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AUSTRALIAN MILITARY FORCES

(6)

SUBJECT:- PROPELLANTS

Prepared and Issued

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AMMUNITION WING

Publication No.

Date

A.J.S.—5M—10/44

LHQ AAOC SCHOOL

AMMUNITION WING

RESTRICTED

JUNE 45

# PROPELLANTS

BRITISH — Types - Composition, Examination, Tests.

AMERICAN — General Notes.

ENEMY PROPELLANTS.

The information contained in this publication has been extracted from the following :-

RAOS Part 8, Pamphlet 7
Text Book of Ammunition 1936
Text Book of Ammunition 1943
Text Book of Explosives 1938
Notes on North American Equipment and Stores, Sect. 9 Amn.
C.I.O.O's Circulars

Supplemented by research by AAOC School staff.

## DEFINITION OF A PROPELLANT.

A propellant is an explosive, which, by its regularity of burning, produces moderately high and sustained gas pressure in the bore of the 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 the propellant when used under the conditions for which it is intended.

## BURNING OF A PROPELLANT.

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

   (a) Burning is purely on the surface and normal to the surface; that is to say, at right angles 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 rate of burning of the propellant. Two propellants of the same calorific value may have wholly different rates of burning.

## POINT OF MAXIMUM PRESSURE.

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 slowly until all the propellant has been consumed. The pressure will then fall more rapidly because of expansion and heat losses.

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.

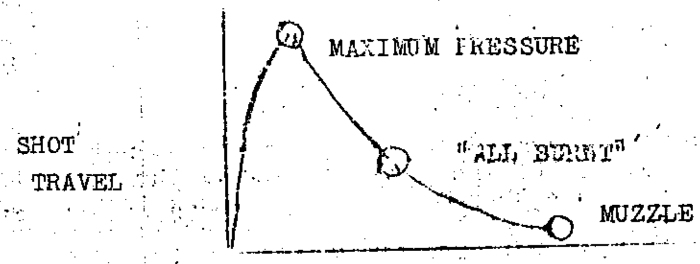
4. Notice, too, that the point of maximum pressure is reached very quickly. The maximum acceleration of the projectile results in very great "setback" effect on the projectile. This effect is important in the design of shell and fuzes.

## ALL BURNT POSITION

5. 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.

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. 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.




## PROPERTIES OF AN IDEAL PROPELLANT

According to the Text Book of Ammunition 1943, 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-BURNT" 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 the surface inwards.

If these three conditions are satisfied, the rate of pressure development depends upon the ratio. :-

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

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 the gun may cause pre-ignition of the following charge.

(d) IT SHOULD BE FLASHLESS

Muzzle flash and backflash 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 hight, 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 or tanks. Most propellants produce carbon monoxide on firing. (See appendix).

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

Erosion is a continuous and progressive process, and it is due to the hot washing action of the gases; being caused partly by their high velocity, but mainly by their high temperature. The rapid heating and cooling to which the bore of the gun is subjected further tends to disintegrate the surface metal.

(g) IT SHOULD BE EASY TO IGNITE

Most modern propellants are not easy to ignite, and the use of gunpowder 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. 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 neutralised, 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 magazine 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.

Hygroscopic explosives necessitate extra trouble in providing air-tight 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 variations 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.

## DEVELOPMENT OF SMOKELESS POWDERS.

Until about 1880 the only propellant used for military and sporting purposes was gunpowder, but with advent of modern high power explosives the invention of new and correspondingly powerful propellants was inevitable. The nitrocellulose propellants are superior to gunpowder not only in power, but also by reason of their smokeless nature, their definite rates of burning, and their resistance to damage by wetting.

Nitrocellulose is the basis of nearly all smokeless powders, but it cannot be used as a propellant in its fibrous form. When it is ignited in confinement the hot gases of the combustion are forced by the pressure into the pores of the unburnt material and the rate of burning is progressively increased, exerting an excessive and uneven pressure. The rate of burning may be reduced by compressing the nitrated cotton or by mixing it with certain inert materials or with cooling agents; but the most effective control is achieved by gelatinising the explosive, thereby rendering it non-porous.

The first successful smokeless powder was made by Major Schultz of the Prussian Artillery in 1865. It consisted of a species of nitrolignese impregnated with saltpetre or barium nitrate. Another highly successful smokeless propellant was E.C. powder, manufactured by the Explosives Company at Stowmarket. This was introduced in 1882 and consisted of a mixture of nitro-cotton and nitrates of potassium or barium in the form of grains hardened by being partly gelatinised in ether-alcohol.

These powders were highly successful as charges for sporting gun cartridges, but their action was too rapid for rifle weapons. In 1885 the introduction of small calibre magazine rifles made the problem of securing a suitable smokeless propellant urgent. It became realised that to obtain the degree of slowness required the structure of the original cellulose had to be entirely destroyed by gelatinising it.

The first service propellant of this type was Poudre B, adopted in France in 1886. This was made by gelatinising a mixture of guncotton and collodion cotton (soluble nitrocellulose) with ether-alcohol and working up the paste into small squares of a dry horn-like material.

Ballistite (see page 26) invented by Alfred Nobel, followed in 1888, and other powders began to appear on the Continent.

In England, experiments resulted in the production of the first cordite which was introduced into the service in 1893.

## MODERN PROPELLANTS

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. Cordite belongs to the latter.

Until the beginning of the present war, 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 requirement, to purchase single-base propellants from the U.S.A. Certain single-base propellants are manufactured for special purposes, such as for S.A.A. and mortar ammunition.

To bring out the gelatinisation of nitrocellulose for the manufacture of propellants, the methods adopted are :-

(a) Single-base types (Nitrocellulose powders) Volatile solvents such as ether alcohol have to be used.

(b) Double-base types (Cordites, etc.)

(i) By the action of a volatile solvent, such as acetone or ether-alcohol.

(ii) By the action of heat in the presence of a gelatiniser such as carbamite.

Nitrocellulose propellants 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 nitrocellulose of high nitration and of a substantial proportion of water-repellant ingredients (dini trotoluene and dibutylphthalate).

(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 combustion of solvent is high.

(e) They are liable to give sporadic high pressure 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 container, 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 are :-

(a) They are cooler burning and therefore less erosive than the majority of double-based propellants.

(b) They give considerably less flash than ordinary cordites.

(c) Their ballistics are less affected by changes in charge temperature.

(d) Theyrequire less fats or oils or other foodstuffs, as nitroglycerine is not used.

(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.

Cordite is the name applied to a group or series of propellants which consist of nitroglycerine, nitrocellulose and a stabilizer, incorporated together and gelatinised with the aid of a suitable solvent. Other substances may be included to reduce flash, etc.

By gelatinisation, the fibrous nature of the nitrocellulose is destroyed and it is converted into a colloidal form which is capable of being worked into any convenient shape.

This dense substance will burn comparatively slowly and regularly from the surface inwards, even under the pressure set up during its combustion in a gun. The rate of burning can, therefore, be controlled. Pressure increases the rate of burning and high initial pressures such as would strain or burst the gun are avoided by the use of a suitable size of cord.

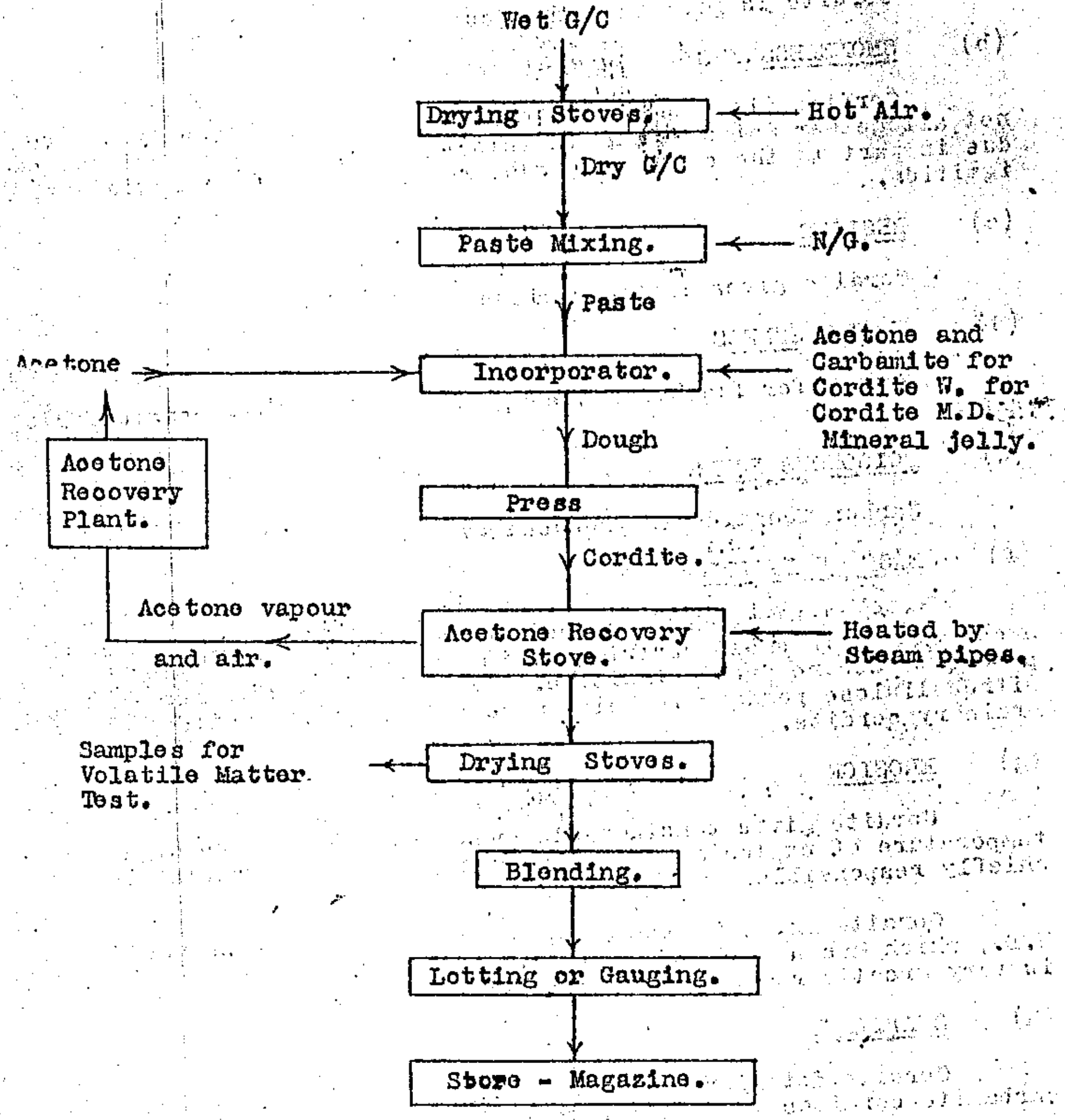
Cordite varies in colour from light to dark brown, but this natural colour is lost in certain types in which the stabilizer has for identification purposes been dyed; the practice of dyeing the stabilizer is now to be discontinued.

It is poisonous and has little smell, but certain cordites have a slight but pungent odour which is due to the stabilizer which is used. Some kinds resemble hard rubber, but others are brittle and easily fractured. Ignited in the open it burns away fiercely though if large quantities are packed close together there is danger of explosion.

Although by no means the ideal propellant, cordite has stood the test of time - several other propellants have been introduced as substitutes but they are not so generally efficient as cordite. It must be considered one of the most successful smokeless powders ever produced and it still remains the standard propellant in our Service.

The propellant is usually employed in the form of sticks or cords ( hence the name "Cordite") though this is by no means invariably the case.

FLOW DIAGRAM FOR MANUFACTURE OF CORDITES M.D. & W.




NOTE: The process is identical for the manufacture of Cordites M.D. or W., the only difference being that M.D. has Mineral Jelly as a stabilizer, while W. has Carbamite.

## COMPARISON OF THE PROPERTIES OF THE IDEAL PROPELLANT WITH THOSE OF CORDITE

(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 flashless types, all cordites give considerable flash.

(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.

Cordite Mk. I 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 effect stability are :-

(i) High storage temperatures - The rate of decomposition reaction increases approximately 1.8 times for every 10° 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 cordites. 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 nitro-cellulose is also very harmful because of the acid products it introduces.

(A catalyst is a substance which assists a chemical change in another substance).

(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.

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 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 moderate climatic conditions. The figure 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 carbamite 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 loss of stabilizer and the stability is affected in consequence.

(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.

SUBSTANCES USED IN THE MANUFACTURE OF CORDITE

CELLULOSE

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

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 term "soluble" and "insoluble" applied to nitrocellulose refers 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. of nitrogen is called guncotton.

Nitrocellulose made from cotton and soluble in ether-alcohol is known as collodion cotton.

## NITROGLYCERINE

N/G is a colourless oil of a specific gravity of 1.6, which is only very sparingly soluble in water, but is readily soluble in organic solvents (alcohol, acetone, etc.) N/G is very poisonous giving rise to violent headache ("N/G head") even by the absorption of minute quantities through the skin. Workers in factories, however, soon become inured to those effects and are no longer troubled by them. Cordite (which contains N/G), if eaten, gives rise to a relapsing fever which resembles the "trench fever" of the 1914-1918 War.

N/G is slightly volatile, decomposes without boiling when heated and ignites at about 180°C, to burn quietly with a flame whose edges are tinged with green.

The use of N/G is somewhat restricted by its sensitivity and its liquid condition.

N/G is gradually hydrolyzed by moisture in the presence of either an acid or an alkali. It possesses inherent instability, the acid products of its breakdown serving to accelerate its rate of decomposition unless they are freely allowed to escape or are neutralized by some stabilizer.

N/G is a very powerful explosive with a maximum velocity of detonation of 8,000 metres per second, and is very sensitive to impact or friction. It is an important constituent of dynamite, blasting gelatine and gelignite; but by far its most important use in the service is for the manufacture of the cordite propellant.

## STABILIZERS.

Both nitrocellulose and nitroglycerine are unstable substances. The decomposition products are positive catalysts which will accelerate the rate of decomposition.

### The action of, and choice of stabilizers.

These are substances which will combine with, and so render inactive, the decomposition products of cordite, which products would otherwise accelerate the further decomposition of the remaining cordite. It is clear that the stabilizer must not react with the cordite itself, although it must be so well incorporated with the other constituents of the cordite as to give a homogeneous colloid.

An ideal stabilizer must have the following properties :-

(a) Must absorb oxides of nitrogen.
(b) Must be capable of neutralizing any acid in the propellant.
(c) Must form a colloidal solution with the nitrocellulose or nitroglycerine.
(d) 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 :-

(i) Mineral jelly, which is used in Cordite Mk. 1 M.D., R.D.B., and W.M., and "cracked" mineral jelly in Cordite M.C. It only satisfies (a) and (d) above.

(ii) Diphenylamine, which is used for certain nitrocellulose powders, such as N.C.T., NH., and FNH. It fails to satisfy condition (c) above and tends to accumulate in spots on the surface of the nitrocellulose.

(iii) Carbamite, which is used in Cordites, S.C., H.S.C., W and W.M. It agrees with the above conditions.

(iv) Methyl, centralite, which is used in Bofors Cordite and many single-base propellants. Besides being a good stabilizer with propellants very similar to those of carbamite, is also useful as a moderant in nitrocellulose propellants. In this connection its high melting point (121°C. as against 72.5°C for carbamite) is advantageous.

The earlier variations 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.

NOTE:- Land service cordites containing carbamite employ a dye in the manufacture to ensure that the carbamite has been included - the presence of this dye imparts a violet colour to the cordite. However, in Australia, advice has been received that production of Cordite W or WM, using carbamite, dyed Violet, has not been satisfactory from the point of view of colour. While all carbamite used since the change over to dyed materials, has been found to contain the correct quantity of dye, the resultant colour varied from normal amber colour met with in cordite entirely free from dye, through various shades of green, to a normal violet.

Considerable investigation into the probable cause of the colour variation has established fairly definitely that, with materials available in Australia (we have not the dyes as those used in U.K.), it is virtually impossible to obtain a satisfactory uniformity of colour.

The use of dyes of various colours may lead to confusion among I.O.O's when examining cordite so dyed and, as its continued use in the service serves no useful purpose, it has been recommended that in future <u>local</u> production, the dye will be omitted.

(C.I.O.O. Circular 15)

## 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. I, M.D., MC., W.M., N., and NQ. Cordite R.D.B. employs 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.

### ACETONE

Acetone is a colourless volatile liquid of characteristic odour. Its importance in explosives lies in its ability to dissolve highly nitrated nitrocellulose (over 13.0 per cent. nitrogen).

### ETHER-ALCOHOL.

The soluble nitrocelluloses (up to 13.0 per cent. nitrogen) are distinguished from those which are termed insoluble by their being dissolved in a mixture of ether and alcohol, maximum solvent power being obtained with a mixture of ether and alcohol in the proportion of 2 to 1.

Ether or alcohol alone will not dissolve any but the lowest nitric esters of cellulose.

While endeavouring to avoid someof the objectionable features of Ballistite, which is hot burning, erosive, and not very stable, Sir Frederick Abel and Professor Dewar found that the solution of guncotton and nitroglycerine could be achieved by mixture with a liquid capable of dissolving them both, and, on evaporating off the liquid (acetone) the guncotton and nitroglycerine remained behind in a gelatinous mass.

Mineral Jelly was originally introduced as a lubricant to reduce the wear on the bore of the gun, but it was found subsequently by investigations on the keeping properties of cordite, that Mineral Jelly fulfilled the important function of acting as a stabilizer and prolonged the life of the cordite.

The composition of the first British smokeless powder made on this principle, and introduced into the Service in 1893 was :-

| | |
|---|---|
| Nitroglycerine ............... | 58 per cent. |
| Nitrocellulose ............... | 37 per cent. |
| Mineral Jelly ............... | 5 per cent. |

This was originally called CORDITE, on account of the cord like form into which it was pressed.

On the introduction of Cordite M.D. the name was changed to CORDITE MARK 1 for the purpose of distinction.

CORDITE MARK 1 is soft and plastic, golden in colour and greasy to touch. It is smokeless but owing to its high nitroglycerine content, is hot burning and there fore very erosive. It gives considerable flash. The stability is not very good and it is more liable to sulphur infection than the later types.

Its use is now confined chiefly to certain S.A.A. (e.g. proof rounds, pistol ammunition).

## CORDITE M.D.

Experience with Cordite Mark 1 showed that , owing to the excessive erosion of the bore which it produced, shooting was rendered inaccurate after a comparatively small number of rounds had been fired. This was clearly demonstrated during the South African campaign.

Experiment check led to the adoption of a modified cordite known as CORDITE M.D. of the following composition :-

| | |
|---|---|
| Nitroglycerine .................. | 30 per cent. |
| Nitrocellulose .................. | 65 per cent. |
| Mineral Jelly .................. | 5 per cent. |

Compared with Cordite Mk. 1, it is cooler burning, less erosive, darker in colour, harder and more brittle. It is slower burning and therefore a smaller size is used in a given gun to obtain the same ballistics as Mk. 1, also larger charges of M.D. are required.

Because it is harder than Mk. 1. the decomposition products cannot escape so readily from it, and so in spite of the 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 in place of a small percentage of Mineral Jelly to improve its stability. It is then known as Cordite C.D.T.

The composition of Cordite C.D.T. is

| | |
|---|---|
| Nitroglycerine | .............. 30 per cent. |
| Nitrocellulose | .............. 65 per cent. |
| Mineral Jelly | .............. 4.5 per cent. |
| Carbamite | .............. 0.5 per cent. |

## CORDITE M.D.C.

Cordite M.D.C. is Cordite M.D. broken down and reworked with Carbamite. It is used chiefly in India.

## CORDITE M.C.

This is similar to Cordite M.D. except that the Mineral Jelly has been specifically treated with a view to increasing its stabilizing value and so prolonging the life of the cordite. This process is known as "cracking".

The composition is as follows :-

| | |
|---|---|
| Nitroglycerine | .............. 30 per cent. |
| Nitrocellulose | .............. 65 per cent. |
| "Cracked" Mineral Jelly | .............. 5 per cent. |

## CORDITE R.D.B.

R.D.B. is an abbreviation of Research Department "B" formula.

It was introduced into the British Service during 1914-18 War, to overcome the difficulties caused by the shortage of acetone.

The guncotton used in Cordite M.D. was replaced by soluble nitrocellulose to allow of the use of ether-alcohol instead of acetone as a solvent. The percentages of nitroglycerine and of Mineral Jelly were adjusted so as to give ballistics similar to those of cordite M.D. It compares favourably with M.D. in stability and is cooler burning.

Cordite R.D.B. is somewhat tougher and less brittle than Cordite M.D., but not so pliable as Mark 1. Its composition is as follows :-

| | | |
|---|---|---|
| Nitroglycerine | .......... | 42 per cent. |
| Nitrocellulose | .......... | 52 per cent. |
| Mineral Jelly | .......... | 6 per cent. |

CORDITE M.D.T. AND R.D.B.T.

These are Cordite M.D. and R.D.B. pressed in a tubular form to obtain increased burning surface. The former is used in small arm ammunition, and both are used with certain forms of gun and howitzer cartridges. M.D.T. is also used for certain practice charges where it is desired to arm a fuze with low velocity.

All the foregoing cordites are obsolescent except for minor uses. Certain cartridges have been filled during the present war with Cordites Mk. 1, M.D, M.C., or R.D.B. of last war manufacture. These Cordites were given an extension of their official life and the cartridges and packages distinguished by special markings.

INTRODUCTION OF CORDITES W & S.C.

After the War of 1914-1918, the War Office and the Admiralty initiated research into new types of propellant. The War Office required a propellant which should be free from flash and smoke. Cordite W. was evolved. This Cordite is essentially similar to Cordite M.D., being incorporated in a similar manner. In Cordite W. carbamite is used instead of Mineral Jelly as a stabilizer. It is somewhat superior to Cordite M.D., both in regards time of drying of the larger sizes and as regards stability.

The naval propellant, Cordite S.C. (i.e. Solventless carbamite) is unique in that no solvents are needed in its incorporation. This has the great advantage of dispersing with a large acreage of drying stoves for the larger sizes and of speeding up production, there being no long time for drying, as for Cordite M.D. or W.

CORDITE W.

The composition of this Cordite is as follows :-

| | | |
|---|---|---|
| Nitroglycerine | ............ | 29 per cent. |
| Nitrocellulose | ............ | 65 per cent. |
| Carbamite | ............ | 6 per cent. |

A very small quantity of chalk is included during manufacture.

"W" stands for Waltham Abbey, where Cordite W. was developed.

It is a modified form of M.D. Cordite, the carbamite replacing the Mineral Jelly and so increasing the stability with consequent gain in life. There is, however, a saving in acetone and there is also less time required to evaporate out the solvent in stove drying.

It is the standard propellant for the land service until Flashless Cordites can be produced in large enough quantities.

CORDITE W.M.

This Cordite is approved as a wartime alternative to Cordite W in order to economise in Carbamite, a small percentage of Mineral Jelly replacing a small percentage of Carbamite. Its properties are similar to Cordite W. but it requires a slightly larger stick in order to give the same ballistics as W.

Its composition is as follows :-

| | | | |
|---|---|---|---|
| Nitroglycerine | ........29.5 per cent | 0.6 per cent. | |
| Nitrocellulose | ........65 per cent | 0.6 " | " |
| Carbamite | .........2 per cent. | 0.15 " | " |
| Mineral Jelly | ......... 3.5 per cent. | 0.15 " | " |

A very small quantity of chalk is included during manufacture.

CORDITE H.W.

This is a modification of Cordite W for "hotter" burning and consequent high velocities for a comparatively small weight of charge. It contains a slightly higher percentage of Nitroglycerine than W. Cordite.

The composition is as follows :-

| | |
|---|---|
| Nitroglycerine .......... | 35 per cent. |
| Nitrocellulose .......... | 62 per cent. |
| Carbamite .............. | 3 per cent. |

SOLVENTLESS CORDITES.

The use of volatile solvents (e.g. acetone and ether-alcohol) in cordite manufacture entails various disadvantages. Their manufacture and import presents considerable difficulties in time of war.

In addition to these drawbacks, their use is attended by technical disadvantages. Recovery and drying stoves are necessary; these are expensive to erect, costly to maintain, and cover a large acreage. During the process of recovering and drying much time is occupied, and many weeks supply of Cordite is thereby held up; a serious matter in an emergency.

The stoving operation also reacts disadvantageously on the propellant, introducing irregularities in the Cordite consequent upon the shrinkage, which occurs during the evaporation of the solvent. The "Life" of M.D. Cordite is also appreciably affected by its maintenance at comparatively high temperatures (about 45°C.) for many days.

To overcome these difficulties, the "solventless" process was designed.

The principles employed are not very different from those underlying the manufacture of Ballistite. That is to say, the gelatinization of the nitrocellulose is mainly carried out by the nitroglycerine, but, to admit of the use of higher proportions of nitrocellulose than would be possible by this means alone, a high proportion of carbamite is added, which while acting as a stabilizer in the finished propellant, serves during manufacture to enhance the gelatinizing action of the nitroglycerine.

The name "solventless" Cordite is, therefore, somewhat misleading; the characteristic feature of the propellants being the employment of a <u>non-volatile</u> solvent.

The time occupied in manufacture is very much less than in the production of other forms of Cordite. It is, however, not quite so safe to manufacture, as the extremely viscous nature of the sheet Cordite necessitates the use of high temperatures and heavy pressure for extrusion. Particular attention has to be paid to the provision of screens, so that the workers are adequately protected. As an offset to this disadvantage, the entire absence of loose dry nitrocellulose must be noted.

## ADVANTAGE OF "SOLVENTLESS" CORDITES

1. Increased "life" of the propellant, and increased output in a given time are a result of the absence of the stoving operations which of necessity attend the use of a volatile solvent.

2. Initial expense and cost of maintenance are reduced, since the plant required for the manufacture of these Cordites is much smaller than is necessary for the production of other types.

3. The absence of the stoving and drying process eliminating the possibility of shrinkage and distortion of the finished Cordite. "Solventless" Cordite is very uniform in its dimensions, which conduces to regular ballistics.

4. In use, it is a cool burning propellant, and its general properties are not unlike those of M.D.

## DISADVANTAGES

A disadvantage of "solventless" Cordite is the impossibility of straining it during pressing. It is difficult, therefore, to avoid the inclusion of small particles of foreign matter, but this disadvantage is more than outweighed by the higher degree of stability which is conferred by the stabilizing effect of the carbamite.

## CORDITE S.C.

This Cordite consists of :-

| | | |
|---|---|---|
| Nitroglycerine | .......... | 41.5 per cent. |
| Nitrocellulose | .......... | 49.5 per cent. |
| Carbamite | .......... | 9.0 per cent. |

A small quantity of chalk is included during manufacture.

In appearance it is smooth and has a characteristic odour of carbamite, rather like the smell of pepper.

In this Cordite there is no solvent to evaporate out, so that stove drying is eliminated, the carbamite assisting in gelatinization and forming the stabilizer for the Cordite.

### REGULAR BALLISTICS.

S.C. Cordite is uniform in dimensions, which conduces to regular ballistics.

### STABILITY.

Carbamite is superior to Mineral Jelly as a stabilizer; it is therefore expected that Cordites made up with this will have long life. New S.C. Cordite is light in colour, but, as the carbamite is used up, it imparts a dark colour to the Cordite, which is a very good indication to its "present" and "remaining life".

Carbamite gives out an emanation which softens paint and varnish.

### TEMPERATURE.

At low temperatures (40 deg.F) S.C. Cordite shows remarkable resistance to exudation of nitroglycerine.

Cordite S.C. in good condition is smooth and flexible. When new, it is light amber yellow in colour but darkens with age to a reddish-brown. It possesses an aromatic odour due to its carbamite content.

As previously stated, Cordite S.C. cannot be filtered during manufacture and may therefore contain foreign matter such as particles of wood, aluminium, carbonaceous matter, etc. As this type of Cordite is highly resistant to any ill effect from such contamination these impurities need not be regarded with apprehension. White or opaque spots or streaks may be found in many sticks; these are due to air inclusions or particles of unevenly gelatinized carbamite or nitrocellulose and may be disregarded as they will not affect stability or ballistics.

Local deterioration due to the presence of impurities in S.C. Cordite is revealed by local discoloration(reddish brown to blue in colour) or, in more advanced stages, by a rising of the surface of the Cordite at the affected portion forming pastules which may be almost black in appearance. Any cordite that is found to be pastulated should be forwarded to the C.I.O.O.

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

## FLASHLESS CORDITES

Compared with gunpowder, modern propellants produce little or no smoke, but they have the disadvantage of giving muzzle flash.

In the case of Cordite and Ballistite, this flash is most pronounced, with the single-based propellants it is less so, though distinctly visible. Its intensity varies with the gun, in some cases it is so low as to practically negligible.

The cause of the bright flash (secondary flash) is the ignition of the hot inflammable gases on contact with the outside air.

To overcome this the addition of certain chemical substances is made during manufacture - these substances are such that their decomposition requires a great deal of heat and so the temperature of the gases at the muzzle is considerably lowered.

Flash-reducing charges were issued in the war of 1914-18, for use with the N.C.T. charges for the 6-inch and 8-inch howitzer. A charge consisted of a small quantity of flash-reducing powder (equal parts of sodium oxalate and R.F.G. meal powder) enclosed in a bag. It was loaded into the chamber in advance of the cartridge. No variation in ballistics was experienced when these charges were used. There was, however, a tendency to produce fouling of the bore, but this was readily removed by water.

With the more modern propellants the flash reducing agents are incorporated during the actual manufacture of the propellant. The chief agent is Picrite. This substance is made from Calcium Carbide and is cheap to manufacture. It forms the greater percentage of the ingredients in these propellants. Cryolite is another substance added as a flash-reducing agent though in only very small quantities. Some propellants often include a small amount of potassium sulphate in an endeavour to improve flashlessness.

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 a very short duration, is of relatively small importance. A disadvantage of the flashless propellants is that they are not entirely smokeless. It is an apparent feature of the flashless - smokeless phase of modern propellants that the elimination of one means the introduction of the other.

### NOMENCLATURE

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

(i) Flashless cordite of 775 cals/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 cals/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 are now actually employed in the Land Service, Cordite N. and Cordite NQ.

Recently the use of potassium cryolite in small proportions in both flashing and flashless Cordites has been introduced. Its purpose is to reduce flash in the case of flashing Cordites (e.g. HSCT/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.

CORDITE N.

Cordite N. is made from guncotton and is based on the Cordite previously known as RDN. AQ. (Cordite N/P is Cordite N with the addition of a small amount of potassium to improve flashlessness.)

The composition of Cordite N is :-

| | |
|---|---|
| Nitroglycerine .............. | 18.7 per cent. |
| Nitrocellulose .............. | 19.0 per cent. |
| Carbamite .............. | 7.3 per cent. |
| Picrite .............. | 54.7 per cent. |
| Cryolite .............. | 0.3 per cent. |

A small quantity of chalk is also added during manufacture.

CORDITE N.Q.

Cordite N.Q. is made from guncotton, and is based on a Cordite formerly known as Cordite R.D.Q.

| | |
|---|---|
| Nitroglycerine .............. | 20 per cent. |
| Nitrocellulose .............. | 21.5 per cent. |
| Carbamite .............. | 3.5 per cent. |
| Picrite .............. | 54.7 per cent. |
| Cryolite .............. | 0.3 per cent. |

A small quantity of chalk is also added during manufacture.

AUSTRALIAN FLASHLESS CORDITE

Flashless Cordites now being manufactured in Australia (March '45), include Cordite known as N.F.Q. and N.Q. The constituents are as follows :-

| | N.G. | N.C. (13.2%N) | PICRITE | CRYOLITE | CARBAMITE | CHALK |
|---|---|---|---|---|---|---|
| N.F.Q. | 21% ± 0.5% | 16.5% ± 0.5% | 55% ± 1% | 0.3% ± 0.1% | 7.5% ± 0.3% | 0.2% |
| N.Q. | 20.6% ± 0.5% | 20.8% ± 0.5% | 55% ± 1% | 0.3% ± 0.1% | 3.6% ± 0.2% | 0.2% |

Dyed Carbamite is still being used in N.Q. Cordite but this practise may be discontinued when present stocks are used up.

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 plants as Cordite W.

(iv) Drying time shorter than for Cordite W.

(v) Produces 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 :-

(i) Bulkier than Cordite W. An increase of about 15 per cent in charge weight if necessary to obtain 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.

CORDITE A.N.

This is a solvent Cordite composition which was primarily designed for use in relatively low velocity field guns. Although Picrite is absent from the formula, the cordite is flashless and can be regarded as the equivalent of Cordite N.Q. for this purpose. Smoke has been reduced to a minimum by keeping the Potassium Nitrate content as low as possible.

| | |
|---|---|
| NG | 25.5 |
| NC | 56.5 |
| DNT | 10.0 |
| Carbamite | 4.5 |
| M.J. | 3.5 |
| Pot.Nitrate | 0.7 |

CORDITE A.N.S.

A cordite similar in design and properties to Cordite AN but made by the solventless process.

CORDITE A.

Cordite "A" is the nomenclature given to Cordite "AN" not having Potassium Nitrate in its composition.

NITROCELLULOSE CANNON POWDERS

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

Nitrocellulose cannon powders, developed in the U.S.A. have now been adopted as service propellants. These propellants vary in colour from 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, 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 dimensions in this respect are the web size and thickness of propellant between the perforations.

Diphenylamine is used as a stabilizer in these propellants.

It is necessary to leave a certain amount of residue 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 ballistics. To guard against such charges these propellants are packed in air-tight packages, 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 burning, less erosive, and give less flash than ordinary cordites. In general, they require more gunpowder for satisfactory ignition.

The natures which may be met with are :-

N.C.T. POWDER

This is the name given to a propellant of American design which was made during the war of 1914-1918, and of which there are still large quantities in existence. It consists of nitrocellulose gelatinized by means of a volatile solvent and containing a small percentage of diphenylamine as a stabilizer. It is formed by pressing and cutting into short cylinders pierced longitudinally with either one or seven holes. The main disadvantage of this type of propellant is that it is particularly hygroscopic.

The composition of N.C.T. is as follows :-

| | |
|---|---|
| Nitrocellulose .............. | 99.5 per cent. |
| Diphenylamine .............. | 0.5 per cent. |

The other natures, N.H. (non-hygroscopic) powders
FNH )
FNH/P )flashless non-hygroscopic powders

FNH/DB (flashless non-hygroscopic double-base powders),

are dealt with in the section American Propellants. The advantages and disadvantages of the nitrocellulose cannon powders compared with cordite are discussed on page 6.

## MORTAR & S.A.A. PROPELLANTS

Ballistite, as was mentioned earlier, was invented by Alfred Nobel and is one of the oldest of the smokeless powders.

The general properties are similar to those of Cordite, but it 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 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 pressure would make the use of cordite impracticable.

Originally, the process of gelatinisation was perfomed entirely by the nitrocellulose, but during the last war a volatile solvent (acetone) was added in order to quicken the rate of production.

It is used in flake form.

There are two ballistites now used in the service.

(1) Ballistite A. which consists of -

| | |
|---|---|
| Nitroglycerine ............ | 39.5 per cent. |
| Nitrocellulose ............ | 60.5 per cent. |

used in rifle grenade cartridges.

(2) Ballistite B which contains a small percentage of carbamite and is therefore more stable. It is also made slightly more porous in order to increase the rate of burning and ease of ignition.

The composition is as follows -

| | |
|---|---|
| Nitroglycerine ............ | 38 per cent. |
| Nitrocellulose ............ | 60 per cent. |
| Carbamite ............ | 0.5 per cent. |

Remainder - Potassium Nitrate and Graphite.

Used in mortar bomb primary cartridges.

## NEONITES

These are modern nitrocellulose propellants used mainly for S.A.A. The name covers a series of nitrocellulose powders of different but unrelated 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 sustained accuracy are essential.

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

Neonites are essentially nitrocellulose coated with methyl centralite as a moderant.

## N.C. (Y).

This is developed from the sporting gun propellant E.C.3.

Quick burning and burns regularly at low pressures. Hence it is 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.

The composition is :-

| | | |
|---|---|---|
| Nitrocellulose | .............. | 83 per cent. |
| Camphor | .............. | 5 per cent. |
| Barium Nitrate | .............. | 12 per cent. |

N.C.(W). is the smokeless N.C.(Y) and is dyed a brilliant green.

## N.C. (Z).

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.

The composition is :-

| | | |
|---|---|---|
| Nitrocellulose | .......... | 92.4 per cent. |
| Diphenylamine | .......... | 0.6 per cent. |
| plus Dinitrotoluene and Graphite. | | |

## NOBEL'S "SUPERIM"

This is a double-base propellant containing carbamite as a stabilizer and has been introduced as an alternative to ballistite in rifle grenade cartridges.

It is made in the form of flattened spheres and graphited, diameter 0.08-cm., thickness 0.006 cm.

## DUPONT M 4 X

An American propellant introduced as an alternative to N.C.(Y) in augmenting charges for mortar bombs. It is also used in artillery ammunition for burst short charges with heavy A.A. equipment.

The details of this propellant will be found on page 36 in the section dealing with American propellants.

## HERCULES 81 M.M. MORTAR POWDER

An American propellant introduced as an alternative filling for primary and secondary cartridges for 3-inch M.L. mortar, also for 0.303-inch with rifle grenade cartridges.

It is practically identical with Ballistite B16 but is non-porous.

Further details will be found on page 36 in the section dealing with American propellants.

## SHAPES OF PROPELLANTS

One of the essential properties of a propellant is that it should be controlled. 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 modern propellants is that they can be made in various shapes and forms, e.g., sticks, tubes.

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 charge in most guns except those of very small calibre.

(c) TUBE FORM

The surface area during the 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.

(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.

Graphited to increase slip between flakes and to act as waterproofing.

## PROPELLANTS - NOMENCLATURE

### Nomenclature - denoting shape.

| SHAPE | LETTER |
|---|---|
| Cord | No letter |
| Tubular | /T. |
| Multi-Tubular | /M. |
| Slotted Tube | /S. |
| Drilled Tube | /D. |
| Grooved, slotted tube | /S/G. |
| Square flake | /S.F. |
| Ribbon cordite | /R. |

### DESIGNATION OF SIZE OF PROPELLANTS.

Dimensions of the earlier cordites (that is the Mineral Jelly cordites) and also of Ballistite are expressed in hundreths of one inch. These are die sizes, but owing to the 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 pressed has an external diameter of 0.07-in, and an internal diameter of 0.02-in.

Dimensions of the latter types of cordite (S.C., H.S.C., W., W.M., N. and N.Q. are expressed in thousandths of an inch.

These are actual sizes.

Examples :-

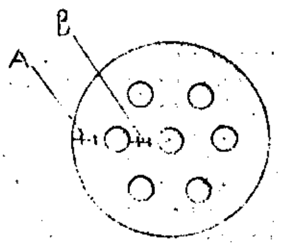
"S.C.048" represents cordite S C. in cords of 0.048-in diameter.

"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.

The dimensions of the multi-tubular nitrocellulose cannon powders (N.C.T.; NH; FNH;) are expressed in thousandths of an inch. The average web-size 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 $\frac{a + b}{2}$ equals 0.065 inches.

RIBBON PROPELLANT

Only cordite propellants have been used, they are designated by the thickness followed by the width of the strip, each figure expressed in thousandths of an inch and separated by a multiplication sign, e.g., 014 x 048.

ADDITIONAL NOMENCLATURE

The following additional letters are used with flashless cordite to indicate the addition of particular ingredients to reduce the flash.

| | |
|---|---|
| /P | When Potassium Sulphate is added. |
| /K | When Potassium Cryolite is added. |
| /Q | When Natural Cryolite (e.g. Sodium Cryolite) is added. |

TYPE OF CELLULOSE USED

A - cotton cellulose
C - straw cellulose.
F - wood cellulose.

GENERAL NOTES :-

With all the foregoing the letters adopted to indicate each of the particulars stated are grouped by means of oblique strokes.

The size follows the nomenclature for composition and shape in the case of cordite.

The length of the cords or tubes is expressed in inches and this figure follows the dimension of size, e.g., 316- 100/21.

## AMERICAN PROPELLANTS.

Explosives currently used in practically all types of American ammunition as propellants have a nitrocellulose base and are commonly known as smokeless powders. Various organic and inorganic substances are added to the nitrocellulose base during manufacture to give improved qualities for special purposes.

These powders are distinguished by such terms as N.H. (non-hygroscopic), F.N.H. (flashless, non-hygroscopic), double-base, as well as commercial trade names or symbols.

It must be realised that the terms "smokeless" and "powders" are purely relative terms.

These propellants are not entirely smokeless, they are only relatively so compared with earlier propellants and with black powder (gunpowder). Further they are not, in fact, powders. They are manufactured in the form of flakes, strips, pellets and perforated cylindrical grains.

Nitrocellulose smokeless powder is used as the propellant for small arms and larger calibre ammunition. The perforated form of grain is the most commonly used in United States military powder. Single perforated grains are used for small arms, minor calibre cannon and certain howitzers. Powder with seven perforations are used for larger calibre weapons.

### BURNING ACTION

As with British propellants the same factors governing rapid and progressive burning of the propellant, surface area, pressure and the all-burnt position have to be taken into account.

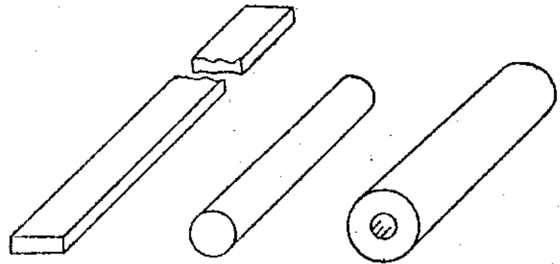
The meet these essential conditions the Americans have found it convenient to make powder grains with a number of holes, or perforations, running length-wise through the grain. As the grain is perforated, it will burn on the inside and outside at the same time and gas will be created much faster than if the grain were solid. The grains are made with varying diameters and lengths.

The type of grain most favoured in the American artillery is the cylinder, or tube, with one or seven perforations. The grain with seven perforations is generally referred to as the multiperforated grain. This grain gives the essential progressive type of burning the surface area increasing continuously as the burning proceeds. A reference to the diagrams on page 32A will show the burning of a typical grain of this nature. Experience has shown that in the burning, a small portion of the grain, between the perforations, remains unconsumed, until after the main, progressive stage of burning. This portion is called the "sliver" and is not considered an entirely satisfactory feature of the propellant. To overcome this the shape of the grain has been altered in certain types to the form shown in the diagram, and generally referred to as "Rosette" or "Sliverless" grain. This does greatly overcome the somewhat unsatisfactory feature of the straight standard grain.

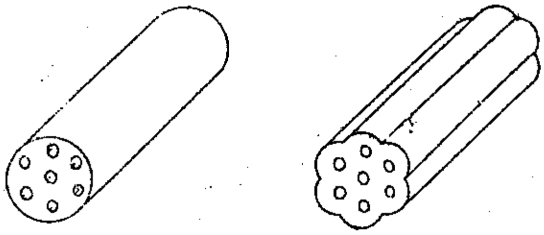
### PYRO POWDER.

For many years the standard propellants in the American Service were straight nitrocellulose powders. Commonly referred to as pyro-powders, or pyrocellulose, this powder is now used only as a substitute for the standard N.H. or F.N.H. powders. The disadvantage of this early powder was the production of muzzle flash on firing. It is also hygroscopic and has a relatively low potential.

## TYPES OF POWDER GRAINS.

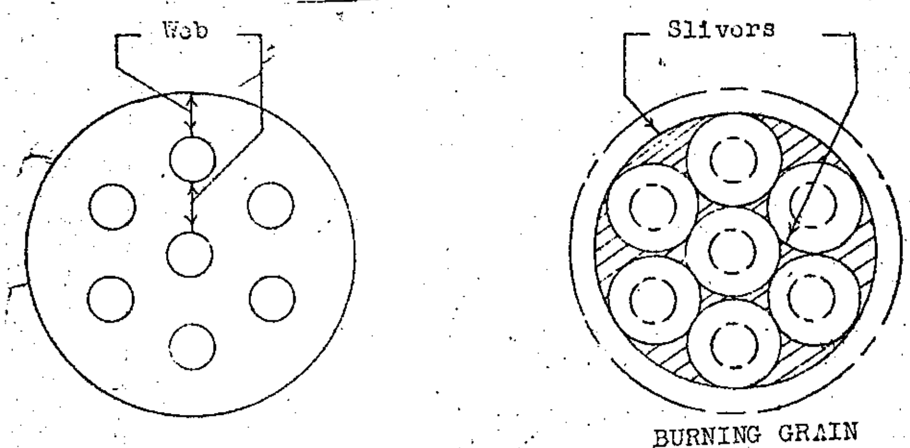


Strip   Cord   Single perforated

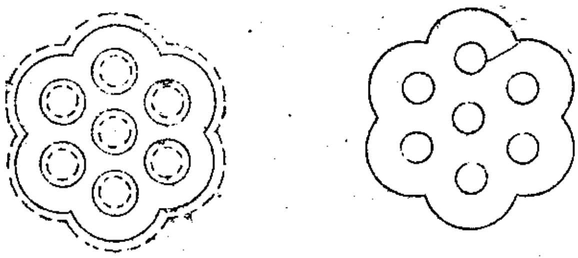


Multi perforated (Standard)   Resotto or Slivorless

## BURNING OF POWDER GRAIN.




BURNING GRAIN



Burning grain

Improvements over a number of years have led to the introduction of powders which are now standard.

F.N.H. and N.H. POWDERS.

In an endeavour to overcome the "flash", inert or partly inert materials are added to the nitrocellulose to cool the products of combustion, and to reduce the hygroscopic nature of the powder, such powders are given the nomenclature F.N.H. (Flashless, non-hygroscopic). It is an essential feature of F.N.H. powders that they may be flashless in one type of weapon yet produce a flash in another type.

Flashlessness depends upon the quantity of the powder used and upon the length of the bore equally as much as it does upon the presence of the cooling agents incorporated during manufacture. It must be appreciated that, with the incorporation of too much cooling agent it is possible to reduce the potential of the propellant.

When a flashless (F.N.H.) powder does not attain the quality of flashlessness in a particular weapon, it is, for that particular weapon, classified as an N.H. powder and no other qualities are claimed for it.

The straight N.H. (non-hygroscopic) powders differ essentially from the F.N.H. powders in that they do not have incorporated in them quantities of material which act as cooling agents to reduce the flash. They are a definite advancement upon the pyro-powders and upon the N.C.T. powders introduced into the British Service during the war of 1914-1918 (and which are essentially similar to the pyro-powders) in that they have incorporated in them substances which reduce the hygroscopicity of the powder.

The F.N.H. and N.H. powders are used as propellants for most guns and Hows. of 37 mm. and larger calibre.

DOUBLE BASE POWDERS.

The term double base powder is applied to powder containing both nitrocellulose and nitroglycerine; the nitroglycerine serves to increase the potential. As with the F.N.H. powders, certain substances are incorporated to reduce the flash and hygroscopicity.

These powders are used in small cannon, in trench mortar where special burning is required, and in certain high velocity ammunition.

STANDARD POWDERS.

After many years of experimentation to reduce smoke and flash four types of powder have now been adopted as standard. These are :

Dupont F.N.H. powder M.1.
P.A. (Picatinny Arsenal) F.N.H. powder M.3.
Hercules F.N.H. powder M.2.
Hercules F.N.H. or N.H. powder M.4.

It has been found that these types stand up well under varying conditions of storage, and at the same time smoke and flash have been reduced to a minimum. The Hercules F.N.H. powder M.2. is a nitrocellulose-nitroglycerine base powder, that is a double-base powder.

CHARACTERISTICS OF N.H. AND F.N.H. POWDER.

The nitrocellulose cannon powders vary in colour from a light amber to a deep brown or black.

The nitrocellulose used in the manufacture of these powders is of a high nitration.

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 of ballistics. To guard against such changes these propellants are packed in air tight containers, or with Q.F. fixed ammunition of the fixed type, the joints between the projectile and cartridge case and at the primer hole are carefully sealed. When a container of these powders is opened the characteristic odour of ether-alcohol vapours will be noticed. This is an entirely normal condition, but the container should be immediately closed to prevent the escape of these vapours. This odour should not be mistaken for the acid odour of nitrous fumes denoting decomposition.

The cylindrical grains of the nitrocellulose, cannon powders are made with a length of about twice the diameter. The size of the 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 of thickness of propellant between the perforations. (See page 31)

N.H. NON-HYGROSCOPIC POWDERS. COMPOSITION.

The term N.H. covers the modern propellants made by the American firms Dupont and Hercules. They differ essentially from the N.C.T. powder chiefly in the addition of Dinitrotoluene and also Dibutylphthalate (in the case of the Dupont powder) to reduce hygroscopicity. Although very much less hygroscopic than N.C.T., they are not entirely free from this disadvantage.

The composition is as follows :-

| Dupont Powders | | Hercules Powders | |
|---|---|---|---|
| Nitrocellulose | 86 per cent | Nitrocellulose | 82 per cent |
| Diphenylamine | 1 " " | Diphenylamine | 0.9 (app.) |
| Dibutylphthalate | 3 " " | Dinitrotoluene | 17 " " |
| Dinitrotoluene | 10 " " | | |

F.N.H. FLASHLESS NON-HYGROSCOPIC COMPOSITION.
F.N.H./P.

The flashless powders differ essentially from the N.H. 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 F.N.H./P.

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

The composition is as follows :-

| F.N.H. Dupont | | F.N.H./P | |
|---|---|---|---|
| Nitrocellulose | 84 per cent | Nitrocellulose | 83 per cent |
| Diphenylamine | 1 " " | Diphenylamine | 1 " " |
| Dibutylphthalate | 5 " " | Dibutylphthalate | 5 " " |
| Dinitrotoluene | 10 " " | Dinitrotoluene | 10 " " |
| | | Potassium Sulphate | 1 " " |

## F.N.H./D.B. COMPOSITION.

The /DB refers to the fact that the propellant is "double-base" that is, it contains a percentage of nitroglycerine.

The composition is as follows :-

| | | |
|---|---|---|
| Nitroglycerine | ........................ | 20 per cent. |
| Nitrocellulose | ........................ | 75.5 " " |
| Dinitrotoluene | ........................ | 1 " " |
| Diphenylamine | ........................ | 0.75 " " |

Plus (Barium Nitrate
(Potassium Nitrate

## AMERICAN SMALL ARM PROPELLANTS.

The smokeless powders used for small arms differ from that used for cannon in that they are usually glazed with graphite to facilitate machine loading and thus present a black polished appearance. Since the powder grains are small they ignite more readily and burn more freely than the cannon powders. When moisture if present or abnormal temperature prevails, they are subjected to more rapid deterioration than the larger grains.

The powders are of commercial manufacture and are designed to give a muzzle velocity of 2,600 feet per second, with a pressure not exceeding 48,000 pounds per sq. inch. Numerous experiments have been carried out to improve the completeness of combustion, reduce the flash and smoke produced, etc., and this has led to a more or less standard powder. This consists of

Nitrocellulose
Tin dioxide
Potassium sulphate
Dinitrotoluene (cooling agent)

The whole is coated with graphite.

This type of powder gives a muzzle velocity of 2,500 feet per sec. with a pressure of 45,000/lbs per sq. inch.

## E.C. SMOKELESS POWDER.

E.C. smokeless powder, or E.C. blank fire, consists of nitrocellulose with inorganic nitrates. It is usually orange or pink in colour, and resembles coarse sand, though it is soft and light. It is sensitive to friction, shock or heat. It burns extremely rapidly in the open, but explodes if confined. It is used as a bursting charge in fragmentation hand grenades. It is also used in calibre .30 and calibre .50 blank cartridges.

## DUPONT M 4 X.

This is a double-base propellant made up in flattish grains which are graphited. It is a comparatively slow burning propellant.

The composition is as follows :-

| | | |
|---|---|---|
| Nitroglycerine | .................... | 32 per cent. |
| Nitrocellulose | .................... | 66.15 " " |
| Diphenylamine | .................... | 9.6 " " |
| Potassium Sulphate | .................... | 0.25 " " |
| Graphite | .................... | 1.0 " " |

It has been adopted in the British Service as an alternative to N.C.(Y) in the augmenting charges for mortar bombs and also as the propellant in artillery ammunition for burst short charges in heavy A.A. ammunition. Owing to its comparatively slow rate of burning it is not suitable for replacing Ballistite B. in mortar primaries without modification of the cartridge assembly. The stability of the powder is satisfactory, but not as good as ballistite containing carbamite.

## HERCULES 81 m.m. MORTAR POWDER.

The composition of this double-base propellant is as follows :-

| | | |
|---|---|---|
| Nitroglycerine | .................. | 40 per cent. |
| Nitrocellulose | .................. | 57.75 " " |
| Diphenylamine | .................. | 0.75 " " |
| Potassium Nitrate | .................. | 1.5 " " |

(The propellant is issued in two thicknesses 0.01 inches and 0.005-inches. It is practically identical with the ballistite B.16 but is non-porous and is approved by the British Service as an alternative for 3-inch M.L. mortar primary and secondary cartridges and also for the .303-inch rifle grenade cartridge).

NOTE :-

The letter "X" appearing before the lot number indicates that the powder was "water dried", this type of powder being not quite as stable as the air dried type. Large quantities of this type of powder are likely to be encountered as the water drying process speeds up the rate of manufacture quite considerably.

CODE LETTERS.

For a considerable period in the Land Service the following Code Letters (within a rectangle) have been used on packages containing gun or howitzer ammunition to denote the type of propellant.

| | |
|---|---|
| A | ......................Flashless Cordite N. or N.Q. |
| B | ......................Ballistite. |
| C | ......................Cordite R.D.B. in Cord or Tube. |
| D | ......................Cordite M.D., M.C., or M.D.C. in Cord or Tube. |
| E | ......................Cordite W. or W.M. |
| F | ......................Cordite M.D. or R.D.B. in Flake. |
| H | ......................Cordite H.S.C.T. |
| J | ......................Bofors |
| K | ......................F.N.H/DB Powder |
| L | ......................F.N.H. Powder or F.N.H./P Powder |
| M | ......................M.4.X. |
| N | ......................N.C.T. of 1914-1918 manufacture. |
| O | ......................N.H. Powder. |
| S | ......................Cordite S.C. or S.U. |
| X | ......................Cordite A.N. |
| H.K. | ......................Cordite HSCT/K |

The code letter is stencilled on the ends and sides of the package, also on the side of Q.F. Cartridge cases by the silver nitrate or other approved process and on B.L. Cartridge bags, in black printers ink, but always within a rectangle, thus [A]

PROPELLANTS, CODE LETTERS, MARKINGS.

(C.I.O.O. Circ. 21)

Approval has been given for the discontinuance of marking Propellant Code Letters on BL and QF cartridges and their packages.

England now advises that all such cartridges and packages will instead be marked with the nomenclature of propellant with which they are filled, viz.

WM, FNH, SC/T, NQ/R, etc., as follows :-

| Present. | Future. |
|---|---|
| (1) Where the existing marking does not include the nature and size of Propellant. | In the position now occupied by the code letter, but without an outer frame. |
| (2) Where the existing marking includes the nature and size of the propellant. | Increase the size of the letters for nomenclature by about 50%. |

NOTE:- The nomenclature of propellants includes the "Shape" e.g. WM/T means tubular WM Cordite, and NQ/R means NQ Cordite in ribbon or strip form.

The altered method of marking was commenced on 1st Jan, 44 but any stocks of empty BL cartridges bearing old marking will continue to be used without alteration.

Existing filled cartridges will not be altered, Both types of marking will therefore be in existance in the service side by side.

TESTS.

To avoid danger due to advanced deterioration, explosives which are suspect are subjected to tests, which indicate their condition. Attempts have also been made to use "auto-indicators", i.e. substances incorporated in the explosive, which indicate the advent of pronounced decomposition by a change of colour.

Most stability tests are based on the detection or measurement of the oxides of nitrogen liberated in a measured time at a definite temperature.

They may be divided into three main types :

(i) Trace Tests in which the first minute traces of gas given off are detected by the colouration of a delicate test paper or solution. The time for the development of a standard tint is taken as an indication of the stability of the explosives.

(ii) Fume Tests in which the explosive is heated to about 120°C. The time taken to produce distinct fumes of nitrogen peroxide, or to affect some course indicator such as litmus paper, is the guiding factor.

(iii) Quantitative Tests in which the volume of gas evolved in a given time under standard conditions is the criterion.

ABEL'S HEAT TEST.

(1) This is the oldest stability test and it is still the most frequently applied on account of its simplicity. For a detailed description reference must be made to R.A.O.S., Part 8, Pam. 7, Appendix 1.

The explosive to be tested is carefully crushed and sifted, and a sample is weighed out into a test tube. Suspended above the sample is a starch-potassiumiodide test paper, which has been previously prepared under standardized conditions. The upper half is wetted, immediately before it is used, with a non-drying solution of glycerine and water. The lower end of the test tube is immersed in a water bath, which is maintained at a constant temperature (usually about 80°C. indicated by the thermometer). During the test the exposed positions of the tubes are protected by a cover as light affects the test.

The first traces of nitrogen peroxide are detected by a change in colour at the junction of the wet and dry portions of the test paper. This assumes a brownish tint which gradually deepens, and the test is complete when this tint matches that of a standard test paper. This test is extremely delicate, as the standard tint is produced by 0.000135 milligram of nitrogen peroxide.

The time from the first immersion of the tube, containing the sample, in the water bath, to the development of the standard tint, is taken as a measure of the stability of the explosive. For instance, the acceptance test for new cordite M.D. lays down a minimum of 30 minutes at a temperature of 180°F. (82.2°C) Cordite M.D. which is in the Service is required to pass a test of not less than 10 minutes at 160F (71.1°C).

The Abel heat test is applicable to any explosive forming nitrogen peroxide on decomposition. It is open to certain objections arising, chiefly, from its extreme sensitiveness. The test paper can be affected by other gases than nitrogen peroxide (e.g. ozone), the presence of which does not necessarily imply instability. Again, the test may give false indications owing to the presence, in the explosive, of some substance, such as mercurichloride, which prolongs the heat test by retarding the action between the test paper and the nitrogen peroxide. The test is not suitable for explosives gelatinized with ethyl acetate since this solvent prolongs the test unduly.

The test time given by an explosive depends on a number of factors besides the intrinsic rate of decomposition of the ingredients, such as the nature of gaseous products formed by the action of the stabilizer and their solubility in the explosive. There is therefore for each type of explosive a standard peculiar to that type. Cordite S.C., for example, though much more stable than cordite M.D. gives a lower heat test.

Other trace tests have been suggested from time to time, the main difference between them and the heat test being the use of other indicators.

(2) THE COLOUR TEST OF S.C. AND W CORDITE.

The colour test is a measure of the amount of stabilizer which has been used up during the life of the cordite in combining with the acid products of decomposition. The bodies so formed produce a coloured solution when the cordite is dissolved in acetone and the intensity of the colour of this solution is compared with those of various standard colour solutions of graded intensity.

The darker the colour of the solution the less is the amount of carbamite left; and the condemning limit is reached when the cordite contains only half of its original carbamite.

In practice the colour test (which is described fully in R.A.O.S. Part 8, Pam. 7, Appendix V, is carried out by matching in a colorimeter, the colour of solution of one gram of cordite in 50 m.l. of acetone against a standard solution which represents the colour produced by a sample of cordite which retains only half of its original carbamite content. The standard solution used in the testing of S.C. cordite has the composition :-

| | | |
|---|---|---|
| Potassium bichromate ($K_2Cr_2O_7$) .. .. | 1.2 grams | ) Made up to one |
| Cobalt ammonium sulphate $Co(NH_4SO_4)_2 6H_2O$ .. .. .. | 32.7 " | ) litre with ) water. |
| Concentrated sulphuric acid .. .. | 12.s.m.l. | |

The Colour Number of the cordite is recorded as

$$25 \times \frac{\text{Depth of column of standard solution}}{\text{Depth of column of cordite solution.}}$$

When the Colour Number reaches 25, the cordite is condemned. If the colour number is 5 or smaller, the colour is found by direct comparison of the cordite solution against standard solutions having colour numbers of 1 to 5.

CORDITE "W" AND "WM" - TESTS WHEN DYED CARBAMITE USED.

The sentencing of cordite W and WM of Australian manufacture will be by heat test only if a colour test cannot be taken due to violet colouration of the cordite. Controlled trials and observations have shown that the violet colouration disappears by degrees. The colour number can then be determined by the normal procedure and it is thought that the colour will bleach sufficiently for the application of the colour test before the carbamite content falls to 3% in Cordite W.

As the tests conducted by MSL show that it will be years before the carbamite values fall to 3% the sentences to be imposed on the cordite as a result of the heat test will be governed by those for cordite having a carbamite content of over 3%.

Cordite W and WM of UK manufacture containing coloured carbamite does not vary in colour as in the case of similar cordites of Australian manufacture. This more satisfactory uniformity of colour is due to the use in UK of a more effective dye which is not available in Australia.

The colour variation in Cordite of local production led to difficulties in examination and doubts arose as to whether subjection to the Colour Test of Cordite would give misleading results. To obviate the likelihood of confusion, the use of dye in Australian production was discontinued.

Information requested from England regarding similar Cordites of UK manufacture has now been received. The following is an extract giving comments on this matter -

"You enquired on behalf of Australia whether colour tests of Cordites containing coloured carbamite are valid. This was considered when putting up additions to Naval Cordite requisitions, when it was stated that if the dye had not faded (i.e. still interferes with the colour test), it can be assumed that the colour test is satisfactory, and no further action on that score is necessary. Relatively little deterioration of the propellant causes fading of the dye and our results show that this occurs long before the limiting colour numbers are attained and without appreciable effect on the colour". (CIOO Circ. 26/23).

(3) THE HUNDRED PER CENT. SURVEILLANCE TEST.

The test is described in R.A.O.S. Part 8, Pam. 7, Appendix Vl.

The 100 per cent. surveillance test is applied to mineral jelly cordite in bulk, and in B.L. charges, and is designed to indicate whether the cordite in any package is approaching a dangerous condition. Each package is provided with a glass window through which can be seen a coloured test paper which is exposed to the air inside the package. The test paper is stained with a chemical "indicator", which is affected by the gases given off by cordite during storage, and gradually changes colour. With new cordite, the change in colour takes place in the course of several months, the duration of the test depending on the temperature of storage. As the cordite ages, the test stands to become shorter. When the cordite is reaching a dangerous condition, it takes place in a few days. Individual packages containing cordite which for any reason has deteriorated more rapidly than that in similar packages containing the same lot will be indicated by the papers changing in colour markedly more rapidly.

It is essential to ensure, for the gases, as free a path as practicable, between the cordite and the test paper.

The original colour of the test papers is blue and on exposure to the gases emanating from the cordite, it changes gradually to a purplish-red. If test papers are left in contact with the gases from cordite beyond this point, the red colour becomes brighter and resembles that shown at the right side of the chart. The purplish-red colour designated as "P" on the chart is taken as the end-point of any test.

Two types of test paper are issued, namely C.B.H. for hot, and C.B.T. for temperate magazines. For the purpose of this test, temperate magazines are defined as those in which the mean annual temperature is 70°F. The C.B.H. papers are punched with a small hole to facilitate recognition.

The test papers are of a sensitive character and it is important that when they are not in use, the pads should always be stored sealed up in canisters in which they are supplied, in a cool, dry place away from acid fumes. The test papers are affected by material containing iron (scissors, knives, etc.) and should not be trimmed nor cut except with bronze scissors.

The change of colour of test papers is sometimes uneven during protracted tests on account of the masking effect of the window fitting, but when rapid tests occur the effect is of little significance. It does not, for example, appear to have caused any difficulty at Malta, where a large number of short tests have been observed. In such cases of uneven tinting, the observer takes the most advanced tint on the paper as his datum in sentensing the cordite under test.

In order to facilitate the work of the observers, standard end tints are provided. They can be carried round the magazine and used for comparison with the tints in the cordite packages under identical conditions of lighting. To prevent the tints from fading, the boxes, containing them should be kept shut when not in use and stored with the same care and precautions as are observed with the test papers. Fresh standard end tints in boxes will be issued every two years to prevent the use of any which may have become faded or damaged.

Packages for test should be stacked in the magazine in such a manner that the "inspection" windows are easily accessible for inspection and renewal of test papers.

Inspection. The test papers are examined at intervals to ascertain whether they have reached the end tint. The intervals between inspections are indicated in the following table :-

100 PER CENT. SURVEILLANCE TEST OF CORDITES. FREQUENCY OF INSPECTION (B.L. AND BULK).

| Average temperature of magazine | Inspection period. |
|---|---|
| 80° - 90°F. | Every two days. |
| 70° - 80°F. | Twice weekly. |
| 70° and below. | Weekly. |

On reaching the end tint, the test papers should be changed, the new paper bearing the date of change. In any case, they should not remain in the cordite packages longer than six months.

Sentencing.

(i) Packages in which the test papers reach the end tint in less than eight weeks are to be regarded as under suspicion; they should be placed in an easily accessible position in the magazine and specially watched.

(ii) When the test falls to four weeks or less, the procedure is as follows :-

(a) Where the test has been installed for less than 12 months, the packages are removed from the magazine and segregated. The contents are broken down, inspected visually and tested by such tests as are applicable to the type of cordite concerned.

(b) Where the test has been installed for more than 12 months, the cordite will be examined visually for signs of deterioration and tested by such tests as are applicable to the type of cordite concerned. A 2 lb. sample of the worst material should be set aside for further examination if required and the remainder destroyed.

(4) CLIMATIC TRIALS

The deterioration of explosives at tropical temperatures of storage is sometimes ascertained by "climatic" trials in which the explosive is stored in chambers, artificially heated to regulated temperatures, in either a dry or a moist atmosphere. Moisture has an important influence on the rate of deterioration.

(5) WALTHAM ABBEY SILVERED VESSEL TEST

This was a fume test originally introduced for the examination of Cordite, Mark 1.

A weighed amount of cordite which has been ground and sifted, is contained in a Dewar vacuum flask, the outer jacket of which is silvered. A thermometer is situated so that its bulb is covered by the explosive. A side tube branches off horizontally from the upper part of the neck of the vessel, to facilitate the observation of the red fumes which are given off towards the close of the test.

The cordite is maintained at a temperature of 80°C by immersion in a bath, heated by a burner which is controlled by a gas regulator. After some time, red fumes are observed in the side tube, followed by a rise in temperature. The test is finished when the thermometer indicates a rise of 2°.

A good cordite would stand such a test for 500 or 600 hours. It was usually applied to samples of cordite which have given results under the heat test of between four and eight minutes at 160°F.

It will be noticed that this test was intended to imitate adverse conditions of storage.

(6) WILL TEST

This test which is usually applied to nitrocellulose, is a quantitative test.

The explosive is heated to a temperature of 135°C, in an atmosphere of carbon dioxide. The nitrogenous gases evolved are reduced to elementary nitrogen in a combustion tube containing metallic copper and copper oxide at a red heat; this also served to convert the organic gases which are evolved to carbon dioxide and water. The volume of nitrogen so obtained is measured in a gas burette filled with potassium hydroxide solution in which carbon dioxide is readily absorbed.

(7) BERGMANN AND JUNK'S TEST - 132° C. TEST.

This quantitative test is an alternative to the Will test, and is now much more frequently applied as it is quicker and the apparatus is much more simple.

The nitrocellulose to be tested is pressed between filter papers and dried for 6 hours at 50°C. After cooling, it is passed through an IMM Standard 50-mesh sieve.

The sample before heat test should contain a minimum quantity of moisture. Two gramms of the sieved sample are placed in two of three glass tubes, one of which is used as a blank.

The two test tubes after being fitted with absorption bulbs containing 30 to 40 c.c. of distilled water, are mounted in copper tubes in the heating bath. They are then maintained at a constant temperature of 132°C. for two hours. There is a condensor for condensing and returning the vapour from the liquid used in the bath, A liquid having a boiling-point of 132°C. is used.

On cooling, some of the water in the absorption bulbs is drawn into the test tubes, the remainder being poured into a flask. To the water in each test tube, and to the contents of the blank, 20 c.c. of N/10 hydrochloric acid are added. After corking, the contents of the tubes are shaken for 15 minutes and then filtered. Care is taken to remove all acid by careful washing.

To the solutions from the heated samples and from the blank 25 c.c. of N/10 potassium hydroxide solution are added. The excess of alkali present is then estimated by nitrating with N/10 hydrochloric acid, using methyl orange as an indicator.

Then if A equals number of c.c. of N/10 Hydrochloric acid nitrated in the case of the heated sample, and B is the corresponding figure for the blank experiment, then the amount of nitrogen liberated per gramme of nitrocellulose is :-

0.7 (B - A) milligram.

VISUAL EXAMINATION OF CORDITE, BRITISH N.C. POWDERS N.C. (Y) AND BALLISTITE.

The following notes are, except where otherwise stated, extracted from R.A.O.S. Part 8, Para 7.

They are in no way intended to supersede the instructions issued in the above mentioned authority being intended to supply preliminary notes only.

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(1) The cordite in a package of cartridge from which a sample for testing is selected will be examined for general appearance, colour, smell and sweating.

(a) CORDITE MK. 1 in good condition is smooth and tough, the colour varies from light to dark brown and it has little smell.

(b) CORDITE M.D. is of a horny nature and harder and more brittle than Cordite, Mk. 1; it is somewhat darker in colour and smells slightly of acetone.

(c) CORDITE W. resembles Cordite M.D. but can be distinguished by its aromatic odour due to its carbamite content.

(d) CORDITE R.D.B. resembles Cordite M.D. in being of a horny nature, harder and more brittle than Cordite Mk. 1. The larger sizes, however, are noticeably safer than Cordite M.D. and usually show a more uneven surface. Cordite R.D.B. smells slightly of alcohol.

(e) CORDITE S.C. in good condition is smooth and flexible. When new, it is light amber in colour but darkens with age to a reddish-brown. It possesses an aromatic odour due to its carbamite content.

(f) CORDITE BOFORS is hard and greenish in colour. The colour darkens somewhat on keeping and may become rather brownish. As with Cordite S.C., particles of foreign matter, such as wood and metal, may be present. Local deterioration is revealed by localized reddish-brown discoloration which may bleach to a light patch, sometimes accompanied by some exudation.

(g) CORDITE N. and N.Q. unlike the preceding natures of cordite which are translucent, is white and opaque. It is hard, smooth and very brittle.

(h) CORDITE H.S.C. is of a similar composition to S.C. but has a higher nitro-glycerine content and lower carbamite content.

(Reference to page 12 in this publication).

(2) "It should be noted that the practice has been for the carbamite used in the "Land Service" to be dyed Violet. This imparts to the Cordites, using this particular stabilizer, a distinctive colour and thus in Cordite W. and W.M. particularly, the colour indicated above will be masked. In Cordite S.C. being a Naval Cordite, the carbamite is not dyed.

(The use of dyed Carbamite will be discontinued in cordites made in Australia.")

(3) Deteriorated cordite, Mk. 1, M.D. and R.D.B., may be more brittle and is usually darker than new cordite. It has a sour smell, sometimes resembling that of ether. Bubbles in cordite must not be mistaken for the light-coloured patches caused by local deterioration. These light coloured patches should be specially looked for in cordite, M.D.; if found, a heat test should be taken on the affected parts.

(4) Cordites, S.C. cannot be filtered during manufacture and may, therefore, contain foreign matter such as particles of wood, aluminium, carbonaceous matter, etc. As this type of cordite is highly resistant to any ill effect from such contamination, these impurities need not be regarded with apprehension.

White or opaque spots may be found in many sticks; these are due to air inclusions or particles of unevenly gelatinized carbamite or nitrocellulose and may be disregarded; as they will not affect stability or ballistics.

(5) If a suspicious looking patch is observed in cordite M.D., it should be cut open and a piece of blue litmus paper, carefully

moistened with distilled water (i.e. neutral to litmus) should be applied; if a distinctly acid reaction is obtained, local deterioration is indicated.

(6) Local deterioration due to the presence of impurities in S.C. cordite is revealed by local discoloration (reddish brown to blue in colour) or, in more advanced stages, by a raising of the surface of the cordite at the affected portion forming a pustule which may be almost black in appearance.

(7) The surface of cordite is sometimes moist; this condition is called sweating. This is due to the exudation of nitro-glycerine, which is liable to take place in certain cordites after exposure to cold and subsequent warming. The exudation occurs most readily in cordite of high-glycerine content. Thus Cordite Mk. 1 may exude after storage at 45°F. or below, and Cordite S.C. after storage at 40°F. or below, but exudation is rarely observed in Cordite M.D. unless the temperature has fallen to 32°F. or below. Cordite R.D.B. is intermediate in composition and may be classed approximately with Mk. 1. The sweating is due to freezing of the nitro-glycerine, which crystallizes on the surface and consequently melts when the temperature rises.

(8) Sweating does not injuriously affect cordite, and if it occurs in made-up cartridges no action need be taken; but if it appears on cordite in bulk the cordite must not be removed from its packages for any purpose till it recovers its normal state, which it will do if the temperature is kept above 45°F., by the reabsorption of the nitro-glycerine; when this has taken place the cordite is serviceable.

(9) An oily appearance is also sometimes seen on Cordite Mk. 1. M.D. or R.D.B.; this is due to exudation of mineral jelly, and does not affect the cordite.

(10) To distinguish the exudation of nitro-glycerine from that of mineral jelly, wipe a stick of the cordite with a strip of clean blotting-paper, about ¼-in. in width, so that the stain from the exudation appears about the centre of the strip. Then in some comparatively dark place apart from the laboratory, etc., hold the strip in a horizontal position and light it at one end. If the exudation is nitro-glycerine, the flame will travel faster and become distinctly green on reaching the stain.

## WET CORDITE.

(1) If the cordite has become wet from any cause :

(a) It will, if wet with fresh water, be dried in a well-ventilated building, a sample being then subjected to heat test and colour test if applicable, and, if it passes the test, the consignment will be repacked and retained as fit for service in all respects.

(b) If wet with salt water, it will first be washed thoroughly in fresh water, then the procedure will be as in (a).

(2) In the case of tubular cordite it is necessary to ensure that the water enters and circulates through the tubes sufficiently to clear away any deposit. To effect this the tube should not be thrown into the water and left to soak in a horizontal position, as there would then be some danger that the water would not fill the tubes, but a bundle of tubes should be dipped under the water, being kept vertical, and worked up and down a few times, then lifted out of the water and allowed to drain. This process should be repeated a number of times until the tubes are clean.

If facilities exist, it may be found more convenient to hold the cordite under a tap of running water, so as to allow the water to run through the tubes. In order to dry them they must be allowed to drain, and the drying can be assisted by whisking a bundle of the tubes through the air while held in the hand.

Care will be taken that during these operations the cordite is not exposed to direct sunlight and that the Lots are kept distinct.

The foregoing is the normal procedure, but if the quantities are large or the circumstances exceptional, the matter will be reported.

(3) For cordite in cartridges, with gunpowder ignitors which have become wet from any cause - see the notes following under the heading "Sulphur-Infected Cordite".

SULPHUR-INFECTED CORDITE.

(1) Cordite will be considered "sulphur-infected" when it is in cartridges fitted with gunpowder ignitors :-

(a) which have become wet from any cause;
(b) with broken igniter bags;
(c) where gunpowder dust from the ignitor is found on the cordite.

(2) Cordite found to be sulphur-infected will be dealt with as follows:-

(a) Mk. 1 cordite, whether affected with wet or dry gunpowder will be destroyed.

(b) M.D., R.D.B., S.C. or W. cordite affected as at (a) of para 1 will be destroyed, but, if affected as at (b) or (c) of that para., a sample of the Lot concerned will be washed in distilled water, when possible, dried, and subjected to heat test as directed in Appendix 1, R.A.O.S. Part 8, Pam. 7, if the sample passes the test, the remainder of the contaminated cordite of that lot will be wiped free of gunpowder with a clean, dry cloth, and will then be considered serviceable.

(c) N. and N.Q. cordites will be reported immediately.

CARTRIDGES BL - DAMP IGNITERS - SULPHUR INFECTION.

During the wet periods of the year the Gunpowder ignitors of ready use BL Cartridges at gun positions are liable to be affected by damp.

The results of damp ignitors are failure to fire or hangfire, the latter being disturbing as there is some risk of the breech being opened with a smouldering cartridge when an explosion may occur. Units should therefore be urged to ensure that ignitors are well protected against wet or damp.

From the IOO's point of view it is useful to know that a gunpowder ignitor cannot normally sulphur infect the cordite charge through the action of the atmosphere. The ignitor will usually require to be wetted, that is, in contact with water, rain etc. before sulphur infection of the cordite occurs. Consequently an IOO should discriminate in sentencing, between wet ignitors which cause sulphur infection and damp ignitors which do not. There is no Service tests for indicating when a gunpowder ignitor becomes unserviceable through dampness. The moisture test given in RAOS Part 8 relates to gunpowder in bulk only. It may be assumed however that a moisture content up to 3 per cent will not affect the serviceability. The real test is the practical one of "feel" so that as long as the powder is not caked and the ignitor "feels" dry, it can be taken as serviceable. Caking sometimes occurs with dry powder, consequently the ignitor should be massaged gently to bring the contents to the powder form.

Spare ignitors are issued to Coast defence Units generally in the proportion of 5% of the cartridges held. These units are expected to replace damp ignitors by serviceable spare ignitors under the supervision of the Master Gunner, whilst Field Units simply tie the additional dry igniters over the damp igniter and load the lot in the gun. Obviously special care must be exercised to keep these spare igniters, which are issued in special packages, dry and free from damp.

Sulphur infected Cordite according to RAOS is to be destroyed on receipt of confirmation of the sentence, but it is useful to know that sulphur infection does not render the Cordite unserviceable immediately. In fact, with the carbamite cordites this deterioration is comparatively slow. The cartridges suitably marked to facilitate indentification should be segregated in all cases, but if the supply of fresh cartridges presents difficulties the doubtful cartridges can be retained on unit charge, though segregated, for sometime and of course used up in firing as soon as possible. (CIOO Circular 27/6).

TREATMENT OF CONTAMINATED PROPELLANTS.

(1) Experience has shown that the stability of modern propellants is not seriously impaired by contamination with water and/or oil. Double base propellants may suffer a loss of nitroglycerine with a consequent upset in ballistics. Cordites S.C., H.S.C.T., and particularly the flashless picrite types - N, NQ, NA and NS may be appreciably ballistically effected, according to the degree and duration of contamination.

(2) RAOS Part 8, pamphlet 7, paras. 30 to 32 inclusive, details the method to be adopted when certain natures of cordite have been wetted and pre-supposes that a first hand knowledge will be available as to whether such cordite has been wetted with fresh or salt water; also the period that it has been wet. The principles outlined are to be adhered to; also when it is suspected that immersion has been for a period, the usual examination, heat and colour tests will be applied before final sentence and release for service.

(3) Oil contamination should be dealt with in the same manner as salt water contamination except that all stocks will be first wiped free of oil with a clean, dry rag and heat test applied.

(4) The question of the treatment of SC., HSCT., N, NQ., NA and NS cordites however requires further consideration. It can be successfully dealt with as described in the preceding paragraph but the loss in ballistics is the greatest factor to be reckoned with. This could be determined by gun proof, pressure and velocity, by Inspection Division. It is however, extremely improbable that complete cordite lots will come forward but rather that small parcels, bits and pieces, from several lots will be detected from time to time. Should a complete lot or a parcel of sufficient size from a particular lot come forward, gun proof will be resorted to. On the other hand, small parcels are to be sentenced "Unserviceable - Destroy".

(5) Propellants that have been cleansed and re-sentenced as in para. 2 above will be distinguished by the letter "C" followed by the month of cleansing after the lot number on cartridges and packages e.g. C.11.43. (Extract C.I.O.O. Circular No. 12).

DESTRUCTION OF UNSERVICEABLE CORDITE.

(1) The cordite will be conveyed to the ground selected in its original packages or in barrels and cases, the usual precautions for transport of explosives being observed.

(2) The ground on which the cordite is to be burnt and its neighbourhood must be free from dry grass or other inflammable material.

Cordite for burning will be laid out in a train about 100 ft. long to every 500 lb. of cordite, and a second burning will not be carried out on the same ground, or in the vicinity, until the operations detailed in para. 6 have been performed.

The cordite will then be burnt under the personal superintendence of the Inspecting Ordnance Officer :-

The following stores are required :-

Cells, inert "A" as required.
Suitable firing-key or switch.
Cable, electric, E.1., Mk. 11.
Fuze, electric, No. 14.
Two water-buckets.
Two watering-cans.
Tools as necessary for opening packages.
Two Shovels.

(5) After having ascertained that the ground and vicinity is clear and that the wires are disconnected from the battery, the operator will connect up the fuze and place it in the train of cordite so that the direction of burning may be, as far as possible, against that of the wind. (This should be taken into consideration when the train is laid out). He will then proceed to the battery and, when ordered to do so by the Inspecting Ordnance Officer, will connect the leads of the battery and fire.

All persons must be at a safe distance (not less than 20 yds.) from the cordite before the firing-key of the battery is actuated.

(6) Immediately after the cordite has burnt out, the ground will be well watered, for which purpose the two watering-cans and two buckets will be ready filled. The ground will then be carefully examined to see that no fire remains. Any uncomsumed cordite will be carefully collected and burnt.

## INSTRUCTIONS FOR THE EXAMINATION AND TESTING OF NITRO-CELLULOSE POWDER, IN BULK OR IN CARTRIDGES (BRITISH MANUFACTURE).

(1) It is most important that packages should not be left open in a damp atmosphere.

(2) ODOUR.

Immediately on opening the package or cartridge the odour of the contents should be noted. The odour will be ethereal if the powder is in good condition, but pungent, acid and characteristically nitrous if the powder is unsound and decomposing.

If the decomposition has reached an advanced stage, the cartridge bag and case will have been attacked by the acid fumes liberated.

(3) COLOUR.

The grains of sound powder differ very considerably in colour; they may be buff, linen-brown, greenish, dark green-blue or nearly black, and progressive change through this range of colours will take place on storage.

This change of colour is due to slight change in the stabilizer present in the powder, and does not indicate marked deterioration of the nitro-cellulose.

When seriously deteriorated, the very dark grains become light again in colour, patches of orange-yellow may develop, and the whole of the grains ultimately become orange-yellow (see para. 5 below).

(4) CONSISTENCY.

The grains of sound powder have a rough surface and are very hard and tough. As deterioration proceeds, the grains become brittle. The development of small cracks round the edges of the grains is another sign of decided deterioration.

(5) REACTION TO LITMUS.

The grains of sound powder are neutral in reaction, but the orange-yellow deteriorated grains in a state of advanced decomposition are decidedly acid to Service blue litmus paper.

(6) ABEL HEAT TEST.

This heat test will be carried out at 180°F., with the usual precautions, on the sample ground to cordite heat test size (see Appendix 1, R.A.O.S. Part 8, Pam. 7). The test must, however, be taken as complete on the development of a definite brown line of whatever character.

(7) DESTRUCTION.

Nitro-cellulose powder sentenced for destruction must be destroyed in small quantities at a time, as laid down for the destruction of unserviceable cordite.

INSTRUCTIONS FOR THE EXAMINATION AND TESTING OF N.C.(Y) POWDER IN BULK AND OF CARTRIDGES M.L. 3-IN. MORTAR AUGMENTING.

(A) N.C.(Y) IN BULK.

(1) APPEARANCE AND ODOUR.

The N.C.(Y) powder should be in the form of small, freerunning rounded grains either coloured with an orange dye or plain white and having an odour of camphor. The presence of an occasional undyed or deeply dyed grain may be disregarded in packages containing dyed N.C. (Y) powders. A slight fading of the dye occurs on prolonged storage.

(2) REACTION TO CONGO RED.

The N.C.(Y) powder should not show an acid reaction when tested with congo red paper. The portion taken for the test is placed between two moistened pieces of the Congo red paper and the whole is pressed between two clean glass surfaces for about half a minute. The congo red paper should show no bluing due to acidity.

(3) HEAT TEST.

The heat test will be carried out at 170°F. in the manner as for cordite (see Appendix 1, RAOS Part 8, Pam 7), except that the material for the test is not to be ground or sieved.

(4) DAMP OR WETTED POWDER.

N.C.(Y) powder which is damp or has been wetted tends to become caked. If it is suspected that the powder has been affected by moisture, a report should be made.

(B) CARTRIDGES M.L. 3-IN. MORTAR AUGMENTING.

(1) These will be broken down and the N.C.Y. powder examined in accordance with the directions in "A" above. At the same time the celluloid containers should be examined. They should be transparent and practically colourless. Celluloid on deterioration becomes brittle, yellow in colour and opaque; it also develops acidity. If any doubt is felt as to the condition of the container, it should be tested with Congo red paper.

(2) The moistened Congo red paper should be pressed on the surface of the container for about half a minute and should show no blueing due to acidity.

(3) If a container is found to be acid, it must be destroyed together with its contents. A report should then be made and 10 further containers from the same lot, selected as being the most deeply coloured, should be forwarded for special examination.

INSTRUCTIONS FOR TESTING AND SENTENCING BALLISTITE IN BULK OR IN CARTRIDGES EXCEPT IN SMALL-ARM AMMUNITION.

The inspection, selection of samples and testing of ballistite in bulk, or in cartridges, including 96-grs. mortar cartridges (but excepting that in small-arm ammunition cartridges), will be carried out on similar general lines to those laid down for Cordite M.D. and cordite R.D.B.

Lots will be sentenced on the results of heat test in accordance with the table shown in RAOS Part 8, Par. 7, Appendix 1V.

When the stock sentenced for destruction on the results of heat test is large, or circumstances unusual, the results of test and amounts involved should be reported.

DISPOSAL OF CARTRIDGES FROM WHICH SAMPLES OF CORDITE HAVE BEEN TAKEN FOR TEST.

Cordite selected from cartridges, (other than 3.7 and 4.5), will be replaced by cordite of the same lot and size, held in bulk.

Where cordite of the same lot and size is not held in bulk, the cartridges will be broken down and components taken on charge separately. Any cordite remaining will be held on charge in bulk, and used for future replacements.

If however, the quantity of cartridges is small, and no bulk, cordite is held for replacement, cordite of the same nature and size, giving similar ballistics, may be used as replacement.

## APPENDIX 1.

### FUMES FROM FIRED PROPELLANT.

Cases have been reported of members of gun crews collapsing or being ill following the firing of the guns on which they are serving.

It is possible that fumes from the burnt propellant gases can cause discomfort to gun crews and FNH powders are more toxic than cordite. The theoretical percentage of carbon monoxide in muzzle gas.es being :-

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Cordite | W | - | 35% | carbon | monoxide | in | muzzle | gases. |
| " | WM | - | 37% | " | " | " | " | " |
| " | MD | - | 36% | " | " | " | " | " |
| " | SC | - | 39% | " | " | " | " | " |
| " | N | - | 29.1% | " | " | " | " | " |
| " | NQ | - | 24.4% | " | " | " | " | " |
| Powder | FNH | - | 48.1% | " | " | " | " | " |
| " | NH | - | 47% | " | " | " | " | " |

Whilst these figures are not from actual determination, they indicate that a much higher percentage of carbon monoxide will be present in the gases from the NH and FNH powders.

This is published for information of IOOs and the remedy for isolated cases of affected personnel lies with the Gun crew routine and the Unit concerned.

## TABLE OF PROPELLANTS

| TYPE | % NG | % NC | % STABILIZER | % OTHER COMPONENTS | CODE* LETTER | SOLVENT |
|---|---|---|---|---|---|---|
| Cordite Mk.1 | 58 | 37 | 5 Mineral Jelly | - | - | Acetone |
| MD | 30 | 65 | 5 Mineral Jelly | - | D or F | Acetone |
| MC | 30 | 65 | 5 Mineral Jelly | - | - | Acetone |
| CDT | 30 | 65 | 4.5 M.J. 0.5 Carbamite | - | - | Acetone |
| RDB | 42 | 52 | 6 Mineral Jelly | - | C or F | Ether-Alcohol |
| SC | 41.5 | 49.5 | 9 Carbamite | 0.15 Chalk | S | Solventless |
| SU | 41.5 | 49.5 | 9 Carbamite | - | S | Solventless |
| HSC | 47 | 49.5 | 3.5 Carbamite | 0.15 Chalk | H | Solventless |
| W | 29 | 65 | 6 Carbamite | 0.4 Chalk | E | Acetone |
| WM | 29.5 | 65 | 3.5 M.J.2.0. Carbamite | 0.4 Chalk | E | Acetone |
| N | 18.7 | 19.0 | 7.3 Carbamite | 55 Picrite0.3 Cryolite 0.2 Chalk | A | Acetone |
| HN | 34 | 25 | 1.Carbamite | 40 Picrite 1.0 Pot. Sulphate | - | Acetone |
| NQ | 20.6 | 20.8 | 3.6 Carbamite | 55 Picrite 0.3 Cryolite 0.15 Chalk | A | Acetone |
| AN | 25.5 | 56.5 | 3.5 M.J. 4.5 Carbamite | 10 DNT 0.7 Pot. Nitrate | X | Acetone |
| ANB | 25.5 | 56.5 | 3.5 M.J. 4.5 Carbamite | 10 DNT 0.7 Pot. Nitrate | X | Solventless |
| Bofors | 26 | 66.6 | 0.7 Diphenylamine<br>1.5 Meth. Centralite | 5.2 Diamylphthalate | J | - |
| Superim | 24 | 73 | 3 Carbamite | 0.3 Chalk, up to 0.6 Graphite | - | - |
| Ballastite A | 39.5 | 60.5 | - | .35 Graphite | B | Solventless |
| Ballastite B | 38 | 59.9 | 0.6 Carbamite | 1.5 Pot. Nitrate, 0.6 Graphite | B | Solventless |
| M4X (Dupont) | 32 | 66.15 | 0.6 Diphenylamine | 0.25 Pot. Sulphate, 1 Graphite | - | - |
| N.C.T. | - | 99.5 | 0.5 Diphenylamine | - | N + | Ether-Alcohol |
| NC(Z) | - | 92.4 | 0.6 Diphenylamine | 0.5 Graphite 6.5 DNT | - | " " |
| NC(Y) | - | 76.5 | - | 11.5 Barium Nitrate 2.5 Camphor plus Pot. Nitrate, M.J., Starch, etc. | - | " " |
| Neonite (typical) | - | 95 | 1 Diphenylamine<br>2 Meth. Centralite | 2 Dibutylphthalate | - | Ether-Alcohol |
| NH (Dupont) | - | 86 | 1 Diphenylamine | 3 Dibutylphthalate 10 DNT | O | Ether-Alcohol |

| TYPE | % NG | % NC | % STABILIZER | % OTHER COMPONENTS | CODE * LETTER | SOLVENT |
|---|---|---|---|---|---|---|
| NH (Hercules | - | 82 | 0.9 Diphenylamine | 17 DNT | O | Ether-Alcohol |
| FNH | - | 84 | 1 Diphenylamine | 5 Dibutylphthalate 10 DNT | L | Ether-Alcohol |
| FNH/P | - | 83 | 1 Diphenylamine | 10 DNT, 5 Dibutylphthalate 1 Pot. Sulphate | - | Ether-Alcohol |
| FNH/DB | 20 | 75.5 | 0.75 Diphenylamine | 1 DNT 1 Barium Nitrate 1 Pot. Nitrate | K | Ether-Alcohol |
| Hercules 81 mm Mortar Powder | 40 | 57.75 | 0.75 Diphenylamine | 1.5 Pot. Nitrate | | |

* The marking of the propellant code letters on all BL and QF Ctgs and their packages will be discontinued and replaced by the letters indicative of the type of propellant, e.g. WM, NQ, FNH, etc.

\- Of 1914 - 1918 manufacture.

NOMENCLATURE TO DENOTE SHAPES OF CORDITE

| | | |
|---|---|---|
| No letter | - | Cord |
| T. | - | Tubular Propellant |
| M. | - | Multi tubular Propellant |
| S. | - | Slotted Tube Propellant |
| R. | - | Ribbon Cordite |
| D. | - | Drilled ) in Cordite SU only |
| G. | - | Grooved ) in Cordite SU only |
| X. | - | Cruciform Cordite |

ADDITIONAL NOMENCLATURE

| | | |
|---|---|---|
| /P | - | Potassium Sulphate added. |
| /K | - | Potassium Cryolite added. |
| /Q | - | Sodium Cryolite added. |

(Extract from MCS Publication) 14 Nov 44.

## APPENDIX 3.

## ENEMY PROPELLANTS.

### JAPANESE PROPELLANTS.

Two standards of propellant-one for Army and one for Navy appear to have been adopted by the Japanese. Single and double base propellants appear in the ammunition of both services. Typical Army propellants are :-

Single Base:

| | |
|---|---|
| Nitrocellulose (graphite coated) | 98% |
| Diphenylamine | 2% |

Double Base:

| | |
|---|---|
| Nitrocellulose | 67.8% |
| Nitroglycerine | 29.3% |
| Diphenylamine | 0.7% |
| Sodium Chloride | 2.2% |

The first type (single base) is by far the most widely used and is found almost invariably in gun ammunition propellant charges.

The Double Base type is used chiefly in mortars. The sodium chloride is a flash reducer. The only Japanese "flashless" propellants so far examined have contained sodium chloride for this purpose.

Captured documents designate Single Base propellant as "C" type and double base as "G" type, "G" type propellants are further subdivided into "A" and "B" types-"A" if a solvent is used in manufacture and "B" if it is solventless. "B" type is tending to replace "A" type because of its speed of manufacture.

Typical Navy propellants are as follows :-

Single Base:

| | |
|---|---|
| Nitrocellulose | |
| Dinitrotoluene | 0.95% |
| Diphenylamine | 0.8 % |
| Graphite | 0.25% |

Double Base:

| | |
|---|---|
| Nitrocellulose | 65.6 % |
| Nitroglycerine | 29.2 % |
| Carbamite | 3.7 % |
| Sodium Chloride | 1.5 % |

This propellant is not unlike British "W" cordite.

The Navy use of carbamite as a stabiliser is notable. Army propellants examined to date have never been found to contain carbamite. Some Navy propellants possess a sweet cherry-blossom odor. This is due to the presence of up to 4 per cent of methyl-betanaphthyl ether.

These Japanese propellants are usually in the form of cords. Tubes are rarely used.

In the larger calibres (e.g. 75 mm) the propellant is contained in a silk bag in the cartridge case and is in the form of flat, square flakes usually 1 cm. square. Sometimes (e.g. in the 75 mm A.A. type 88 gun) it is loaded directly into the cartridge case in the form of flat strips and in this case is not graphite coated.

In such ammunition as the Navy 25 mm pom-pom and the Army 20 mm A.A/Tk A. type 98, the propellant is in the form of chopped graphited tubes and contains 5 to 8 per cent of dinitrotoluene (at the expense of the nitrocellulose).

## JAPANESE SMALL ARM PROPELLANTS.

### 13 mm S.A.M.G. - Naval Manufacture.

This propellant consists of :-

| | |
|---|---|
| Nitrocellulose | 91.4 % |
| Diphenylamine | 1 % |
| Dinitrotoluene | 5.3 % |
| Granulated tin | 2 % |
| Graphite | 0.3" |

## JAPANESE IGNITERS.

Japanese igniters are usually gunpowder filled.

## GERMAN PROPELLANTS

German propellants are of three main types as follows :-

(a) "Gudol" propellant. These have GU in the nomenclature and contain nitrocellulose, diethylene glycol dinitrate and nitro quanadine in the approximate proportions 1:1:1. They are flashless and stable.

(b) "Diglykol" propellants. These are double-base propellants containing nitrocellulose and diethylene glycol dinitrate. They have "DIGL" in the nomenclature.

(c) "Nitroglycerene" propellants. The chief constituents are nitrocellulose and nitroglycerine. They have "NGL" in the nomenclature.

The Germans use "Gudol" and "Diglykol" propellants in large quantities and make little use of the nitroglycerine type.

Diethylene glycol dinitrate is used because it is obtained from dethylene made from calcium carbide, which makes use of a native raw material.

Propellants made with this ingredient are much less sensitive than double base propellants made with nitroglycerine. Hence the output can be much greater because the safety precautions are less onerus.

It is thought the Germans adopted the idea from the French, who first used diethylene dinitrate as an igredient for propellants.

The French solventless powder "SD" was :-

| | |
|---|---|
| Nitroglycerine | 25% |
| Nitrocellulose (11.7% nitrogen) | 66% |
| Carbamite | 9% |

This was gelatinised on rolls and extruded at 100°C. It was worked at high temperatures. Then the French "C" powder appeared. Nitroglycerine was dropped and the constituents were :-

| | |
|---|---|
| Diethylene glycol dinitrate | 33.7% |
| Nitrocellulose (11.7% nitrogen) | 64.3% |
| Carbamite | 2 % |

This had the following advantages :-

(a) Less sensitivity and less danger in manufacture.

(b) Lower consumption of carbamite.

(c) Greater ease and rate of production due to increased gelatinising power.

(d) Higher nitrocellulose content than British S.C. cordite and a cool propellant.

Typical German propellants of this type are :-

5 c.m. P.A.K. A.P. 40 (Arrowhead).

| | |
|---|---|
| Nitrocellulose | 66.13% |
| Diethylene glycol dinitrate | 31.18% |
| Akardite | 2.34% |
| Graphite | 0.11% |
| Potassium Sulphate | 0.24% |

10.5 c.m. 1.F.H.18.

| | |
|---|---|
| Nitrocellulose | 64.15% |
| Diethylene glycol dinitrate | 35.21% |
| Akardite | 0.44% |
| Graphite | 0.20% |

Akardite is unsymmetrical diphenylurea.

GERMAN FLASHLESS PROPELLANTS.

These are found in flake form 4 x 4 x 0.6 mm. Their composition is as follows :-

| | A. | B. | C. |
|---|---|---|---|
| Nitrocellulose | 35% | 38% | 38% |
| Diethylene glycol dinitrate | 35% | 31% | 31.5% |
| Nitroguanidine | 30% | 30% | 29.5% |

It is thought the Germans adopted the idea from the French, who first used diethylene dinitrate as an igredient for propellants.

The French solventless powder "SD" was :-

| | |
|---|---|
| Nitroglycerine | 25% |
| Nitrocellulose (11.7% nitrogen) | 66% |
| Carbamite | 9% |

This was gelatinised on rolls and extruded at 100°C. It was worked at high temperatures. Then the French "C" powder appeared. Nitroglycerine was dropped and the constituents were :-

| | |
|---|---|
| Diethylene glycol dinitrate | 33.7% |
| Nitrocellulose (11.7% nitrogen) | 64.3% |
| Carbamite | 2 % |

This had the following advantages :-

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Usually potassuim sulphate is added in a separate bag. No flashless propellant containing nitroglycerine has been found. Small quantities of potassium sulphate are frequently found in ordinary double base nitrocellulose-diethylene glycol dinitrate powder to promote flashlessness.

COMPOUND CHARGES.

The Germans make free use of compound charges. Typical of them are the following :-

5 c.m. H.E. Q.F. A/TK Gun.

(a) 230 g. flake flashless propellant 4 x 4 x 0.6 mm.

| | |
|---|---|
| Nitrocellulose | 35% |
| Diethylene glycol dinitrate | 35% |
| Nitroguanidine | 30% |

(b) One 9 g tube diameter 0.665/0.5 mm., length 30 mm.

| | |
|---|---|
| Nitroglycerine | 68% |
| Diethylene glycol dinitrate | 32% |
| Akardite | 0. 6% |

7.5 c.m. H E. Q.F. A/TK gun, model 40.

(a) 780 g flake flashless propellant 4 x 4 x 0.6 mm.

| | |
|---|---|
| Nitrocellulose | 38% |
| Diethylene glycol dinitrate | 31% |
| Nitroguanidine | 30% |

(b) One 60 g central tube

| | |
|---|---|
| Nitrocellulose | 63% |
| Diethylene glycol dinitrate | 35% |
| Potassium sulphate | 2. 3% |

With an additional bag of 19 g of potassium sulphate.

OTHER GERMAN CHARGES.

15 c.m. S.F.H. 18.

There are two types of this charge :- "A" and "B".

| | "A" | "B" |
|---|---|---|
| Nitrocellulose | 64.85% | 55.98% |
| Diethylene glycol dinitrate | 34.7 % | |
| Nitroglycerine | | 42.97% |
| Akardite | 0.30% | 0.94% |
| Graphite | 0.15% | 0.11% |

Usually the propellant is in the form of cords or tubes. Strip Nitrocellulose-diethylene glycol dinitrate propellant is used in the air-borne short 7.5 c.m. tank gun, the strip being 125 x 5 x 0.5 mm.

3.7 c.m. Q.F. A.P. (Arrowhead).

| | |
|---|---|
| Nitrocelluloso | 58% |
| Nitroclycerino | 39% |
| Carbamite | 2.5% |

5. c.m. Q.F. A.P.C. A.Tk.

499 g tubes, length 20 c.m. diameter 2/0. 75 m.m.

| | |
|---|---|
| Nitrocelluloso (11.81%) | 61.75% |
| Diethylene glycol dinitrate | 26.19% |
| Carbamite | 8.09% |
| Waxy material | 2. 9% |
| Potassium Sulphate | 0. 8% |
| Gbaphite | 0.27% |

8.8 c.m. H.E. Q.F. (8.8 c.m. A.A. 18 and multipurpose 36 guns.

The propellant used in these guns is a Nitrocellulose-diethylene glycol dinitrate graphited powder containing sodium bicarbonate.

10.5 c.m. A.F. separate fired in L.F.H. 18 gun howitzers.

These charges consist of flake propellant 4 x 4 x 0.2 m.m. and 4 x 4 x 1 m.m. in five sections. The propellant is a double base nitrocellulose-nitroglycerine powder; or:- Flake propellant 3 x 3 x 0.8 m.m in five sections consisting of a double base nitrocellulose-diethylene glycol dinitrate powder.

21 c.m. Q.F. Separate Heavy Howitzer.

Charge consists of nitrocellulose-diethylene glycol dinitrate powder in five sections. The base bag of section one contains 1000 g flake 3 x 3 x 0.8 mm. The top bag of sections one and sections 2 to 5 contain 6000 g of perforated discs 1.9 mm. in thickness and 15/4 mm. in external and internal diameter respectively.

GERMAN H.V. SMALL ARMS.

The following types of propellants have been found in German HV small arms ammunition:-

| | |
|---|---|
| Nitrocellulose | 56% |
| Penthrite | 34% |
| Diphenylamine ) Carbamite ) Dinitrotoluene ) | Remainder |

| | |
|---|---|
| Nitrocellulose | 32% |
| Penthrite | 60% |
| Diphenylamine ) Carbamite ) Potassium Sulphate ) | Remainder. |

The normal German S.A.A. propellants contain 95 per cent of nitrocellulose (13-13.25% nitrogen). Other ingredients are potassium sulphate, carbamite, diphenylamine and dinitrotoluene.

GERMAN IGNITERS.

The Germans use gunpowder infrequently in their igniters.

Gunpowder seems to have been discarded in favour of a nitrocellulose powder in the form of cylinderical pellets 1.5 m.m. long and 1.5. m.m. in diameter. The powder is made by incorporating potassium nitrate in nitrocellulose and subsequently leaching with water. This removes some of the potassium nitrate and leaves the material with a porous texture. This powder ignites readily and burns longer than gunpowder thus rendering ignition more certain and complete.

Double base powder igniters are found in some larger calibres.

The ignition found in the 10 c.m. K.18 (10.5.c.m. gun hewitzer) consists of 40 g of the usual nitrocellulose powder nearest the primer and separated by a rayon disc from 35 g of a double base nitrocellulose-nitroglycerine powder in the form of flakes, 4.m.m. square by 0.2 m/m. thick.

ITALIAN PROPELLANTS.

An interesting point about Italian propellants is that some of them are unstabilised. For example the propellant charge in the 77/28 H.E. round consists of:-

| | |
|---|---|
| Nitrocellulose | 49.9% |
| Nitroglycerine | 50.6% |

This propellant is unstabilised and is in the form of square, clear flakes. Most of the Italian propellants, however, are stabilised. A typical example is as follows:-

4.7 c.m. H.E.C.F. A/Tk. Gun 35.

| | |
|---|---|
| Nitrocellulose | 62.4% |
| Nitroglycerine | 34 % |
| Carbamite | 2 % |
| Mineral Jelly | 1 % |
| Graphite | 0.8% |

75/27 Q.F. Fixed.

Two types of propellants are found in this ammunition:-

(1)

| | |
|---|---|
| Nitrocellulose | 60.29% |
| Nitroglycerine | 25.54% |
| Dinitrotoluene | 14.17% |

This propellant is not stabilised.

(11)

| | |
|---|---|
| Nitrocellulose | 71.53% |
| Nitroglycerine | 23.73% |
| Mineral Jolly | 4.74% |

Italian propellants are usually in the form of flakes, 12 to 15 m.m. square and 1 to 1.5 m.m. thick.