PYROTECHNICS

The term pyrotechnics is taken to encompass all those items utilising fire to achieve their intended purpose. As mentioned in the introduction these purposes are:

1.Illumination,
2.Signals,
3.Tracers,
4.Screening smoke,
5.Navigational aids,
6.Practice stores,
7.Simulators,
8.Initiators, and
9.Incendiaries.
10.Noise makers

They achieve their intended effect by burning a compressed mixture of a combustible material with an oxidant and various additives to modify the effect. Some pyrotechnic items are simply combustible material without any additives, such as some of the incendiaries and some of the smoke producers. The essential action of a pyrotechnic is a burning taking place at the surface, hence the greater the surface area the greater the burning rate.

In very simple terms pyrotechnics can be regarded as producing four basic effects and these are

SMOKE | LIGHT | FLAME | SOUND

FUELS

These are readily combustible materials such as

ALUMINIUM POWDER | STARCH | SUGAR

CHARCOAL | LACTOSE | MAGNESIUM

THE OXIDANTS

These are the source of the oxygen to support the combustion of the fuels.

Potassium chlorate: $KClO_3$ | Potassium Perchlorate

Sodium nitrate $NANO_3$ | Barium nitrate $BaNO_3$

In addition to a fuel and an oxidant most pyrotechnics require the addition of other materials to achieve the following effects

- Colour the flame
- Bind the ingredients
- Coat the ingredients
- Control the burning rate
- Control the temperature of burning

To achieve the desired flame colour in signal stars, tracers and some illumination compositions the following metallic salts may be used:

METALLIC SALT	COLOUR
Barium	Green
Calcium salts Calcium chloride Calcium suphate	Orange
Copper	Blue
Strontium	Bright red
Lithium	Red
Sodium Cryolite	Yellow
Magnesium Aluminium	Bright white

Some colouring agents also perform the function of Binders. Barium chloride is unstable at normal temperatures so it must be mixed with chlorinated rubber which releases barium chloride under the heat of the pyrotechnic mixture.

BINDERS

These are the materials added to the composition to bring the mixture into a cohesive state.

- Wax
- Shellac

COATINGS

Most metallic powders including those mentioned above suffer from the problem of reactions with residual moisture contained in the pyrotechnic compositions. To prevent corrosion of the metallic particles, coatings are added to the composition. Coatings may also act as binding agents. Some examples are:

Boiled linseed oil

Lithographic varnish

Paraffin wax

BURNING RATE CONTROLLERS

To achieve various effects it is necessary to vary the burning rate of pyrotechnic composition and to achieve this control the following moderants are sometimes used. In some cases the temperature may be so high as to decompose the dyestuff instead of vaporising it so the inclusion of a controller is necessary.

SHELLAC | ACCAROID RESIN | WAX

In addition to additives, the burning rate of pyrotechnics may by varied by the following methods

- Variation to the proportion of ingredients
- Variation to compression of the ingredients
- Variation to particle size,

T E M P E R A T U R E CONTROL

As the temperature directly influences the rate of burning, it is necessary to reduce the temperature to a level where the reactions occurring are not accelerated to uncontrolled levels thus ruining the effect you intended. The violence of the reaction may be such that the pyrotechnic device instead of burning will explode or in some cases such as smoke grenades the thing may even act like a jet and be propelled through the air. Control may be achieved by using:

- SULPHUR (Now you know why this is in gunpowder)
- CALCIUM OXALATE
- POLYVINYL CHLORATE

With every pyrotechnic store in existence the main and insurmountable problem is the susceptibility to moisture which limits their storage life. As with the problems of Gunpowder "It's just the nature of the beast"

LIGHT COMPOSITIONS

These are termed "ILLUMINATING" in military circles and they usually consist of mixtures containing magnesium or Aluminium Powder. These materials provide the very bright light required. The oxidising agent is usually something like barium nitrate or Potassium Nitrate. Both very rich in oxygen. Other ingredients are added if desired to modify the colour of the flame or to stabilise the composition etc. The intensity of the light generated is directly related to the burning rate of the composition. Varying either the density of compression or the proportion of the magnesium can control this rate.

F L A M E COMPOSITIONS

These compositions have two purposes

STARTING FIRES | SIGNALLING

FIRE COMPOSITIONS

These mixtures should ideally produce a very hot molten mass or very intense and prolonged flame that should be very hard to extinguish once ignited. In this category falls the pyrotechnic mixture used for priming other, more difficult to ignite compositions such as tracer elements and propelling charges. One notable pyrotechnic composition is Calcium Phosphide that ignites on contact with water producing both smoke and flame. It is used in marine markers for various signalling purposes. The grain sizes and shape affect burning intensity. Most magnesium used in Pyrotechnics is known as "Cut" and is produced by rasping particles from blocks of the metal. This produces particles of irregular shape that may produce erratic burning. Blowing a molten stream of the metal into a chamber filled with an inert gas produces a particle that is very uniform in shape. Compositions using "Blown" magnesium produced consistent burning time. Aluminium intended for pyrotechnic purposes is supplied in two grades "light" which is flake type and "heavy" which is the blown type.

SIGNALS

These mixtures fall into two types

Coloured Lights | Coloured smoke

Coloured light signals are used for day or night purposes the Chief difference being that signals required for night may be of lesser intensity than those required for day as the light will be visible for a greater distance at night. Those required for day purposes have as their filling one of the metallic powders such as magnesium or Aluminium that burn with a greater intensity. The brighter light generated gives a better chance for the gunner to see where his tracers are going.

The colouring of these signals is achieved by the addition of various metallic salts such as sodium, barium and strontium. Included in this category are the devices used in projectiles to indicate the flight path through the air. These devices are called "tracers"

Coloured smokes signals are used for day signalling and consist of a mixture of a very strong dye and a combustible material and the usual oxidiser. It is important to ensure that the burning isn't too hot, as very high temperatures will decompose the dyestuff instead of vaporising it.

SMOKE COMPOSITIONS

Smoke on the battlefield was for a long time regarded as a nuisance of the first order. The weapons of the times when warfare was beginning to get organised produced immense quantities of smoke and generally obscured the battlefield, hindered the aiming of weapons, and hampered the control of troop movements by the Generals. It is this nuisance value that ensured the place of smoke on the battlefield was so long neglected. The battle of Jutland is a famous example of the early use of smoke for tactical purposes
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The use of smoke in warfare on land as a deliberate stratagem would surely have occurred in some place in history but not as an official, recognised policy. The first deliberate, planned use of smoke in warfare was in the early days of WWI in the summer of 1915. This introduction occurred with the use of gas as a weapon of war. It would seem logical that the value of smoke as a screening agent occurred to some bright fellow.

The British were the first to use smoke to mask their attacks by suggesting to the Germans that a gas attack was coming. Instead the British advanced behind the smoke and surprised the Germans. The first large-scale smoke operation carried out was by the Canadians at Messines ridge on September 20th 1915. Trench mortars fired many thousands of shells to support and mask the attack

A DESCRIPTION OF SMOKE

Smoke is made of either dispersed liquid particles or solid particles held in suspension in the air. Smoke is not a solid, not a liquid and not a gas. It is in fact a "Dispersed" form of matter known as a "Colloidal" suspension or solution. The colloidal state of matter is an intimate admixture of two mediums. In this case the dispersion medium, the air, which is a gas and the dispersed medium the solid or the liquid.

Since the particles making up the smoke are heavier than air they will gradually fall to the ground. The rate at which they fall will be dependent on the size of the particles, the temperature of the air and the vagaries of the air currents.

There are many smoke producing agents, mixtures and methods but there are five main groups of smoke agents and these are:

- Carbon particles
- Phosphoric Acid particles
- Sulphuric Acid particles
- Hydrochloric Acid particles
- Zinc Chloride particles

Included in this group are tracers called "day smoke tracers" these leave a trail of smoke as they travel through the air. Also included in this group are the smoke producing agents included in artillery projectiles to indicate the point of impact by giving off a large quantity of smoke as the projectile explodes. Some explosive projectiles achieve this affect by intimately mixing the smoke composition in with the explosive filling.

BASIC SMOKE CHEMICALS AND HOW THEY FUNCTION

The smoke produced for smokescreens is usually white and is normally generated by dispersing a substance in the air, which absorbs or reacts with the moisture in the air. The most common materials being:

- WHITE PHOSPHORUS (WP)
- CHLOROSULPHONIC ACID (CSA)
- HEXACHLORETHANE (HC)

White phosphorus is the most efficient of the smoke producers but it has several drawbacks, which make it difficult to produce and handle. Firstly it needs no ignition system, requiring only to be exposed to the air to function. This means that all manufacturing steps need to be performed in the absence of air. Secondly it has a very low melting point. This means that steps must be taken to ensure that WP filled items are stored in such a way that any melting of the contents does not create air bubbles or cavities in the filling. Thirdly the easy ignition of WP means that items in storage must be so arranged that any leakers are easily reached and dumped in containers filled with water and placed near the stacks. This limits the quantities of any WP in a stack. It also makes a lot of soldiers very wary of WP filled munitions.

WP is the fastest of the smoke generators being almost instantaneous. Unfortunately the heat generated by burning WP creates an effect called "pillaring' This has the effect of lifting the smoke very quickly into the air thus reducing its time on the ground.

MEASURMENT OF A SMOKE SCREEN

To express the effectiveness of a smoke agent the engineers have come up with a measurement called "Total Obscuring Power" (TOP).

It is arrived at by measuring the amount of smoke from 1lb of smoke composition spread out in a layer of sufficient thickness and density that will just obscure the filament of a standard 40-watt lamp and it is expressed in square feet.

Some examples of smoke composition obscuring power.

SMOKE COMPOSITION	TOP
White phosphorus	4600
Titanium tetrachloride & ammonia	3030
FS mixture	2550
HC mixture	2100
FM mixture	1900
Tin tetrachloride	1860
BM mixture	1400
Berger mixture	1250
Crude oil	200

TRACERS

Tracers are the pyrotechnic devices built into projectiles to give a visual indication of the flight path of the projectile. This is particularly important in cases where the fall of shot is critical, such as anti-tank warfare. Watching the fall of shot using tracers allows the firer to adjust the point of aim thus getting the point of impact on to the target. Two distinct types exist.

DAY TRACER | NIGHT TRACER.

DAY TRACERS

Day tracers are required to be clearly seen in the bright light conditions existing during daylight. This is achieved by making the tracer give off relatively large quantities of smoke thus clearly marking its passage through the air. They also are very bright to aid in the tracking of them.

NIGHT TRACERS

Night tracers are required to be less bright for two reasons. Firstly the tracer being used at night is quite easily seen in the dark and secondly the gunner would be badly effected by the glare of a very bright tracer. His night vision would be completely ruined. Day smoke tracers can be used at night, as they will still function adequately the gunner just has to tolerate the poor night vision after firing. To overcome the problem of loss of vision because of the bright glare the "Dim ignition" tracer was developed. This has a pyrotechnic element that burns for a short period before igniting the tracer element in the projectile. This give the projectile time to travel some distance away from the firer's eyes before the tracer lights up.

SIMULATORS

During training it is required to simulate both battle noises and effects to accustom troops to the noise and confusion produced by loud noises close to them. To achieve this, pyrotechnic devices called Simulators are used. They consist of pyrotechnic mixtures to reproduce very loud noises and very bright flashes. Most of these types are filled with something like the old photographer's blend of Magnesium powder and Aluminium powder. These are the most violent of the pyrotechnic mixtures and should be treated with the utmost caution. Many simulators utilize high explosives to achieve their effects but these are always used by experts and not given to general issue for the troops.

NAVIGATIONAL AIDS

To accurately locate your position at sea when flying over it was rather difficult until the advent of global positioning satellite networks. Now it is a simple matter to consult your hand held gadget which tells you where you are and what direction to go to get home. In the bad old days the Air force chappies would use pyrotechnic devices which produce smoke and flame to give them a reference point on the surface of the sea. They would simply ignite the device and throw it over the side and then do their navigational sums from that point on. This was possible because they then had a fixed reference point to work from. There exist versions of these devices with dyestuffs added to mark the surface of the sea. Quite often these were used in a rescue setting where a victims position needed to be marked in a semi-permanent way.

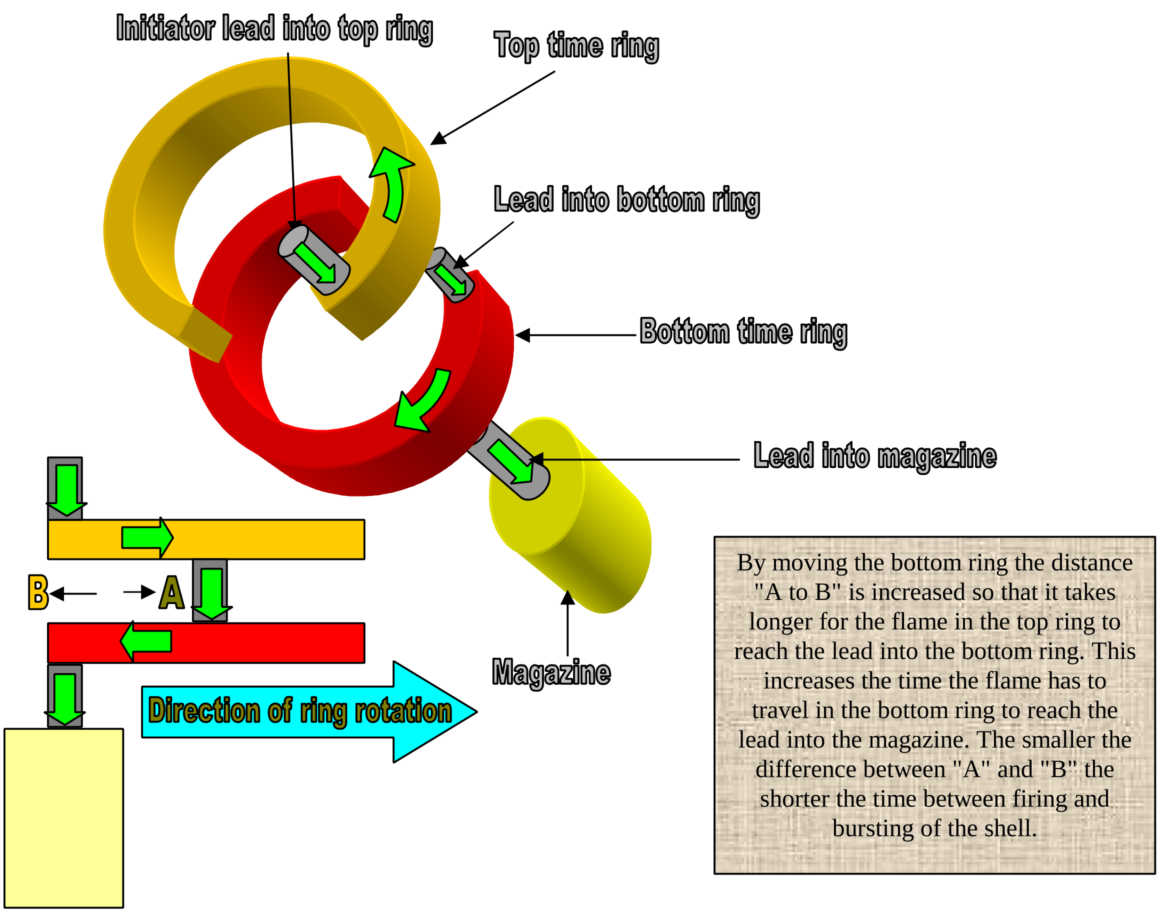
INITIATORS

One of the applications to which gunpowder is put is the igniting agent in artillery propelling charges. It is without peer in this particular application. Everything about gunpowder makes it so. It is sensitive to flash and spark. It gives a high temperature flame when exploding and it lasts for years if kept in good storage. The other application to which it is put is as the filling in fuze blasting time and in fuze time rings. Mind you combustion time fuzes have just about seen their day what with the advent of electronic timing devices of unprecedented accuracy. But they are still around. The filling in both cases is simply gunpowder compressed to a known and well-calculated density, which will give a burning rate accurate to within a few seconds per metre. The huge advantage this system has is the incredible simplicity of it and the very low cost. Mind you once you have lit the fuze and retired to your safe distance you have absolutely no control over when the thing will explode. That is the thing most ammunition experts don't like about Fuze Blasting Time.

An early example of blasting fuze, which in times past was called Fuze Safety.

Another application to which gunpowder is applied is the powder rings in time combustion fuzes. Once again gunpowder is without peer in this regard. The gunpowder is compressed to very fine tolerances to give an accurate rate of burning. Shown below is a schematic layout of the system.

FUZE TIME COMBUSTION RINGS



The above is a schematic arrangement of the time rings in a time combustion fuze. The green arrows indicate the direction of flame travel. A flash from an initiator ignites the top ring. The flame generated by this travels along the top time ring until it reaches the first exit point. This distance is determined by where the bottom fuze ring has been moved to in relation to the top ring. It can be seen that if the ring has been moved all the way round to its greatest setting the exit point will be at the end of the ring. Therefore the flame will take a long time to get to the lead into the bottom ring. The flame will then pass through the lead into the bottom ring and travels round to the second exit point and from there it passes into the lead going to the magazine.

The top ring is fixed and doesn't move. Gasses generated by the burning gunpowder are vented to the atmosphere through brass blowout discs placed around the fuze.

PRACTICE STORES

Because of the dangers involved in some forms of training such as throwing hand grenades it has been found, by hard experience that it is beneficial if the soldier could be first shown the rudiments using a non-lethal version of the real thing. This is where practice ammunition comes in. Using a re-loadable grenade body and a simple gunpowder charge with a re-placeable fuze each time, a soldier can be given all the necessary training without exposing him to dangers inherent in hand grenades of the high explosive types. In addition there is a great financial saving as HE shells, grenades, rockets and mines are all very expensive.

There exist versions of practice stores for just about every explosive device in service, aerial practice bombs, blank small arms ammunition, Artillery projectiles, mortar projectiles and sub-calibre rockets and, believe it or not there was at one time an Atomic bomb simulator.