide	20
picric powder	23
propellants	7
STABILIZERS	9,11
STRACH in time-fuze compositions	31
STRONTIUM compounds	
in signal compositions	32
in illuminating compositions	32
SULPHUR	
in gunpowder	29
in cap composition	22
in pyrotechnic compositions	32
in Q.F. composition	22
in signal compositions	32
in time-fuze compositions	31
SUPERIM (Hobell's)	10,17
SWEATING of CORDITE	12
T	
TETRYL	23
THERMIT	33
TIME FUZE COMPOSITIONS	31
TITANIUM TETRACHLORIDE	34
T.N.T. (Trinitrotoluene)	25
in amatol	26
crystals	23
TRACING COMPOSITIONS	35
TRIDITE	29
TRIMONITE	29
TRINITROPHENOL	24
in shellite	25
V	
VARNISHES	24
VELOCITY of DETONATION see DETONATION	
W	
WAX desensitizing	23
WEB SIZE	15
WOODMEAL	32
Z	
ZINC CHLORIDE	34
ZINC OXIDE	34