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MILITARY PYROTECHNICS

THE MANUFACTURE OF MILITARY PYROTECHNICS

AN EXPOSITION OF THE PRESENT METHODS OF MANUFACTURE, THE MATERIALS AND MACHINERY USED

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PREFACE.

The following volume deals with the manufacture of military pyrotechnics, the materials and machinery used, and the latest approved methods of assembly.

During the progress of the World War, the continually changing needs and requirements of the War Department occasioned their corresponding changes for military pyrotechnics, the result being that when the armistice was signed this branch of the service was undergoing a change and being rapidly developed along more scientific lines.

It is my aim to show in the following work the methods of manufacture, the materials used, machinery, and manner of assembly practiced by the manufacturers engaged in fulfilling contracts for the Government on various forms of pyrotechnics at the time that the armistice was signed.

Military pyrotechnics has passed through various vicissitudes during the development of civilization and its wars, and has come down from a time when the compounding of explosive material was a function of the magician and alchemist.

Such development in the art as it exists to-day has been brought about more from the practical accomplishment of a desired result than from a technical study and carefully planned scientific approach to the subject. As in the various arts having their foundation in practice dating back centuries ago, strange heritages appear. The only excuse for their existence is in the phrase, " It has always been done this way." When the manufacturers were questioned in regard to the reason, from a technical point of view, for many of their operations, it was very evident that a woeful lack of technical knowledge was interfering with the development of the art.

In this volume hardly any attempt will be made to show wherein the present methods of manufacture are faulty, or wherein more approved types of machinery can be used to advantage, or where greater savings in the cost and use of chemicals can be accomplished, and a higher efficiency in the character and degree of the illumination of the various pieces can be brought about. The text deals simply with the present manufacturing conditions, and is given in the form described in order that it may serve as a foundation drawn from practical experience for many years.

As the Eygptian Phœnix rose resplendent in its red and gold plumage from the ashes of its past, so may a new development in the art rise from the ashes of the present antiquated methods of manufacture.

HENRY B. FABER.

INTRODUCTION.

In spite of the fact that the methods of military pyrotechnics as practiced at the present time give every indication of a woeful lack of development along technical and scientific lines, it must be borne in mind that this art was practiced hundreds of years ago and has developed slowly, keeping pace, in a measure, with scientific developments.

A note of caution should perhaps be sounded, as the reader may feel that the art as a whole has shown so little real advancement and may condemn too hurriedly the practices which have been in effect for many years. Bear in mind the fact that many minds and many trained and practiced hands have worked in pyrotechnics, and before discarding the practiced old for the unknown new in compositions and assemblies, it is well to give due credit to the present methods despite their ancient heritage, and not to treat too lightly practices which have at least fulfilled their function in producing a reasonably satisfactory article.

H. B. F.

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MILITARY PYROTECHNICS.

CHAPTER I.

MILITARY SIGNAL ROCKET.

The signal rocket is by far the best-known article of military pyrotechnics. Its importance is due to the fact that it is complete in itself, and may be carried with ease as the firework in its entirety does not weigh over 2½ pounds.

The signal rocket consists of a case or carton approximately 12 inches long by 1¼ inches inside diameter. This case or rocket body contains the propelling charge which consists of approximately 7½ ounces of powder formed into the case, almost filling it. The propelling charge operates by the rapid burning of the powder, producing a large volume of gas, which on issuing from the bottom of the case causes the rocket to be propelled. The case carries a rocket head, which is a carton shorter than the rocket body and slightly larger in diameter, containing the garniture. This consists of the parachute, attached to which is the signal. Attached to the rocket body is a small cylinder or carton containing a composition which is ignited at the same time as that of the propelling charge. This device is called a smoke tracer, and leaves behind it a trail of smoke that aids the observer in determining from what point the rocket made its flight. Attached to the rocket body by means of a socket is a long stick ⅝ inch square and 6 feet long, which serves as a balance for the upward flight of the rocket. The propelling charge is of such composition and of such weight that it will force the rocket upward in its flight to a height of from 800 to 1,000 feet. The rocket is so designed that when the propelling charge has completed its work and the rocket has reached the desired height a blowing charge is ignited which expels the garniture from the head, throwing the parachute and signal to a distance of about 40 feet.

During this flight the parachute frees itself and opens out, holding suspended the signal.

The signals are so designed that they are ignited by the blowing or expelling charge.

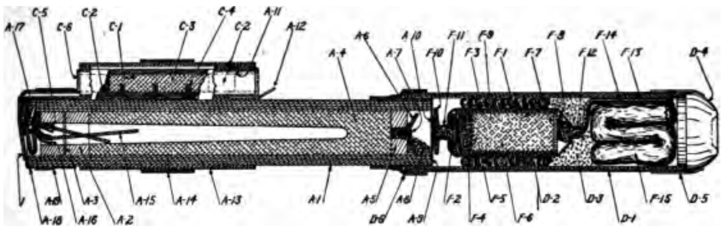


FIG. 2.—Sectional drawing of signal rocket.

SIGNAL ROCKET.

A. Rocket body:
1. Case.
2. Bottom heading.
3. Driving-charge composition.
4. Top clay heading.
5. Expelling-charge match.
6. Expelling-charge-match prime.
7. Expelling charge.
8. Muslin drumhead.
9. Prime.
10. Stick socket.
11. Stick spring.
12. Stick-socket binder.
13. Assembly band.
14. Match.
15. Match pipe.
16. Match staple.
17. Bottom drumhead.
18. Finishing band.

B. Auxiliary parts:
1. Stick.
2. Stick crate.
3. Directions label.
4. Name label.
5. Match packet.
6. Tearing string.
7. Tearing-string staple.
8. Wrapping carton.
9. Rocket wrapper.
10. Drumheads.
11. Outside label.
12. Identification Tag.
13. Rocket packing container.
14. Rocket packing case.
15. Ignition-match tie string.
16. Parachute tie string.
17. Extension cord.
18. Asbestos cord.
19. Parachute.

C. Tracer:
1. Shell.
2. Clay headings.
3. Yellow-smoke composition.
4. Match.
5. Match pipe
6. Wrapper.

D. Rocket head:
1. Case.
2. Wadding.
3. Packing.
4. Cap.
5. Cap band.
6. Muslin head band.

E Yellow-smoke signal:
1. Case.
2. Case ends.
3. First-fire composition.
4. Smoke composition.
5. Match.
6. Match band.
7. Wrapper.
8. Tie strings.
9. Asbestos cord.
10. Parachute.

F. White light:
1. Case.
2. Bottom disk.
3. Muslin disk.
4. Match.
5. First fire.
6. Composition.

F. White light—Continued.
7. Top disk.
8. Muslin wrapper.
9. Wet prime.
10. Ignition match.

G. Red-and-green lights:
1. Case.
2. Bottom disk.
3. Muslin disk.
4. Match.
5. Composition.
6. Top disk.
7. Muslin wrapper.
8. Wet prime.
9. Ignition match.
10. Ignition-match tie string.
11. Parachute tie string.
12. Identification tag.

DRIVING CASE OR ROCKET BODY.

CASE.

This case is made of material which will give strength as well as lightness to the body. As the case has to hold gases exerting a reasonably high pressure and as the walls of the case have to withstand a loading pressure when the powder is driven home, special care is taken to provide proper material for the manufacture. A case having a weight of about 8 ounces, being approximately 12 inches long by 1¼ inches inside diameter, should be so constructed that it will withstand a direct bursting pressure operating at right angles to the long axis of the tube of upward of 1,300 pounds to the square inch and an indirect pressure due to the loading of the powder charge which is driven home in the rocket body at a pressure upward of 2 tons per square inch. The manufacturers do not adhere strictly to any one method of forming the rocket body, but seem to favor the hand-rolled carton. The method of rolling is essentially the same, with slight modifications, among the different manufacturers, and is as follows:

Sheets of Bird's rocket hardware paper are purchased by the manufacturers, cut in sheets 25 by 36 inches. These sheets are manufactured especially for the building of rocket cartons, and consist of two sheets firmly attached together, forming a two-ply sheet 0.022 inch thick. In forming the two-ply sheet, one of the sheets is cut 22 by 36 inches, the small sheet being centered on the larger one with the sides trued up. This allows for a strip of 1½ inches, at both ends of the larger sheet, being single ply. These sheets are now cut lengthwise 12 by 25 inches, one of the large sheets making three of the smaller with the single-ply feathered edge at each end. In order to facilitate satisfactory rolling of the carton, a score of Bird's rocket-hardware-paper sheets are staggered so that only the one-ply edge protrudes. This protruding edge is now brushed with water to soften it. The brushing is violent in order to insure the proper softening of this edge. One of the sheets is now laid upon a flat surface with the smaller sheet constituting the second ply facing upward, and the entire surface is given a coating of paste. On top of this sheet is now placed a second sheet of the two-ply paper, with the smaller sheet also facing upward and pressed down upon the pasted surface of the under sheet in such a manner that the single-ply strip of the under sheet protrudes the distance of its width beyond the upper sheet. The surface is now given a generous coat of paste. A brass mandrel with outside diameter 1¼ inches is now laid across these sheets, the ends of the sheets turned around the mandrel and held firmly. After the sheets have been rolled into a cylindrical form one of the laps is detached for a distance of 2 inches from the cylinder and a sheet of Paddock strawboard 12 by 26 inches, with the grain the 12-inch way, having been previously given a coat of paste, is slipped into the opening and then wrapped around the carton. Paddock strawboard is previously prepared by stacking a number of sheets and feathering the edges by rough rubbing. When complete these cases are ⅜ inch thick and are placed on racks in a drying room for 3 or 4 days at a temperature of 120° F.

CASE ROLLING BY MACHINERY.

The case-rolling machine is a special machine and described in detail, because it is not a standard machine that can be purchased in the open market, but one that the manufacturers have had to build for themselves at their plants.

It is a simple machine similar to a lathe in its design, as shown in figure 3. It consists principally of a driving pulley, and a shaft or spindle capable of both rotation and translation, carried in suitable bearings.

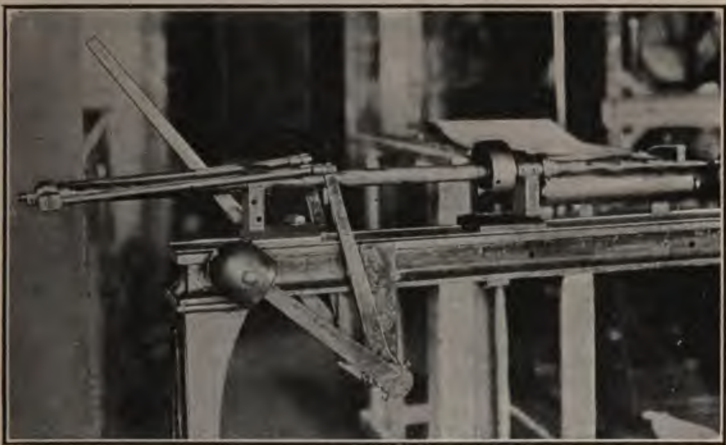


FIG. 3.—Case-rolling machine.

The shaft is moved longitudinally through the pulley and through its bearings by means of a counterweighted lever and is rotated by the engagement of a lug on the pulley with a pin on the shaft. The pulley rotates continuously and is carried in the center bearing of the machine, as shown in detail in figure 4.

FIG. 4.—Case-rolling machine showing pasting notch.

The above figure shows the shaft emerging through the pulley and the edge of the paper engaged in a longitudinal slot in the shaft. This slot extends for a length that will permit the paper to be inserted. The function of the slot is to hold the paper tight while rolling and the function of the pasting notch as shown in the figure is to automatically press the paper that is held in the slot against the inner wall of the case when the finished case is removed from the shaft. The large roller located under the shaft is a "pressure

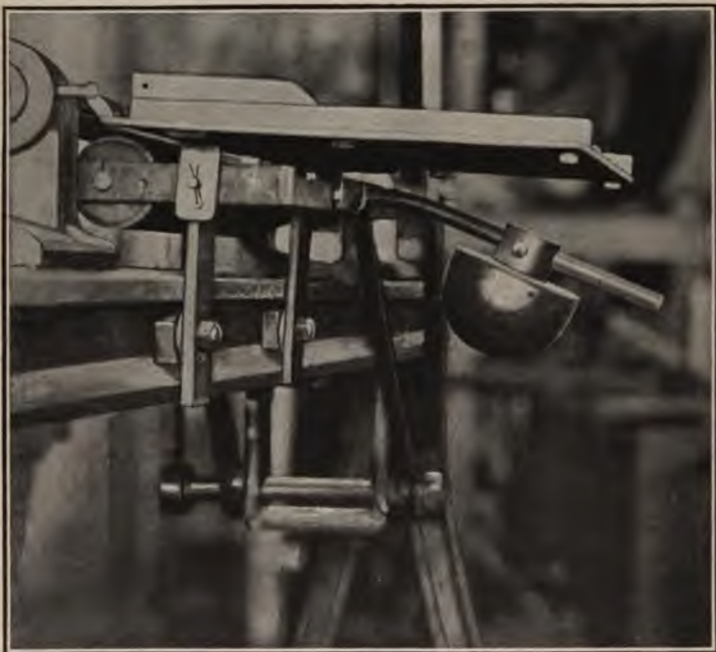


FIG. 5.—Case-rolling machine showing counterweighted pressure shoe.

shoe" which is required in order to roll a tight and compact paper carton. The pressure to be applied by this shoe is regulated by the leverage of the counterweight shown in figure 5

The operation of the machine is as follows:

The paper is given a coating of paste and arranged in the same manner as that for hand operation, the bottom sheet extending over the edge of the tabl(so as to engage in the slot on the shaft.

The lever is thrown to its extreme outward position. The pin of the shaft is now out of engagement with the driving pulley and the shaft is brought back so that its forward end is within the collar of the pulley and the slot on the shaft is in a position permitting the paper to be easily inserted. The position of this slot is defined by the pin on the shaft, following the guide on the rear bearing, so that it is always in the same position. The first operation is to move the lever

FIG. 6.—Case-rolling machine; feeding paper in slot.

forward and to thread the paper into the slot, as shown in figure 6.

The forward movement of the shaft continues until the paper is inserted in the slot of the shaft with the pasting notch protruding beyond the edge of the paper, and the forward end of the shaft resting on the forward bearing. In this position the pin on the shaft is engaged by the lug on the pulley and rolling commences.

FIG. 7.—Case-rolling machine; paper rolled on mandrel.

FIG. 8.—Case-rolling machine showing final operation.

Figure 7 shows the machine in the position for rolling the case, and the counterweight on the lever is shown at dead center. When all the paper is wound upon the shaft the operator, with one hand encircling the revolving case, binds the outer laminations by a slight pressure, at the same time evening up the edges and smoothing down the outer feathered edge.

This operation is shown in figure 8. The completely rolled case is removed from the machine by the simple operation

FIG. 9.—Case-rolling machine; removing case from machine.

of throwing the lever to its rear position, the shaft receding from the case and forcing the feathered edge of the paper, held in the slot, to follow the pasting notch and to be pasted against the inner walls of the case. This latter operation is shown in figure 9.

It is essential that a good paste be used. The following formula is one which manufacturers favor:

A good grade of Hecker's rye flour, 124 pounds, and granulated alum, 5 pounds.

The alum is first dissolved in twenty gallons of cold water, then the flour is added and thoroughly mixed, more water being added so as to bring the slurry to the proper consistency, the total amount of water being approximately 120 gallons. This should make a thick paste. The mixing of the flour, alum, and water is accomplished in a machine shown in figure 10.

FIG. 10.—Paste-mixing machine.

This machine has the capacity of one charge and is provided with blades which revolve and act as cutters and agitators. The machine is essentially a bread-mixer. Live steam is introduced into the slurry and the latter is cooked for about 10 minutes. The manufacturers claim that the use of alum is essential, as it acts as a preservative to the paste.

BOTTOM HEADING.

The bottom heading consists of a high-grade molding clay which is pressed into the bottom of the case by a hydraulic press. The charge of clay varies from 1¼ to 2½ ounces, depending on the quality, and is pressed to a thickness of ¾ of an inch. A tapered orifice is cored in the center of the clay heading by means of a spindle.

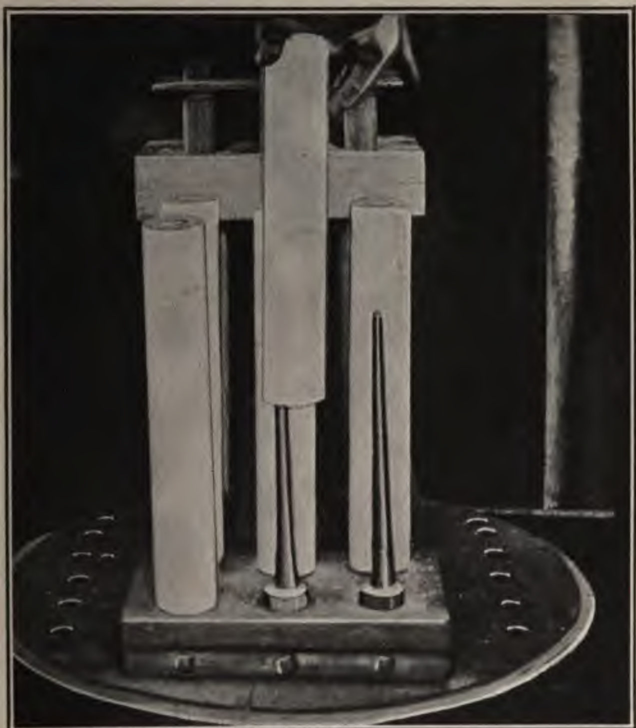


FIG. 11.—Placing cases on spindles.

Fig. 11 shows the operation of placing the cases on the spindles which are attached to a metal table resting on the circular platform of the hydraulic press. Six cases are loaded at the same time in this manner. A guide block is now placed in position on top of the cases, holding them firmly. This guide block is shown in figure 12, as is also the method of introducing the clay into the case.

A rack holding three small measuring cups, having an inside diameter of $1\frac{1}{8}$ inches and a depth of $1\frac{1}{4}$ inches, is used for measuring and introducing two separate charges of clay.

Figure 13 shows the rammers set in position for pressing. On the top of the machine, as shown in the figure, are extra

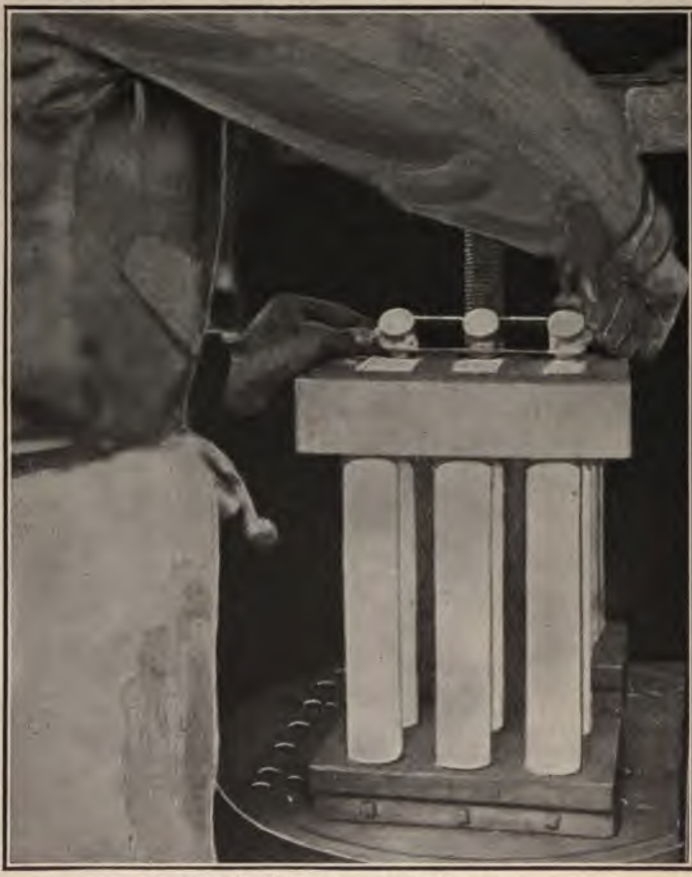


FIG. 12.—Introducing clay into cases.

rammers, which are in reality hollow steel tubes with the inside diameter large enough to pass freely down the spindle. A brass bushing approximately 1 inch long is inserted in the bottom of each rammer to prevent the striking of a spark by a steel-to-steel contact should the rammer strike against the spindle.

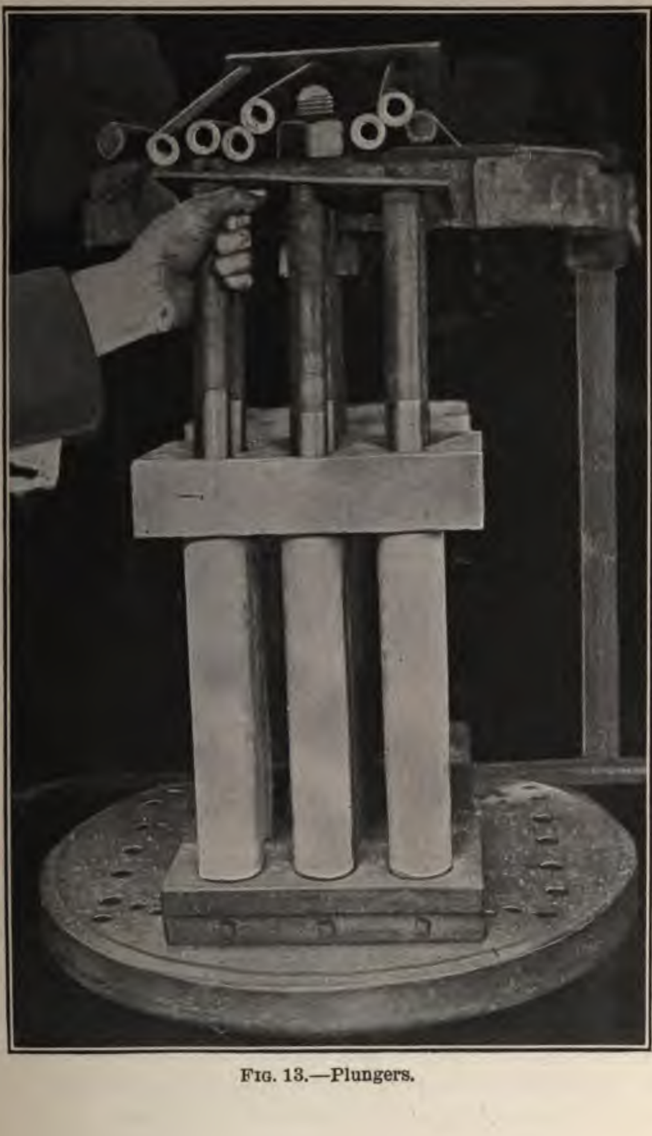


FIG. 13.—Plungers.

Figure 14 shows a case with its clay heading after it has been pressed into position, a pressure of 2 tons on the rammer having been applied. The function of this bottom clay heading is to hold back the gases produced by the burning of the powder charge and cause these gases to forcibly make their way outward through the orifice in the center of the clay plug, which orifice is in reality a vent. The diameter of this orifice influences to a marked degree the functioning of the rocket. It is necessary that the diameter should have a certain definite relation to the speed at which the gases of the charge are liberated in order that these gases should be forcibly expelled through the orifice, thus lifting the rocket

FIG. 14.—Case showing clay heading.

by their impact against the air, and also that the diameter of this hole should not be so small as to allow the pressure of the gases to react to a point where the rocket case will burst. The rapid passage of the highly heated gases rushing through this orifice occasionally breaks away the walls, if the clay is of poor quality, and causes an enlargement of the diameter, thus preventing the rocket from rising to the desired height. Certain manufacturers favor the embedding of a metal disk between the two charges of clay, this disk having a hole in the center registering the same diameter with the hole in the clay heading. This disk fortifies the walls of the opening and prevents enlargement.

DRIVING-CHARGE COMPOSITION.

Three formulas used by the manufacturers for the driving charge are given below:

Composition A consists of—

	Per cent.
Saltpeter	56.2
Sulphur (flour)	12.2
Charcoal	31.6

Charcoal in this case consists of equal parts of No. 1, No. 12, No. 1 XXX, No. XX, D. C. XX.

Composition B consists of—

	Per cent.
Saltpeter	53.9
Sulphur (flour)	13.5
Charcoal (coarse No. 20)	32.6

Charcoal consists of 19.2 per cent. No. 10 XXX and 13.4 per cent. No. 36.

Composition C, which has the advantage of giving very uniform results, consists of a mixture of 15 per cent. meal powder, manufactured by the E. I. du Pont de Nemours Co., and 85 per cent. of a prepared composition, consisting of—

	Per cent.
Saltpeter	72.8
Sulphur (flour)	13.6
Charcoal (coarse No. 20)	13.6

The compositions A and B are made up by mixing 32 pounds of saltpeter, which has been screened once through a sixteen-mesh sieve with 7 pounds of sulphur (flour). After the saltpeter and sulphur have been kneaded and thoroughly mixed by hand they are rubbed through a 12-mesh sieve and 18 pounds of charcoal is added. The charcoal, if several different sizes are employed, is first thoroughly mixed and screened before being introduced into the saltpeter and sulphur mixture. The whole is then thoroughly mixed by hand and again rubbed through a 12-mesh sieve. About 4 ounces of water is sprinkled on the composition and thoroughly kneaded in. The mixture is finally rubbed through a 12-mesh sieve.

Figure 15 shows the way in which the ingredients are mixed by hand.

Figure 16 shows the type of screen or sieve used for screening.

In reference to the mixing of composition C, the saltpeter, sulphur, and meal powder are thoroughly mixed and

FIG. 15.—Mixing composition by hand.

screened before adding the charcoal, which is mixed in a manner similar to that already described.

CHARGING.

The loading of the powder charge into the case requires careful handling as the manner in which this charge is compressed and driven home influences the successful functioning of the rocket.

FIG. 16.—Hand-mixing equipment.

Figure 17 shows a cross section of the rocket case with the powder charge rammed home. At the top and bottom of

FIG. 17.—Sectional view of rocket body.

the charge appear the clay headings. There is an elongated conical chamber extending through the charge from the bottom heading, registering with the orifice in this heading and reaching to within approximately 1¼ inches of the top clay heading. When the powder charge is ignited this elongated conical gallery serves the purpose of offering a relatively large surface for combustion. That portion of the rocket charge between the end of the elongated conical gallery and the clay heading is called by the French "massif" and in our country the "heading." The thickness of this heading is an important item in the manufacture of the rocket, as variations in the thickness alter the time required for the burning to penetrate to and ignite the match which controls the blowing charge. If the match is ignited prematurely the parachute and light will be expelled before the proper height has been attained. On the other hand, if the heading is too thick, the rocket will reach its maximum height, and begin to take its downward course before the contents of the rocket are expelled, endangering the parachute by the falling rocket and stick. One of the methods

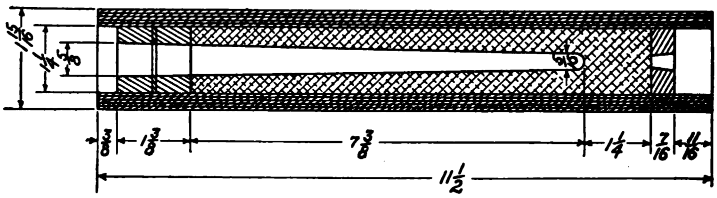


FIG. 18.—Dimensional drawing of rocket body A and B.

of avoiding this danger is to bore a hole into the top of the heading approximately ¼ inch in diameter and to such a depth as to allow the discharge of the contents of the rocket head at the exact instant when the rocket has reached its maximum height. To arrive at the proper depth of this bore tests are made by firing a rocket and noting the time when the contents of the rocket head are expelled. If the blowing charge operates too soon the recess is too deep and vice versa. Careful testing establishes the proper depth of the recess for the composition used.

Figure 18 shows the dimensions where a powder charge is used corresponding to charge composition A, previously discussed.

Figure 19 shows a new set of dimensions which will correspond to a powder charge such as the composition described in composition C, aforementioned.

The method of loading may be described as follows:

From the above description and from the cut showing a cross section of the loaded case, it will be noted that the powder charge is rammed home in the case in a manner that insures a uniform packing or piling of the powder grains. This is done by successive charges, each of which is rammed

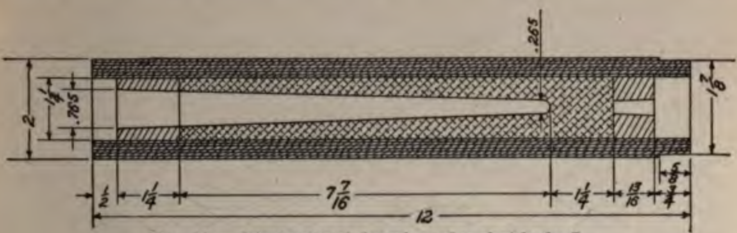


FIG. 19.—Dimensional drawing of rocket body C.

home with a given pressure. The spindle about which the powder is packed provides the central elongated conical chamber previously described.

Figure 20 shows a powder charge which has been formed in this manner, the ribs indicating the boundaries of the successive charges. In order to accomplish this a hydraulic press is used, a picture of which is seen in figure 21.

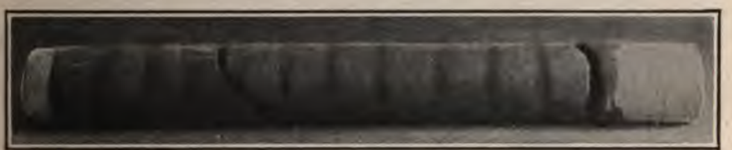


FIG. 20.—Compressed driving charge.

The hydraulic press is controlled by hand valves. The pressure is usually obtained from an individual power-operated pump. A pressure gauge is installed on the line in sight of the operator of the press. This press consists of a circular iron table pivoted in the center to permit a circular movement and designed to be driven upward by means of a ram operated by hydraulic pressure. This ram makes its contact with the table top at a point directly below the line of pressure which is to be exerted upon the frame while charging. Two frames are in operation continually, which may hold from six to eight cases each, ranged in a double row. In operating, only one set of frames comes under the influence of the pressure at a time. During this interval the other set is being charged by the operator. The circular movement of the table top permits the operator to subject the successive batteries of cases to alternative pressure and loading. As is shown by figure 22, the several spindles

FIG. 21.—Hydraulic press.

are bolted firmly to a metal plate, which in turn is attached to the table top.

Figure 23 shows the dimensions of these spindles and the manner in which they are set upon the plunger base. There are four separate sets of plungers used for loading, the number of plungers in each set being the same as the number of rocket cases held by the frames, which may be six or eight in number.

FIG. 22.—Hydraulic press showing cases in place.

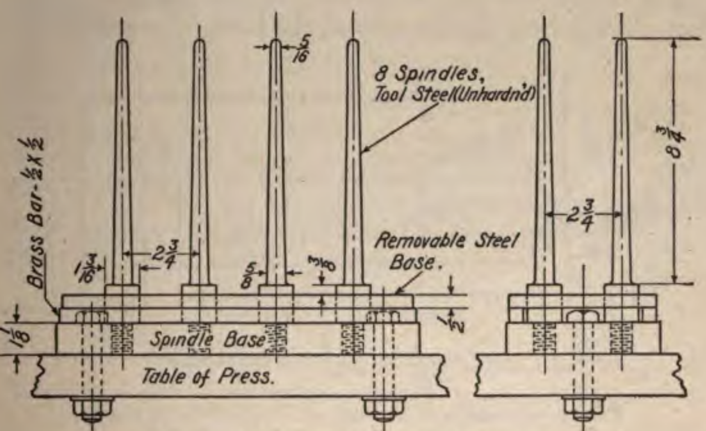
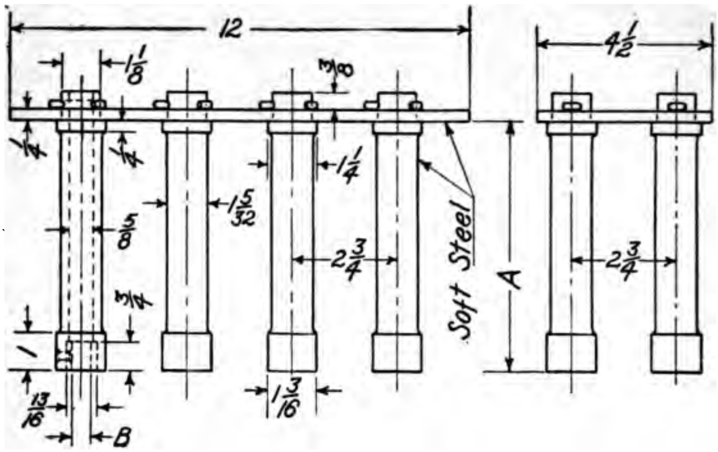


FIG. 23.—Dimensional drawing of spindles.

A fifth set of plungers, differing slightly from the others, is used to pack the clay heading at the top.



	A"	B"
Plunger Set No. 1	13"	5/8
" " " 2	9 3/4	1/2
" " " 3	6 1/2	7/16
" " " 4	4 1/2	(Solid).

FIG. 24.—Dimensional drawing of plungers.

The operation of charging the rocket is as follows:

The empty cases to be charged are pressed upon the spindles, shouldering tightly around the base. Before the intro-

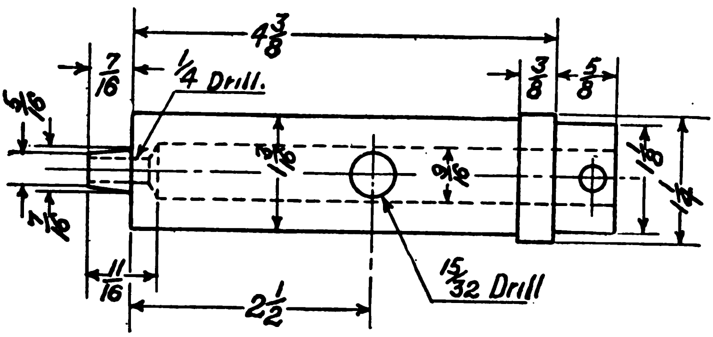


FIG. 25.—Dimensional drawing of plunger for clay heading.

duction of the plungers, the top of the case is often bell-mouthed. This spreading is done by pounding a tapered wood plug a short distance into the case. The bell-mouthing is to insure the easy entrance and withdrawal of the plungers.

The loading of the clay heading has already been described and is the first operation prior to the introduction of the powder charge. Plungers of the set No. 1 are used for ramming this clay heading into place. A pressure is exerted on the ram which when proportioned for each of the separate rammers will be equivalent to approximately 2¼ tons each. After the clay heading has been forcibly pressed into shape the plungers are removed. In order to free the plungers two short brass bars are used as hand levers. No. 1 set of plungers is used to ram home the first to sixth charges of composition, inclusive. The No. 2 set of plungers is used to drive home the seventh to tenth charges, inclusive, and the final charges are rammed home with the No. 3 and No. 4 plungers, respectively. Variation in the climatic condition and humidity will cause a certain slight variation in the number of the charges, as to which practice alone will dictate the proper manipulation. Care must be taken that there is ample powder supplied for each successive ramming to prevent the plunger from striking the spindle. The inside diameter of each set of plungers varies in size, in order that this diameter may be larger than the diameter of the spindle at the point where the charge is rammed home. The 1¼ massif or heading is rammed home in three successive charges, using No. 4 plungers which have no central orifice. As the plungers are withdrawn after each operation there is occasioned a slight dust of fine highly inflammable powder. Care must be exercised in the handling of the plungers and spindle to see that no spark is struck and that metals are used which will minimize the danger of sparking by contact. As a safety precaution, the plungers are equipped with brass bushings and the heads of the last set are often constructed with a center lead inlay.

TOP CLAY HEADING.

The top clay heading consists of a charge of high-grade molding clay weighing approximately ¾ of an ounce. The clay measure described previously is filled with clay and introduced into the case on top of the powder charge and rammed home by means of the plunger described in figure 13.

PREPARATION OF ORIFICE FOR MATCH.

The orifice of the top clay heading is now reamed out in order to clear the walls of this orifice from any accumulation of dirt, and the reamer is forced a slight distance into the massif or heading.

INSERTING MATCH IN ROCKET.

A five-ply quick match is used for this purpose. The match is cut about four inches long, looped into three equal lengths and then forced through the orifice in the clay-heading bottom into the cavity which has been formed in the top of the massif or heading. When the match has been set in place the expelling charge is added.

EXPELLING CHARGE.

This expelling charge consists of approximately 27 grains of 5 F. grain meal powder which is poured on top of the clay heading and is contained in the space between the clay heading and end of rocket case. Some of this powder works its way through the orifice in the clay heading, completely filling it. In this manner the quick match is imbedded in the rapid-burning grain meal powder. The function of the expelling charge is to forcibly eject the contents of the rocket head, consisting of the parachute and light.

MUSLIN DRUMHEAD.

The muslin drumhead serves the purpose of holding the grain meal powder, which constitutes the expelling charge, in place in the case. This drumhead is unbleached muslin cut into a 3½ inch square and is pasted over the top of the rocket case, covering up the match and the expelling charge. The edges of this square piece of muslin are formed over the sides of the case and pasted firmly to it.

PRIME.

The prime consists of a coating, which is applied to the top surface of the muslin drumhead, completely covering it.

This prime is a slurry consisting of grain meal powder and water in which is dissolved some dextrin. Its composition is as follows:

Sixteen parts 5 F. grain meal powder, one part of yellow dextrin and sufficient water to form a thick paste.

The function of this prime is to ignite the fuse connected with the signal light attached to the rocket.

FIG. 26.—Rocket body showing drumhead and prime.

Before attaching the rocket head, which contains the garniture, the body of the rocket is completed by attaching a device for holding the stick and also by attaching an article which produces the smoke trail.

FIG. 27.—Stick socket and spring.

STICK SOCKET.

The socket is a hand-rolled carton made from Bogus paper 0.017 inch in thickness. A strip 5 inches wide and 12 inches long has applied to its surface a coat of paste, the paste being similar to, but not so thick as, that used in rolling the rocket case. This sheet is then formed by hand around a square mandrel 5/8 inch square, producing a case shown in figure 27.

The next operation is to insert between the laminations of this carton a stick spring.

STICK SPRING.

The stick spring consists of a piece of spring steel approximately 1½ inches long and $\frac{5}{16}$ inch wide, which has a barb near one end, the other end terminating in three prongs, which are bent inward at an angle of approximately 45°. This is shown clearly in figure 28.

FIG. 28.—Assembling stick spring in socket.

The function of this spring is to hold the stick firmly in the socket.

ATTACHING STICK SOCKET TO ROCKET BODY.

The rockets are laid in rows upon a bench which has been provided with a raised strip at its edge against which abuts the bottom ends of the rocket bodies. A straight edge about 6 feet in length and 7½ inches wide is laid over the row of rockets, and with a lead pencil a mark is made on the rockets

7½ inches from the bottom. This mark is used as a guide to fix the position of the top edge of the stick socket. The

FIG. 29.—Rocket body showing stick socket in place.

stick sockets are now painted with a stripe of quick-setting glue and pressed in position against the rocket body. The spring in position is shown in figure 29.

FIG. 30.—Stick-socket binder in place.

STICK-SOCKET BINDER.

This consists of a strip of stout Kraft paper 5 inches wide. Paste is applied to one side of the paper, which is wrapped around the rocket body and the stick socket, holding the socket firmly in place against the case.

Figure 30 shows the binder in place.

ROCKET SMOKE TRACER.

The smoke tracer consists of a small paper carton or tube which is closed at each end by means of a clay heading and contains the yellow smoke-producing mixture.

The tracer is made up of the following parts:

A. A paper carton or shell.
B. Clay headings at both ends.
C. The yellow smoke-producing mixture or composition.
D. Fuse or match.
E. The protecting covers or wrappers.

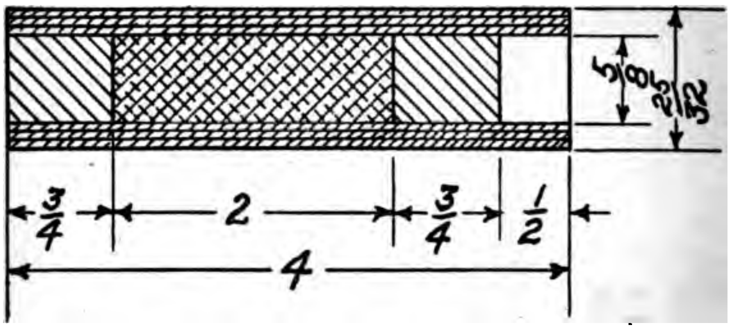


FIG. 31.—Dimensional drawing of smoke tracer.

CARTON OR SHELL.

The shell is a hand-rolled paper carton made from a strip of Bogus paper 0.017 inch in thickness, cut into strips 4 inches wide by 12 inches long. The surface of this strip of paper is given a coat of paste and the strip rolled over a mandrel, producing a cylinder 4 inches long with an inside diameter of approximately 5/8 inch and an outside diameter of $\frac{23}{32}$ inch. Some manufacturers prefer to use a carton 5 inches long so that it will match up in length more nearly with the stick-socket carton. These cartons are set aside to be dried before they are loaded.

CLAY HEADINGS AT BOTH ENDS.

The bottom heading is set in the carton in much the same manner as the clay heading is set in the rocket-body case.

Figure 32 shows a hydraulic press which is similar to the presses used for loading the rocket-body cases, with the exception that it is equipped to hold a battery of 24 small cartons in each of the two racks. Position lugs of a diameter the size of the inside diameter of the carton, projecting from

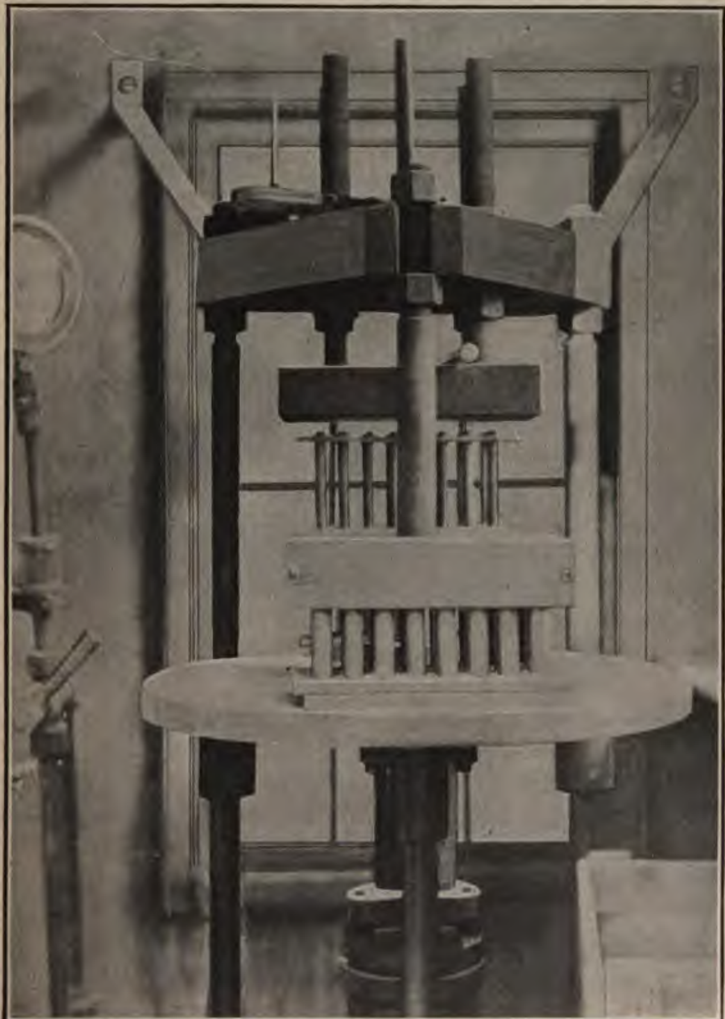


FIG. 32.—Gang press for charging smoke tracers.

the base plate a distance of approximately ¼ inch, hold the carton in position while being charged. The operation of this press has been described previously. A pressure sufficient to firmly drive the clay home is placed upon the plungers. This pressure should be great enough to form the clay into a compact, firm heading, but not sufficient to fracture the walls of the carton. It should be noted here that no spindles are used in charging the carton and that the plungers employed for ramming home both the charge of clay and the composition are solid rods, in place of the steel tubes used in charging the rocket composition.

YELLOW SMOKE-PRODUCING MIXTURE OR COMPOSITION.

The usual formula for this smoke-tracer composition consists of—

	Per cent.
Saltpeter	37.2
Sulphur (flour)	16.7
Arsenic (red)	37.2

A slight deviation from this formula, as shown by the following composition, is also used with satisfactory results:

	Per cent.
Saltpeter	50.0
Sulphur	16.7
Arsenic (red)	33.3

This composition is hand mixed and passed through a sieve in a manner similar to the mixing of the compositions previously discussed. Little cups, attached to a rack holding sufficient composition for the three or four successive charges, are used to introduce the composition into the carton. When the composition has been rammed into place a clay heading is forced into position in a manner similar to that described previously.

MATCH.

The match is inserted in holes drilled in the loaded carton. Figure 33 shows the operator drilling three 1/8-inch holes in the smoke-tracer case. The case is laid on a drill jig and three holes, equally spaced, are drilled into the composition, as shown in figure 34.

These holes penetrate slightly beyond the center of the loaded carton. A quick match, the end of which is first forced into the hole nearest to the center of the tracer, is now looped into two loops, the first being forced in the center

FIG. 33.—Drilling smoke tracer.

hole and the second into the last hole of the tracer, the end of the match protruding a distance of about 3 inches beyond the lower extremity of the tracer.

FIG. 34.—Smoke tracer showing vents.

A small protecting pipe stem of Kraft paper, rolled in a cylindrical form, is used as a support for this match, as shown in figure 35.

PROTECTING COVERS OR WRAPPERS.

Thirty-pound Kraft paper, cut 4½ inches by 7 inches, is pasted around the smoke tracer and the package attached

FIG. 35.—Smoke tracer with match assembled.

FIG. 36.—Parts of smoke tracer.

FIG. 37.—Rocket body showing smoke tracer attached

firmly to the side of the rocket-body case by a stripe of glue which is painted on the surface, the tracer abutting on the stick socket as shown in figure 37.

ASSEMBLY BAND.

A band 1⅜ inches wide by 11 inches long of 30-pound Kraft paper is wrapped tightly around the rocket body and attached firmly to it, holding in place the tracer and stick socket as shown in figure 38.

MATCHES.

The match used for igniting the propelling charge in the rocket body consists of a piece of six-ply slow match cut 6 inches long which is introduced into the orifice of the clay-bottom heading of the rocket body in the following manner:

The smoke tracer which has been attached to the rocket body has a match extending some 3 or 4 inches beyond its lower edge. The match is bent over and the end threaded

FIG. 38.—Rocket body showing bands and drumhead.

through the orifice in the clay heading of the rocket body. This match is held in place while the end of the slow match used to ignite the rocket is inserted into the orifice of the clay heading. The protruding end of the slow match is laid side by side with the match running from the smoke tracer and a small staple is driven into the interior wall of the rocket case just above the clay heading. This staple holds the two matches in position, allowing a free end to the match last mentioned, which is looped and held in position until ready for use by means of a light drumhead. The match is protected by means of a small paper tube similar to that used as a protection for the match of the smoke tracer. This protecting tube encircles only a portion of the length of the match and protects the match from abrasion caused by the staple.

Figure 39 shows the positions of the smoke-tracer match and the rocket-igniting match.

FIG. 39.—Cross-sectional view of completed rocket.

BOTTOM DRUMHEAD.

The drumhead is a piece of 30-pound Kraft paper 3½ inches square, the corners of which have been clipped off ⅝ of an inch. This drumhead is given a coat of paste and smoothed down over the bottom of the rocket. When the rocket is ready to be fired this drumhead is broken and the loose end of the match is drawn out and lit.

FINISHING BAND.

A finishing band of 30-pound Kraft paper is cut in 8-inch lengths, ⅞ inch wide, given a coat of paste and wrapped around the drumhead. Figure 38 shows this band and drumhead.

ROCKET HEAD.

CASE.

The case is made of strawboard which comes in sheets 26 by 28 inches, 0.022 inch in thickness, Paddock strawboard being used. These sheets are cut into strips 7¼ inches wide by 25 inches long. The strips are placed upon a table and one edge feathered. A coating of paste similar to that used in rolling the rocket-body carton is applied to these sheets, which are in turn rolled by hand over a mandrel forming a cylinder with an inside diameter of approximately 2 inches and a length of 7¼ inches. The diameter of this case will permit it to be slipped over the rocket-body case.

GARNITURE.

The garniture consists of the parachute and signal, with the necessary articles for proper packing.

PARACHUTE.

The parachute is made of light, tough Japanese paper. The parachute is composed of seven sectors, the length of

FIG. 40.—Sectional drawing of rocket head.

the sector being 16 inches with an arc approximately 12 inches. These sectors are sewn together with a fine cotton

FIG. 41.—Parachute functioning.

or fiber thread. The parachute strings are tied to the ends of the seams. When completely assembled the parachute has a form similar to that of an open umbrella, often with an inverted cone at the center due to the drawing forward of the central parachute string which is attached to the apex of the parachute. There are eight parachute strings, seven of them extending from the seams where the sectors are sewn together and the eighth being attached to the center or focus of these seams. The strings are knotted together at a distance permitting the free opening of the parachute.

Figure 41 shows a parachute which has opened up and is functioning properly, having been expelled from the case.

It is obvious that careful and delicate manipulation in packing is necessary, to insure the opening of the parachute in a proper manner so that the strings will not become entangled and prevent the proper functioning of the article. There is no standard method of folding the parachute, each manufacturer following his own plan, which according to his experience has given the best result.

SIGNAL.

The signal consists of either a white, red, or green light, a caterpillar (chain of lights), which function at night, or the smoke signal, which functions in the daylight.

WHITE LIGHT.

There appear to be two different methods of manufacturing the various signals, with the exception of the smoke signal. In the first instance the use of a briquetting machine compresses the illuminating charge into the desired form, requiring slightly different assembly than in the second or older method of preparing the light signal, which is the method customarily in use. Both of these methods of manufacture will be described.

SIGNAL LIGHT (WHITE, MADE BY BRIQUETTING METHOD).

A completed signal light consists of a briquette composed of the illuminating composition, a wrapper, wet prime, paper disk, quick match, knot socket, and tie string.

BRIQUETTE.

The composition from which the briquette is molded consists of—

	Per cent.
Barium nitrate	58.3
Aluminum (powdered)	22.9
Potassium chlorate	16.7
Meal powder (black)	2.1

These component parts of the composition are mixed in the manner previously described, namely, by hand mixing in an open tray and successive screenings through a sieve in order to insure a thoroughly homogeneous mixture.

The above composition is made up in unit batches of 24 pounds each, which are moistened with a binder before briquetting. The binder used consists of a shellac-and-alcohol mixture in which the shellac has approximately twice

FIG. 42.—Briquette plunger and mold.

the weight of the alcohol. The usual procedure is to add 1¾ pints of this binder to each 24 pounds unit batch.

The composition is first loaded into a mold which is shown in figure 42.

In the foreground of this figure is shown the rammer.

Figure 43 shows the operator putting the charge in by hand, the mold being filled to the brim. The dimensions of this mold and rammer, which is made of Tobin bronze, are shown in figure 44.

Figure 45 shows the Arbor press which is used to form the briquette.

Figure 46 shows the method of exerting a uniform hand pressure in successive operations.

It is usual to have a lever supporting the base block of such a length that 113 pounds at one end will support a weight of

1,300 pounds at the other or block end. A pressure of 1,300 pounds is that used for briquetting.

Fig. 43.—Loading charge into mold.

Figure 47 shows the briquette after it has been forcibly ejected from the mold, which is 2¼ inches high by 1$\frac{3}{16}$ inches in diameter.

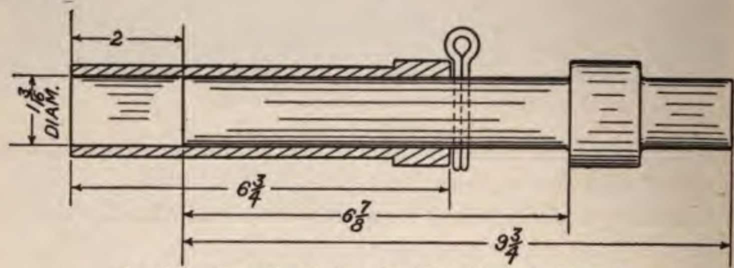


Fig. 44.—Dimensional drawing of mold and plunger.

The briquettes are then dried in a drying room at a temperature of 100° F., remaining there for two or three days. This must be a properly ventilated room in order to carry off the alcohol fumes.

WRAPPER.

The wrapper consists of a strip of 30-pound Kraft paper 2¾ inches wide by 8 inches long. A coat of paste is applied to the wrapper, which is formed around the briquette, flush with one end.

WET PRIME.

A coating of wet prime is applied to the bottom of the briquette, consisting of a paste of meal powder and water.

FIG. 45.—Arbor press.

PAPER DISK.

A tissue-paper disk approximately 2¼ inches in diameter is placed over the wet prime and pasted to the side of the briquette, and on top of the disk is applied a strip of wet prime into which is imbedded the quick match.

QUICK MATCH.

The quick match is a six-ply match cut in length 2¼ inches, the ends being carried down over the edge of the briquette and firmly tied with jute string, as shown in figure 49.

MUSLIN KNOT SOCKET.

This is a piece of unbleached muslin 2½ by 7 inches. It is given a coat of paste and bound around the top of wrapped briquette, covering about 1 inch. This is used to

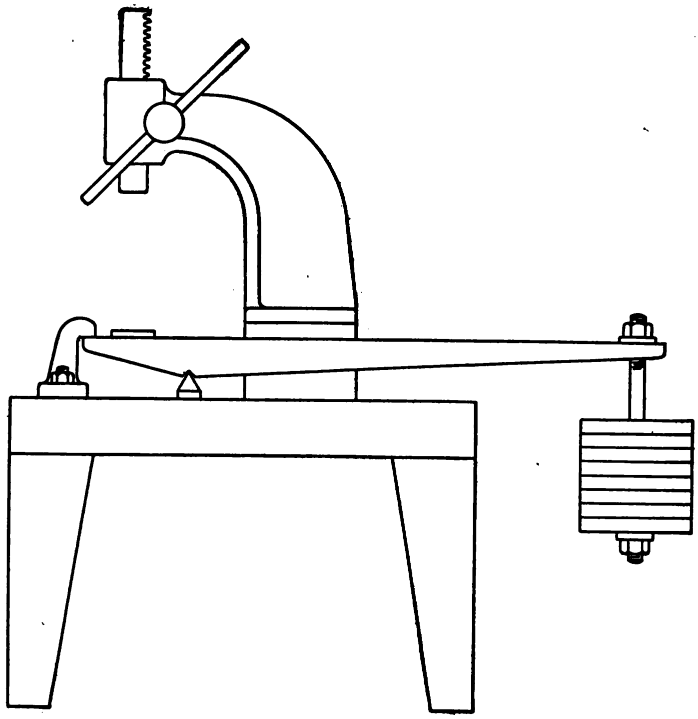


FIG. 46.—Arbor press showing lever and weights.

form a socket in which to attach the end of the parachute strings.

TIE STRING.

The asbestos cord by means of which the briquette is attached to the parachute is inserted in the knot socket, a knot having been previously tied in the end of the cord. The tie string is of jute, cut to a length of 8 inches, which holds the muslin crimped tightly about the cord and makes a lock for the knot.

ASSEMBLY OF THE SIGNAL LIGHT (WHITE) BY THE OLD METHOD.

The signal light consists of the following:

1. Case.
2. Bottom disk.
3. Muslin disk.
4. Match.
5. First fire.
6. Composition.
7. Top disk.
8. Muslin wrapper.
9. Wet prime.
10. Ignition match and tie string.
11. Parachute tie string.

Fig. 47.—Briquette.

Fig. 48.—Wrapped briquette.

Fig. 49.—Wrapped briquette showing quick match and knot socket.

CASE.

The case consists of a cylindrical paper carton made of Kraft paper, 200-pound stock, basis 40 inches by 48 inches. This paper is cut into strips 7 inches wide by 16 inches long. One short edge of the sheet is feathered and given a coat of paste similar to that used in rolling the rocket body or carton, and it is then rolled by hand over a mandrel, producing a cylinder of 1¼ inches inside diameter and 7 inches in length. This cylinder is cut in half, thus making the dimensions of the signal-light carton 1¼ inches inside diameter and 3½ inches in length.

BOTTOM DISK.

This disk measures 1¼ inches in diameter and has a hole ¾-inch in diameter in the center. The disk is cut from 30-pound strawboard, and before being forced into the carton the latter is given a coating of glue on the inside close to the bottom, so that the disk will become firmly attached thereto. The disk is inserted in the top of the case and driven into position at the bottom by means of a rammer where it comes in contact with the glue.

MUSLIN DISK.

This is cut 1⅝ inches in diameter from unbleached muslin and is placed on top of the bottom disk.

MATCH.

A piece of 6-ply quick match, ⅞ inch long, is dropped on top of the muslin disk. The function of this match is to facilitate the ignition of the first fire.

FIRST FIRE.

Different formulas are used by different manufacturers for this first fire. The first fire is a quick-burning composition which takes its ignition from the match and ignites the illuminating composition. A mixture of 50 per cent. of the illuminating composition with 50 per cent. of meal powder slightly dampened with wood alcohol is a characteristic composition. Another formula consists of—

	Per cent.
Saltpeter	57
Sulphur (flour)	19
Black antimony	19
Dextrin	5

This first-fire composition is introduced into the case, occupying a depth of approximately ⅛ inch.

WHITE SIGNAL COMPOSITION.

A variety of formulas are used for the compounding of the white signal light. The basis of these is the use of barium nitrate and some finely divided metallic powder which will burn with an intense illumination. As the composition contains salts that tend on burning to produce a yellow flame, the presence of the barium nitrate which imparts a green color to the flame tones down the yellow and gives the metallic powder an opportunity to burn with a bright white light scarcely masked, if at all, by the burning of the other materials. Two characteristic formulas are given as follows—

		Per cent.
A.	Barium nitrate	75.5
	Aluminum (flake)	21.8
	Sulphur	2.7
B.	Barium nitrate	58.3
	Aluminum (flake)	22.9
	Potassium chlorate	16.7
	Meal powder	2.1

Irrespective of the formulas, the component parts are mixed in much the same manner, namely, hand mixing in an open trough and repeated screening through a sieve to insure a homogeneous mixture.

Figures 50, 51, and 52 show the operation of introducing the charge into the signal-light case, the packing or driving home of this charge by means of a suitable rammer, driven in by a hand mallet, and the insertion of the top disk.

TOP DISK.

This top disk is the same as the bottom disk with the exception that there is no hole in the center. After the disk is set in place on top of the composition charge, glue is wiped around the inside of the carton, holding the top disk firmly.

The composition weighs approximately 4½ ounces and should burn at least 25 seconds, giving a white light of intensity ranging from 9,000 to 12,000 candlepower.

PRIME BLOB.

The case is inverted and a blob of prime is placed in the hole in the bottom disk against the composition.

MUSLIN WRAPPER.

The wrapper is a piece of unbleached muslin cut 6 by 6½ inches. Wet paste is applied to the cloth and the case is now

FIG. 50.—Filling light case.

rolled in this wrapper, which protrudes 1½ inches at either end, as shown in figure 53.

IGNITION MATCH.

The case is now set into a form as shown in figure 54, with the end containing the perforated disk up, a blob of prime having been previously put over the hole in the disk.

The match is an 8-ply quick match cut to a length of 6 inches. This match is folded in the center and the double fold is again folded, forming an L, the short leg of which is inserted into the case to rest on the blob of prime and is tied firmly in place as shown in figure 54.

The parachute cord, at the end of which has been tied a knot, is now introduced into the case which is again reversed.

FIG. 51.—Ramming charge into light case.

Figure 55 shows the introduction of the cord and knot well into the muslin socket and the tying of the muslin socket around the cord above the knot by means of a stout hemp tie string, the operator making a half hitch to insure safety. On making this assembly the parachute string is given a stout pull, the case being held firmly in the hand, to insure a secure attachment.

GREEN SIGNAL LIGHT.

Manufacturers do not adhere closely to any one definite composition, although there is a marked similarity in all the

FIG. 52.—Capping light case.

FIG. 53.—Light case with muslin wrapping.

compositions used. The two representative compositions are given as follows—

		Per cent.
A.	Barium chlorate	90
	Powdered orange shellac	10
B.	Barium chlorate	55.5
	Barium nitrate	33.3
	Powdered orange shellac	11.2

The substitution of barium nitrate for part of the barium chlorate is not an essential difference as both barium chlorate

FIG. 54.—Ignition match tied in place.

and barium nitrate function in very much the same manner when used in combination with powdered orange shellac since each of them gives up its oxygen which aids in the burning of the organic factor, the powdered shellac.

These compositions are prepared in much the same manner as has been previously described, namely, hand mixing and screening through a sieve in order to insure a homogeneous and uniform mixture. The composition marked A may be either briquetted or handled in the method described as the "older method." Composition B is used exclusively for the older method.

It is to be noted here that a certain amount of binder is necessary where the composition is briquetted, which usually consists of a mixture of one pound of gum arabic dissolved

FIG. 55.—Parachute cord tied in place.

in one quart of water. Enough of this solution is taken to dampen the composition.

In reference to the assembly of this light, it is similar to the method explained previously for the assembly of the white signal light. The carton has slightly different dimensions from the carton used to hold the white light, being 1⅝ inches in diameter and 2¼ inches long. One other difference also should be noted, namely, that there is no necessity for a first-fire charge such as has been discussed under the white light. In other respects the methods of assembly are the same as for the white light.

The green signal light burns from 25 to 30 seconds, giving an illumination of approximately 400 candlepower.

RED SIGNAL LIGHT.

There is a variety of formulas used in the preparation of the red signal composition, the basis of these being the use of from 7½ to 11$\frac{2}{10}$ per cent. of powdered orange shellac, which requires a certain oxygen-liberating salt to support its combustion, either potassium chlorate or strontium nitrate, Where strontium nitrate is used in place of strontium carbonate, the potassium chlorate is correspondingly reduced. Three formulas in use are shown as follows—

		Per cent.
A.	Strontium nitrate	66.6
	Potassium chlorate	25
	Powdered shellac	8.4
B.	Strontium carbonate	22.2
	Potassium chlorate	66.6
	Powdered shellac	11.2
C.	Strontium carbonate	46.2
	Potassium chlorate	46.2
	Powdered shellac	7.6

When found necessary these compositions may be dampened slightly with a binder similar to that described previously.

The carton is of the same size as that described under the green light and the assembly, with the exception of the first fire, which is omitted, is identical with that described under the white light.

ROCKET SMOKE SIGNAL (YELLOW SMOKE).

The various parts of the smoke signal are as follows:

1. Case.
2. First-fire composition.
3. Smoke composition.
4. Vents.
5. Match.
6. Match band.
7. Knot.
8. Tie string.

CASE.

The case consists of a paper carton, similar to that used in the assembly of the signal lights and is made of strawboard or Bird's rocket hardware paper. When rolled from strawboard it is customary to use a sheet cut 9 by 22 inches from 100-pound stock, the rolling being done on a mandrel, after the surface of the sheet has been given a coat of paste. This produces a cylinder which when cut into three parts makes a carton 3 inches in length by 1¼ inches inside diameter, which is the size desired. If the carton is rolled by using Bird's rocket hardware paper, a strip 3 by 25 inches is used, also rolled on a mandrel, giving a carton 3 inches long by 1¼ inches inside diameter. These cases are set aside to dry after being rolled.

HEADINGS.

There are two methods of heading up the cartons. One is with the use of molding clay, a plug of which is put in under rather high pressure; the other by the use of a cardboard disk. Where the carton is rolled, from 100-pound strawboard, it is customary to use a clay heading. Sufficient clay is introduced into the carton which on being driven home occupies a space approximately ⅝ inch in thickness, forming the bottom heading. Where Bird's rocket hardware is used to roll the carton, the heading consists of a disk of 30-pound strawboard, cut 1¼ inches in diameter. A stripe of glue is wiped around the inner surface of the carton close to the bottom of the disk and the disk is then forced into place flush with the bottom, adhering firmly to the sides of the carton.

FIRST-FIRE COMPOSITION.

A first-fire composition is used in loading the carton which has a clay heading and consists of a mixture of 50 per cent. of the same composition as is used in charging the rocket body, and 50 per cent. of the smoke composition, to be described later. The carton which is made with the pasteboard disk substituted in place of the clay heading does not have a first-fire charge. The reason for this difference will be shown later under the heading "Vents."

A small charge of this first-fire composition, occupying a full ¼ inch in thickness, is spread on top of the clay heading, and is rammed into place later on when the smoke-producing composition is pressed into shape.

SMOKE COMPOSITION.

Two different formulas are used for the smoke composition, varying only slightly in their component parts.

Formula A consists of—

	Per cent.
Saltpeter	40
Sulphur (flour)	33.3
Red arsenic (realgar)	26.7

Formula B consists of—

	Per cent.
Saltpeter	37.2
Sulphur (flour)	25.6
Red arsenic (realgar)	37.2

It will be noted that these compositions are very similar to those used in the smoke tracer. In mixing the composition the customary method of hand mixing in an open trough and screening through a sieve is adhered to. It should be noted that the red arsenic often occasions discomfort to the operator who is mixing this composition by hand. A discussion of the use of red arsenic, its poisonous character, and the possible substitution of a less poisonous material is given in the chapter on Arsenic, in the volume on Chemicals.

In loading the smoke composition in the carton two rows of five cartons in a frame constitute one-half of the charge of the press, which is operated in much the same manner as the loading of the rocket-body case. This mixture when rammed home occupies a space of 1⅛ inches in thickness and is capped with a clay heading in one instance and with a disk of strawboard when strawboard has been substituted in place of clay.

VENTS.

It must be noted here that in the burning of the smoke signal the composition does not burn away the carton as in the case of the white, red, or green lights, but merely generates a copious volume of smoke without burning through the walls of the carton. Consequently, openings are drilled into the walls of the case for the purpose of allowing the smoke to be forcibly expelled. There are two positions for the vents. In the case of the carton that is loaded with clay for a heading and with a first fire for an igniting charge there are four vents which are perforations $\frac{1}{8}$ inch in diameter spaced equidistant on the same plane, which plane passes through the center of the first-fire ignition. In the second case there are three vents $\frac{1}{8}$ inch in diameter equidistant, and in the same plane located at the center of the smoke-composition charge.

MATCH.

The match which ignites the charge occupies the position shown in drawing, figure 56.

Here two lengths of three-ply fuse cut $4\frac{1}{2}$ inches long are crossed and the ends of the fuse, so clipped as to give them a beveled edge, are bent and forced through the vents. In attaching the match to the carton having three vents a six-ply match $11\frac{1}{2}$ inches long is looped in three loops, the

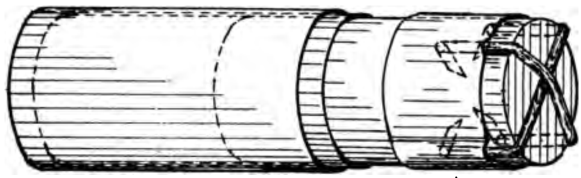


FIG. 56.—Smoke signal showing position of the match.

apex of each loop being forced into one of the vents. The remaining length of the fuse is carried across the bottom of the case and held in place by means of a band.

MATCH BAND.

The match band consists of a strip of stout paper $1\frac{1}{8}$ inches in width, pasted around the case holding the match in place. This may be of 30-pound Kraft paper or 20-pound rope manila. The Kraft paper is cut to $6\frac{1}{4}$ inches, the manila to $6\frac{1}{8}$ inches. The match which crosses the bottom of the signal takes its ignition from the expelling charge in the rocket body.

KNOT SOCKET.

The knot socket is similar to that previously described and is a strip of muslin 3 by 10 inches, pasted around the carton in such a manner as to allow an overlap into which may be inserted the knot tied to the end of the parachute cord.

TIE STRING.

The knot socket is crimped around the parachute cord with the knot firmly held in the crimping and a tie string of jute cord 8 inches long holds the crimping in place by means of two half hitches. After the tie string has been attached a stout pull by the operator insures a satisfactory connection.

CATERPILLAR SIGNALS.

(12 Lights.)

The caterpillar signal may have two or more lights, the 12-light signal being the one usually manufactured for military purposes.

It consists of a carton approximately 3⅛ inches long and ⅜ of an inch inside diameter, which is rolled from 30-pound manila stock sheets 20 by 24 inches. A machine not unlike a cigarette-rolling machine is used for this purpose. The carton is placed on a form and the charge of composition, either white, red or green illuminating mixture, is poured into the case and driven in by a rammer and mallet. The case is filled within an inch of the top. At the bottom of the loaded case there is a slight recess formed by a projection on the block used as a support while loading. This cavity is filled with wet prime up to the level of the edge of the case. At the other end of the case is now inserted a small disk of cardboard cut to a diameter approximately the size of the inside diameter of the carton. This disk has two notches at opposite points on its circumference cut to permit the free passage of a connecting cord.

The connecting cord from which the cartons are suspended is first looped around the cardboard disk and forced, together with the cardboard disk, into the carton where it remains firmly fixed by a drop of glue which is applied on top of the disk.

These several caterpillar cases are spaced approximately 20 inches apart on the supporting cord, one end of which is attached to the parachute string, the other end of the cord traveling free. This gives a span of about 12 inches between the end of the parachute cord and the first light.

The several lights are nested by means of a form shown in figures 57, 58, and 59.

FIG. 57.—Block used for assembling caterpillar signals.

FIG. 58.—Arrangement of caterpillar signals in block.

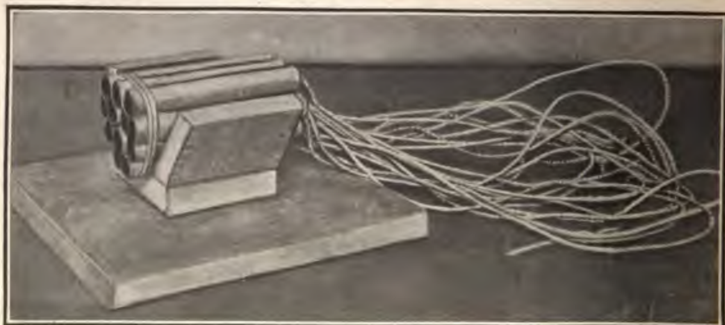


FIG. 59.—Caterpillar bundle complete.

When finally stacked as shown in the figure, a string is tied around the end of the lights close to the primed end.

This string holds the battery of lights in place until the prime is ignited, when the string is burned away and the lights hang in a chain in their respective positions.

Great care must be exercised in stacking the lights in order to insure the free uncoiling of the supporting cord. This cord is common hemp twine and does not burn away because it is attached to the light case by means of the disk acting as an anchor in such a manner as to prevent the light from hanging in a perpendicular position, the light or case making an angle with the cord of approximately 45°, thus bringing the burning end well away from the cord.

LOADING PARACHUTE AND SIGNALS INTO ROCKET HEAD.

The carton of the rocket head may be attached to the rocket body before introducing the parachute and light signals or the parachute and signals may be assembled and the rocket head then attached to the rocket body. In the event that the latter plan is adopted, a small wooden plug is temporarily forced into one end of the carton of the rocket head to act as a temporary bottom until the case is loaded, at which time it is removed and the rocket assembled.

The assembly of the parachute and signals with the exception of this one point is practically the same. The operation consists first of the introduction of the signal, which is shown in figure 60.

After the signal is placed in the carton, cotton batting is tamped into the case and around the signal light. A handful of bran or sawdust poured into the case fills up the space around the cotton batting and acts as an additional buffer to protect the parachute from the flame of the expelling charge, and also acts as a bed in which the parachute rests. Figure 61 shows this operation.

First the parachute is inspected for imperfections. This is done by the operator drawing the parachute quickly through the air by means of the strings, thus inflating it and giving it a test. The perfect parachutes are then rubbed thoroughly inside and out with powdered pumice stone.

This is necessary in order that the parachute shall open freely when expelled from the container.

The next operation is to tie the parachute strings to the tie cord and asbestos cord. The operator before tying the strings again inspects the parachute in a manner similar to that which has been described above. The tie cord and asbestos cord are tied to the parachute strings by a simple knot. The parachute is then ready for folding and the operator doing this work again inspects it in the same manner as above.

FIG. 60.—Placing signal light in rocket head.

The operator holds a parachute at its apex, and first runs his fingers as a comb downward through the strings, insuring against their being entangled. The seams of the various segments are drawn and accordion plaited, very much in the manner of an umbrella folded before being rolled.

The parachute is encircled by the hand, the folds are smoothed down into a cylindrical form, and the entire parachute is then folded double. The strings are caught up and coiled around three fingers of the hand and the coil placed against the side of the folded parachute. After the strings have been carefully arranged the coil is again folded over the strings, making a compact package, ready to be inserted into the case as shown in figure 63.

The parachute is now carefully folded in the manner described, care being taken to plait the folds of the parachute

FIG. 61.—Placing cotton batting and sawdust around light in rocket head.

and to see that the strings are not tangled. The strings are coiled, set against the folded parachute, and the bundle is introduced into the rocket head. Figures 62 and 63 show the above operations.

One method in use which seems to give satisfaction is shown in figures 64 and 65. In this operation a disk of strawboard forms a ring around the light just above the match, having an outside diameter the same as the inside diameter of the rocket head. The disk acts as an additional barrier to prevent the igniting flame from charring the parachute.

Fig. 62.—Plaiting folds of parachute.

IDENTIFICATION PLUGS.

Each type of rocket is supplied with a distinctive top or wooden cap.

The reason that a special shape is given to the identification plug rather than a mark is to enable the operator to distinguish in the dark the character of the signal light by the sense of touch. Figure 66 shows the different types of these identification plugs.

The identification plug is made of hardwood, 2 inches in diameter and 1¼ inches deep, and is shouldered $\frac{1}{16}$ of an inch in order to permit the lower part of the plug to be introduced into the rocket head.

Fig. 63.—Folded parachute ready for insertion in head.

IDENTIFICATION PLUG BAND.

The band consists of a strip of rope manila 20-pound stock cut into strips 1½ inches wide by 8 inches long. This strip is given a coat of paste, wrapped around the end of the rocket head and crimped for about ½ inch around the identification plug. Figure 68 shows this band in place.

ASSEMBLY OF ROCKET HEAD TO ROCKET BODY.

The rocket head is now attached to the rocket body by slipping it over the muslin drumheaded end of the rocket body, the muslin having been previously given a coating of

FIG. 64.—Briquette attached to parachute.

glue. The rocket body is telescoped into the rocket head approximately ¾ of an inch.

MUSLIN HEAD BAND.

This band consists of a strip of light unbleached muslin, 1¾ inches wide by 12 inches long, which encircles the rocket

FIG. 65.—Briquetted light with protecting disk.

FIG. 66.—Identification plugs.

twice, half of its width pasted to the rocket head and the other half attached to the rocket body, the muslin having been given a coat of paste on both sides.

FIG. 67.—Placing identification plug in position.

FIG. 68.—Rocket head showing band holding identification plug in position.

PAINTING OF ROCKET.

The rocket body is given a coat of gray paint irrespective of the character of the signal. A formula for a standard paint is as follows—

3 gallons of alcohol.
5 pounds of rosin.
15 pounds of powdered orange shellac.
30 pounds of white lead (dry).
¼ ounce lampblack.

The rocket head is painted to represent the color of the signal. The same formula may be used for this paint as previously mentioned, with the substitution of the coloring matter for the lampblack.

LABELS.

Labels giving directions for the firing of the rockets are shown below:

SIGNAL ROCKET MARK I.

WHITE PARACHUTE.

Directions for firing.

Tear off wrapper by means of protruding string with tag attached. Pull string straight up the length of wrapping paper. Insert stick firmly in socket. Break drumhead on bottom of rocket, uncoil quick match in end of rocket, letting it extend ready for firing.

Box of five matches inclosed in outside wrapper.

MANUFACTURER.

JULY, 1918.

SIGNAL PARACHUTE ROCKET, MARK I.

YELLOW SMOKE.

Directions for firing.

Tear off wrapper by means of protruding string with tag attached. Pull string straight up the length of wrapping paper. Break drumhead on bottom of rocket, uncoil quick match in end of rocket, letting it extend ready for firing.

Box of five matches inclosed in outside wrapper.

MANUFACTURER.

AUGUST, 1918.

DIRECTIONS.
Break through
this paper and
pull down the
fuse found
within.

The rectangular labels are pasted on the rocket head and the circular label is pasted at the ignition end of the rocket. Fig. 69.

FIG. 69.—Rocket head attached to rocket body.

TEARING STRING.

This string is 31 inches in length, of two-ply Italian shell twine, one end of which is fastened to the rocket body by means of a No. 9 coppered-iron wire staple, which is driven into the wall of the rocket body. Fig. 70.

WRAPPING CARTON.

The rocket is now introduced into a packing carton which consists of a cylinder 18¾ inches long by 3 inches inside diameter, rolled from Bogus paper of 0.013 inch thickness from sheets 18¾ inches wide by 26 inches long, cut 10¼ by

FIG. 70.—Assembled rocket, showing tearing string.

18¾ inches, the carton being rolled on a wooded mandrel. The rocket is inserted into this carton by putting the end to which the string is attached in first, so that when the rocket is pushed into place the string protrudes from the far end of

FIG. 71.—Placing rocket in wrapping carton.

the carton, thus permitting a longitudinal tear the full length of the carton.

Five wind matches are wrapped in a small package and dropped in the wrapping carton, figure 71.

THE ROCKET WRAPPER.

The rocket wrapper is usually 30-pound Kraft paper cut 15 by 22 inches. This paper may be gummed along one edge or may be crimped and tied as shown in figure 72.

FIG. 72.—Rocket wrapped.

DRUMHEADS.

The drumheads are pieces of 30-pound Kraft paper cut 7½ by 7½ inches, with the corners clipped off, making an octagon. A coat of paste is applied to both sides of these drumheads before they are placed over the ends of the package. The drumheads are smoothed down very carefully against the walls of the package and make a tight fit. A label similar

FIG. 73.—Assembled rocket labeled and paraffined.

to that used on the inside of the package is now pasted around the center.

IDENTIFICATION TAG.

The identification tag consists of a piece of cardboard, one edge of which has the same contour as the identification plug. This disk is attached to the tearing string as shown in figure 73.

The various shapes designating the character of the signals are shown in figure 74.

WRAPPER WATERPROOFING.

Melted paraffin is used as a dipping bath. White paraffin with a melting point of 120° F. is melted in a steam-jacketed kettle, the dipping temperature being between 120° and 125° F. Alternate ends of the rocket package are dipped into this bath. Then the whole package is submerged, and withdrawn and placed on a rack to drain. This insures a moisture-tight package, figure 75.

FIG. 74.—Identification tags.

Packages are frequently subjected to a test of thirty seconds' submergence in water to insure satisfactory application of the paraffin coating.

ROCKET-PACKING CONTAINER.

This box is a folded corrugated-paper container, holding 25 rockets, and when assembled measures 17 by 19⅝ by 11¾ inches. Gummed cloth makes a tight seal on both bottom and top of the container, being pasted along the joints and edges. When sealed the box is dipped into a bath of paraffin in the manner shown in figure 76.

ROCKET-PACKING CASE.

This is a wooden case of ¾-inch material in which one of the rocket-packing containers is shipped. The inside dimensions of the box are 20¾ by 17¼ by 12 inches. The manner of bolting the cover in place is shown in figure 77.

FIG. 75.—Paraffining rockets.

STICKS.

The sticks are made from soft wood cut ⅝ inch square by 6 feet long. The end of the stick, which is inserted into the stick socket attached to the rocket body, is slightly tapered on three of its faces in order to facilitate its easy insertion into the socket. Two saw-cut notches are cut in the top end of the stick. One of them is cut ⅜ inch, and the other $\frac{3}{4}$ inch from the end, about $\frac{1}{8}$ inch deep, which permits the stick spring to lock the rocket stick firmly. It is to be noted that the sticks are sent in separate packages accompanying the rockets, to be attached in the field. These sticks are shipped in bundles wrapped in the following manner:

Six sticks are tied by cord at each end with a half hitch. Then nine of these bundles are again tied together with more

FIG. 76.—Paraffining shipping carton.

cord. Two of these bundles of 54 sticks each are bound together. These are now ready to be packed into a crate holding two bundles, or 108 sticks. It will be noted that this arrangement includes an extra number of sticks, namely, 108 for 100 rockets, the 8 extra taking care of the average breakage in the field.

FUNCTIONING OF ROCKET.

The following figures show the rocket functioning:

Figure 78 shows the manner in which the rocket is supported when the match is lighted.

FIG. 77.—Heading-up shipping case.

Figure 79 shows the rocket being propelled upward by means of the rapid burning of the propelling charge.

Figure 80 shows the rocket having reached the zenith of its flight, the expelling charge having blown out the contents of the rocket head. The garniture, consisting of parachute and signal, may be seen in the upper part of the picture, having been thrown to a distance of approximately 45 feet.

FIG. 78.—Igniting rocket.

Figure 81 shows the parachute opened and the suspended signal functioning properly.

FIG. 79.—Rocket functioning showing gases issuing from orifice.

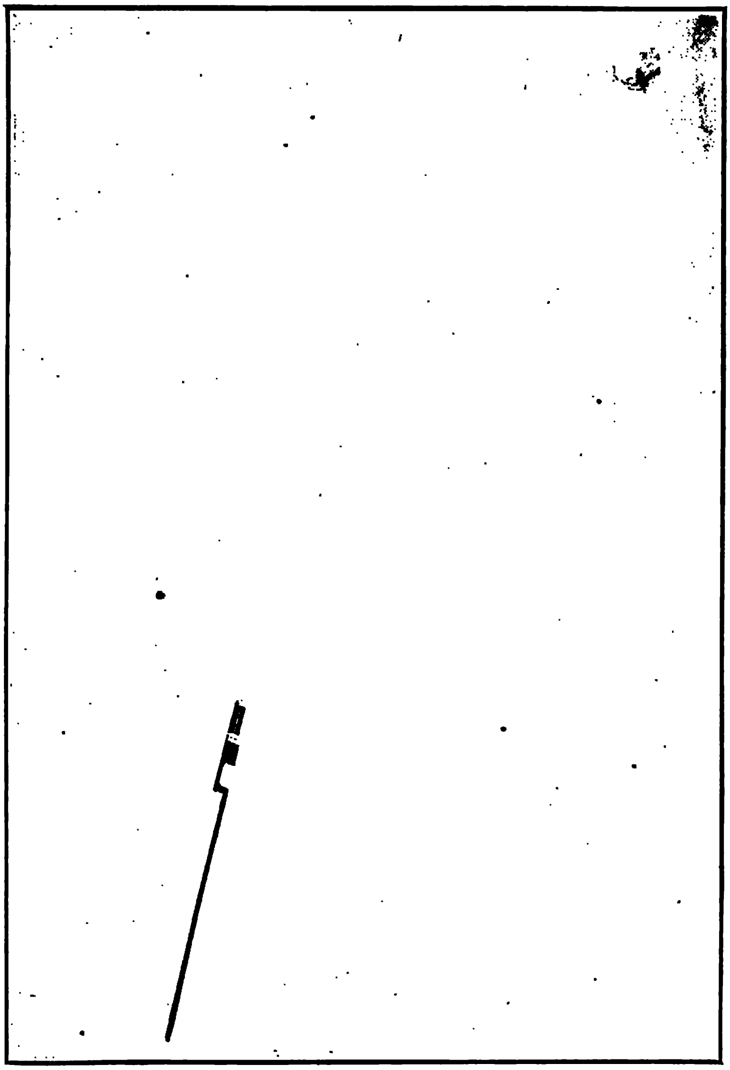


FIG. 80.—Rocket functioning showing signal expelled from rocket.

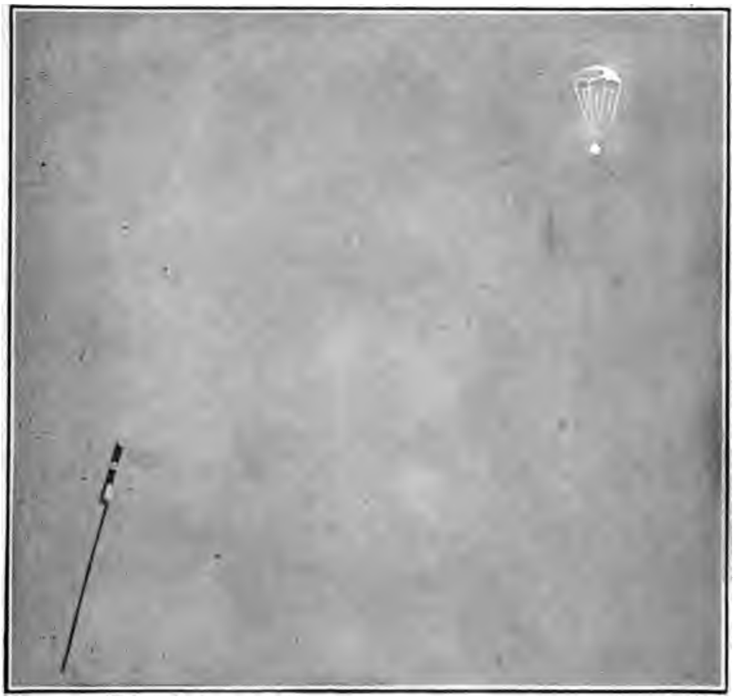


FIG. 81.—Rocket functioning showing parachute opening.

SIGNAL ROCKET FLOW SHEET

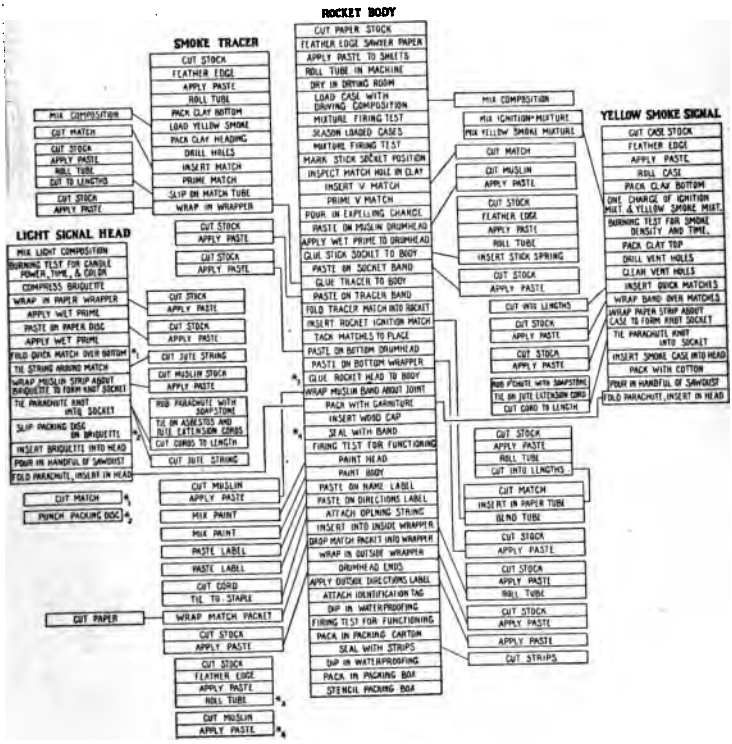


PLATE 1.

SIGNAL ROCKET MATERIAL CHART

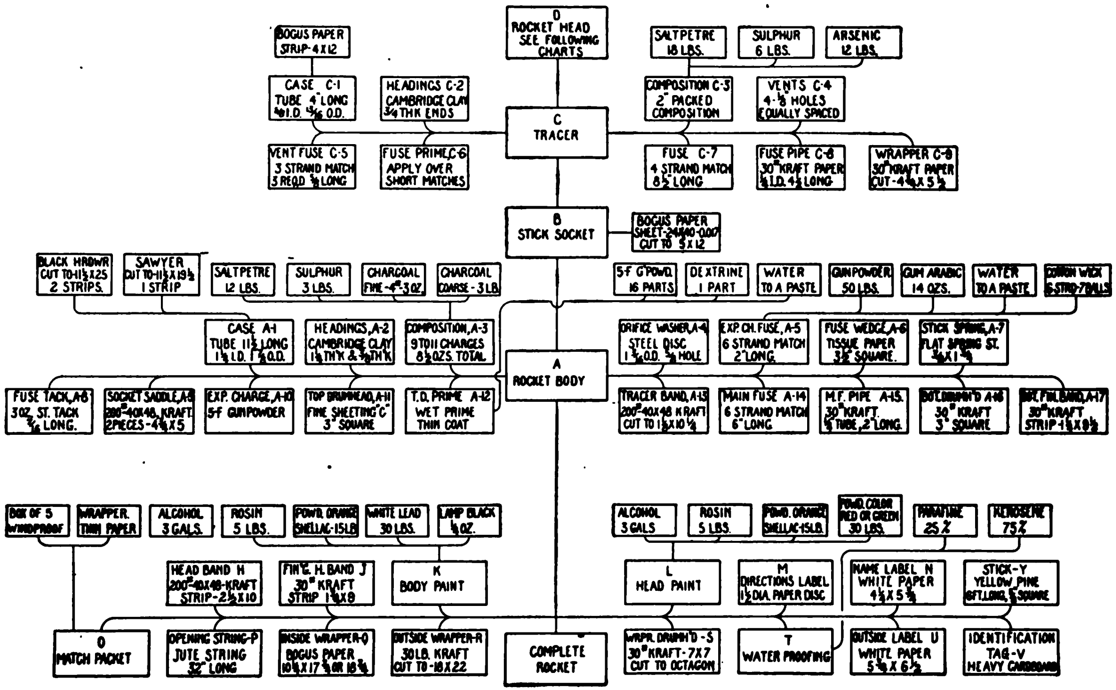


Plate 2.

YELLOW SMOKE ROCKET HEAD MATERIAL CHART

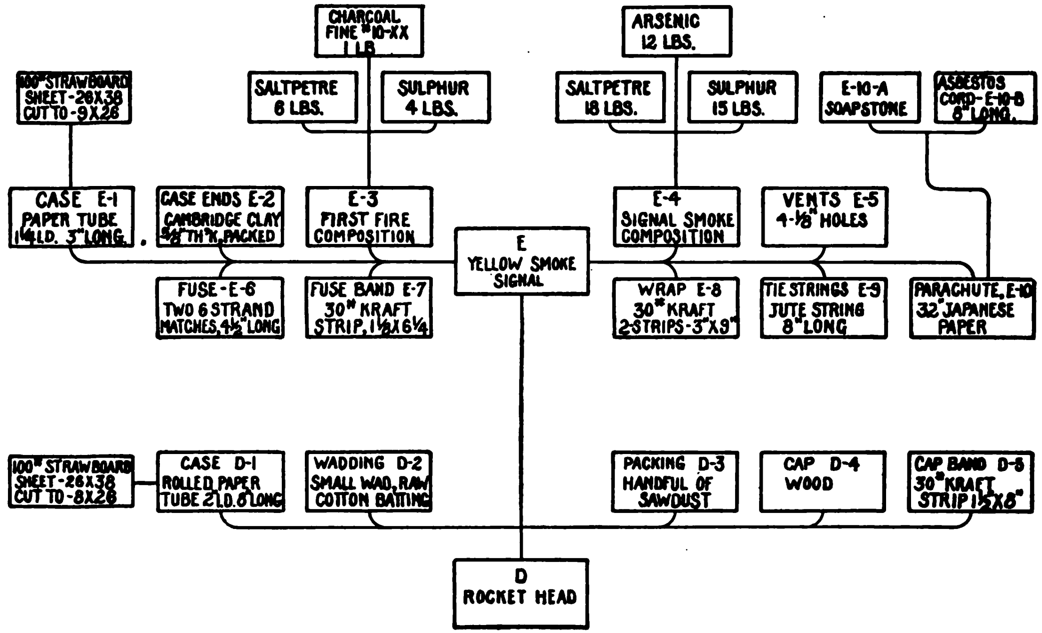


PLATE 3.

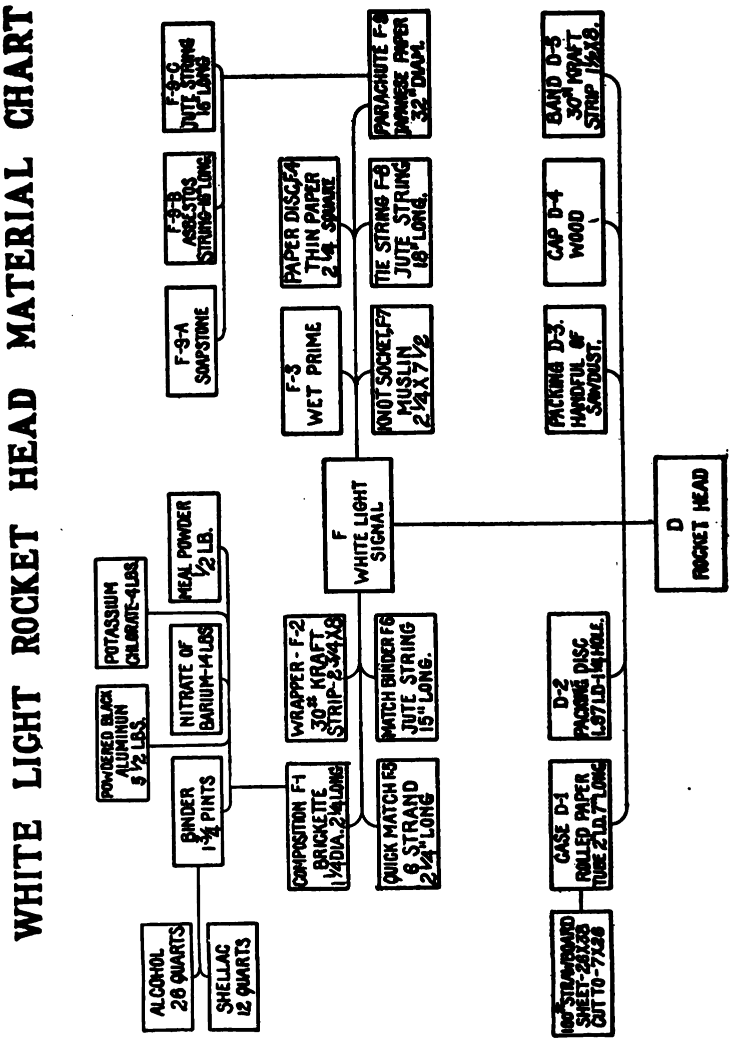

WHITE LIGHT ROCKET HEAD MATERIAL CHART
ALCOHOL 28 QUARTS
SHELLAC 12 QUARTS
BINDER 1¾ PINTS
POWDERED BLACK ALUMINUM 5½ LBS.
NITRATE OF BARIUM-14 LBS.
POTASSIUM CHLORATE-4 LBS.
MEAL POWDER ½ LB.
COMPOSITION F-1 BRICKETTE 1¼ DIA. 2⅛ LONG
WRAPPER-F-2 30# KRAFT STRIP-2¾X8
F WHITE LIGHT SIGNAL
F-3 WET PRIME
PAPER DISC F-4 THIN PAPER 2¼ SQUARE
QUICK MATCH F-5 6 STRAND 2¼" LONG
MATCH BINDER F-6 JUTE STRING 15" LONG.
KNOT SOCKET F-7 MUSLIN 2¼X7½
TIE STRING F-8 JUTE STRING 18" LONG.
PARACHUTE F-9 JAPANESE PAPER 32" DIAM.
F-9-A SOAPSTONE
F-9-B ASBESTOS STRING-18" LONG
F-9-C JUTE STRING 18" LONG
100# STRAWBOARD SHEET-28X28 CUT TO-7X28
CASE D-1 ROLLED PAPER TUBE 2 I.D. 7" LONG
D-2 PACKING DISC 1.97 I.D.-1⅛ HOLE.
PACKING D-3. HANDFUL OF SAWDUST.
CAP D-4 WOOD
BAND D-5 30# KRAFT STRIP 1½X8.
D ROCKET HEAD

PLATE 4.

RED AND GREEN ROCKET HEAD MATERIAL CHART

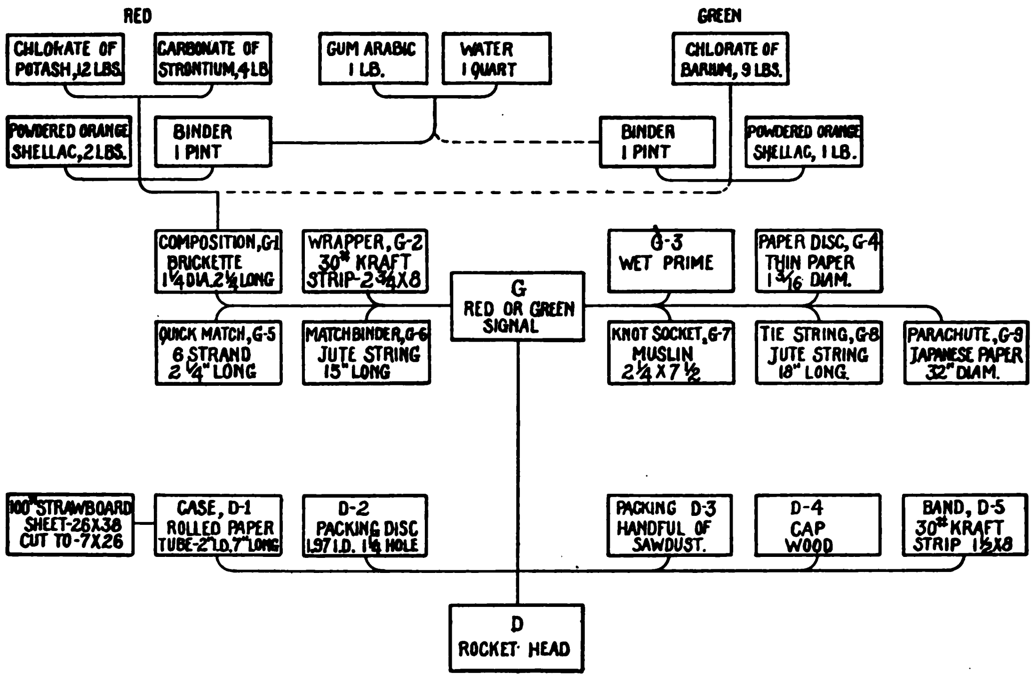


PLATE 5.

FIG. 82.—Aëroplane flare.

AËROPLANE FLARE.

CHAPTER II.

AËROPLANE FLARE.

The aëroplane flare is a pyrotechnic illuminating device of French origin, having a high candle power. It is released from an aëroplane, its function being the illumination of large areas. It consists of a metal container holding a large silk parachute to which is attached a case of compressed composition that will burn with a white light. The flare is attached to the under side of an aëroplane. Suitable rigging holds it in such a position that when released it falls with the igniting end pointed downward and continues in this position by the help of four fins at the upper end of the flare.

The flare is released by the aviator, through the simple movement of a lever, usually at a height of about 4,000 feet. Immediately upon its release, the pin wheel in the igniting end of the flare is set in motion, revolving at a high speed, caused by the resulting upward rush of air against the blades. The stem of this pin wheel revolves with the wheel and is guided forward by means of proper threading until a point is reached where the disengagement of the threads allows the stem to be forcibly pushed inward to strike a detonating cap which lights the firing charge. The firing or igniting charge is a small amount of black powder which is designed to expel the contents of the aëroplane-flare shell. The shell holds a large silk parachute to which is attached the compressed composition charge which is ignited simultaneously with its being expelled from the case.

The parachute opens readily and floats at an altitude of about 2,500 feet over the area to be lighted. Swinging from the cords of the parachute hangs the composition charge which burns with a brilliant light, having an intensity not less than 350,000 candlepower. This light should burn with-

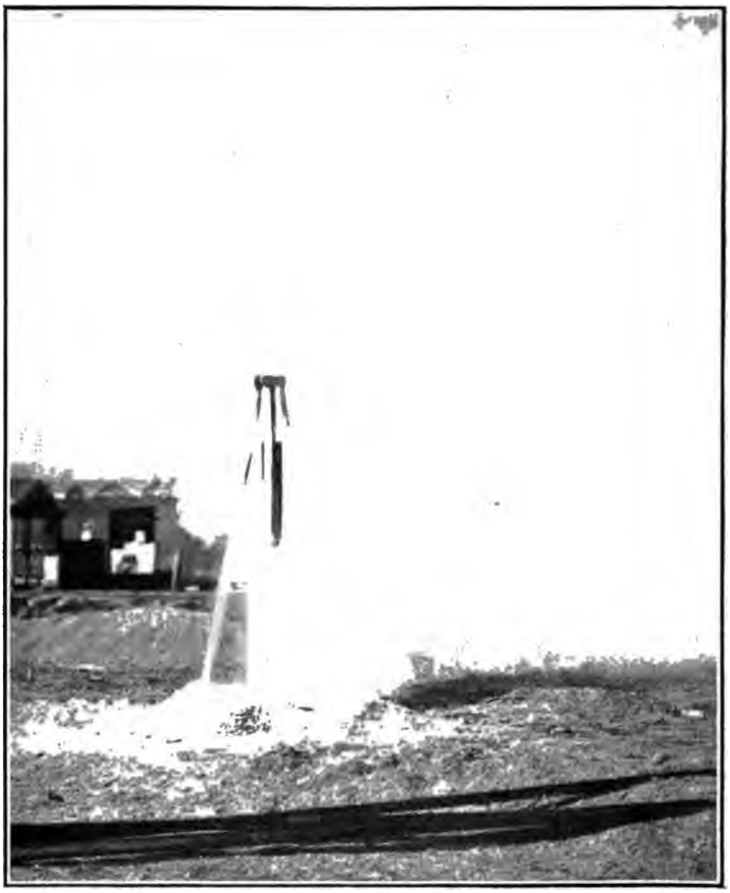


FIG. 83.—Light case being tested for burning time.

out a diminishing candlepower for at least seven minutes. The illumination is so intense that a large area is lighted sufficently to permit of photographing, reconnoitering, and bombing.

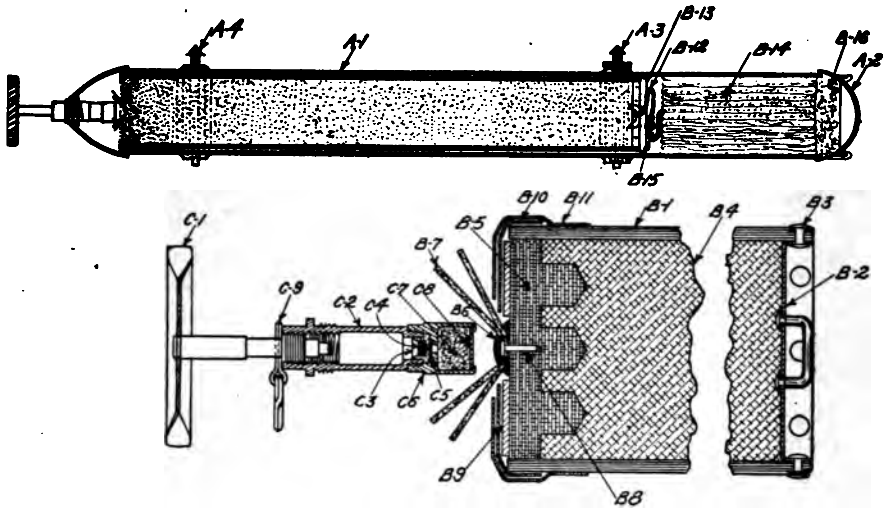


Fig. 84.—Sectional drawing of aëroplane flare.

AËROPLANE FLARE.

A. *Shell:*
1. Cylinder.
2. Cap.
3. Top suspension band and catch.
4. Bottom suspension band and catch.
5. Name label.[1]

B. *Light:*
1. Case.
2. Case top.
3. Case - top rivets and washers.
4. Composition.
5. First-fire composition.
6. Priming.
7. Fuse.
8. Fuse nail.
9. Case bottom.
10. Bottom drumhead.
11. Bottom finishing band.
12. Connecting cable.
13. Wad.
14. Parachute.
15. Tie string.
16. Padding.

C. *Firing mechanism:*
1. Propeller and shaft.
2. Barrel.
3. Detonating cap.
4. Detonating composition.
5. Detonating-cap cover.
6. Expelling-charge holder.
7. Expelling composition.
8. Wad.
9. Safety pin.
10. Detonating-cap packing tube.[1]
11. Detonating-cap packing wad.[1]
12. Detonating-cap wrapper.[1]
13. Detonating - cap - wrapper string.[1]
14. Detonating-cap label.[1]
15. Detonating-cap instruction sheet.[1]

D. *Packing box:*[1]
1. Box.
2. Lining.
3. Cleats.
4. Bolts and washers.
5. Straps and nails.

---

[1] Not shown in cut.

AËROPLANE-FLARE SHELL.

CYLINDER.

Figure 85 shows a longitudinal cross-sectional view of the cylinder which is the container for the light case and parachute. The main body and fins are of tinned steel (No. 24 gauge), and the lower or firing conical end of brass. In the conical or lower end is soldered a tapped brass bushing to receive the firing mechanism. The flange, shown at the juncture of the nose and main body, acts as a stop to fix the position of the light case in relation to the igniting mechanism.

There are four fins, 1 inch wide by 11¾ inches long, spaced equidistant on the outside of the cylinder at the upper end. These have for their function the steadying of the flare when released from the aëroplane, causing the flare to drop

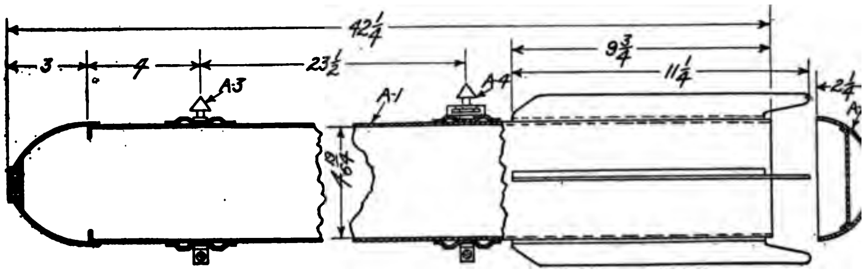


FIG. 85.—Dimensional drawing of shell.

in a perpendicular position, thus insuring the action of the igniting mechanism and the proper functioning of the expelling charge. As shown in the figure above, two rings with ½ inch grooves are soldered to the outside of the cylinder 7 inches and 30½ inches, respectively, from the firing end. These provide spaces for the suspension bands.

CAP.

The cap is shown detached from the cylinder at its head or end opposite to the firing mechanism. This cap is bowl shaped of a diameter permitting it to be crimped upon the main shell of the aëroplane flare, which has a diameter of $4\frac{1}{32}$ inches. This cap has a depth of 2¼ inches. A tinned steel diaphragm of No. 24 gauge is sweated in midway between the top and bottom of the cap. The function of the diaphragm is merely to form an additional protection for capping the end of the flare. When assembled the cap fits snugly over the top of the shell and closes that end of the container. The cap is held in place by crimping, which is done by hand.

TOP SUSPENSION BAND AND CATCH.

The top suspension band located farthest from the igniting end consists of a coppered-iron band, made to encircle the cylinder, with the ends turned up and punched to receive a brass bolt for tightening around the cylinder, being in effect a "hose clamp." At the opposite side is attached a brass plate holding a spear-head projection for attaching to the release mechanism on the aëroplane.

BOTTOM SUSPENSION BAND AND CATCH.

This band is similar to the top suspension band, except that the brass plate is slotted to allow a lateral movement to the catch permitting adjustment, and the spear-head is formed so as to slide in the slot.

NAME LABEL.

After the flare is completed a paper label 2 by 6¼ inches, giving the name of the manufacturer, lot number, date of manufacture and weight, is pasted on the top section of the cylinder between the fins.

LIGHT.

CASE.

The case holds the illuminating composition and is attached to the parachute. The case is made of four sheets two-ply heavy hardware paper. The four sheets having been pasted are rolled together into the form of a cylinder of the dimensions shown in the above figure. This forms a light strong case into which is compressed the illuminating charge. The use of the paper case has the advantage that it burns away with the illuminating charge and thus prevents any chimneying effect and still does not burn so rapidly that the charge is lost.

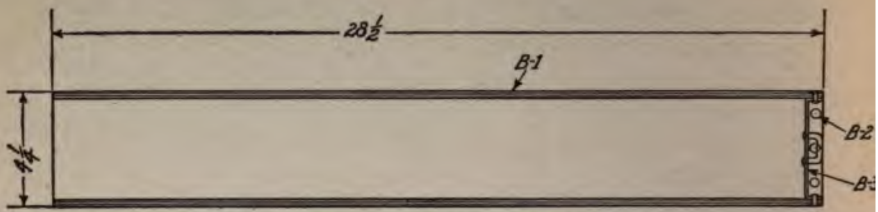


FIG. 86.—Sectional drawing of light case.

FIG. 87.—Pasting machine.

The general tendency abroad is to substitute metal tubes for the stout heavy paper cases.

A belt-driven pasting machine applies the paste to one side of each sheet.

The operator on the left is seen feeding the paper through the guide which carries it over a roller revolving slowly in a trough of liquid paste. These sheets are similar to those used in rolling the rocket body, two ply, the paste being applied to that side having the smaller sheet. This roller distributes the paste in a uniform manner. The sheets com-

FIG. 88.—Rolling machine.

ing off the pasting machine are arranged on the table, with the pasted side uppermost, the first sheet protruding 3 inches beyond the second, the second protruding 3 inches beyond the third, and the third protruding 3 inches beyond the fourth. A set of four sheets thus arranged is laid upon the feed board of the rolling machine.

The set is laid upon the board with the pasted sides upward and the projecting edges of the undermost sheet forward. In this position the set of four sheets is moved forward until

FIG. 89.—Rolling machine; removing case from mandrel.

the undermost sheet is inserted in a slot, provided in the mandrel of the rolling machine.

The mandrel by suitable mechanism is always stopped in a position permitting the sheet to be easily fed into the slot. This slot is cut parallel to the long axis of the mandrel, and has a slightly spiral twist at one end. Care must be exercised to see that the case is tightly rolled as the external diameter must be constant, in order that it may fit into the outer case or shell. The operator, using his hands as a band

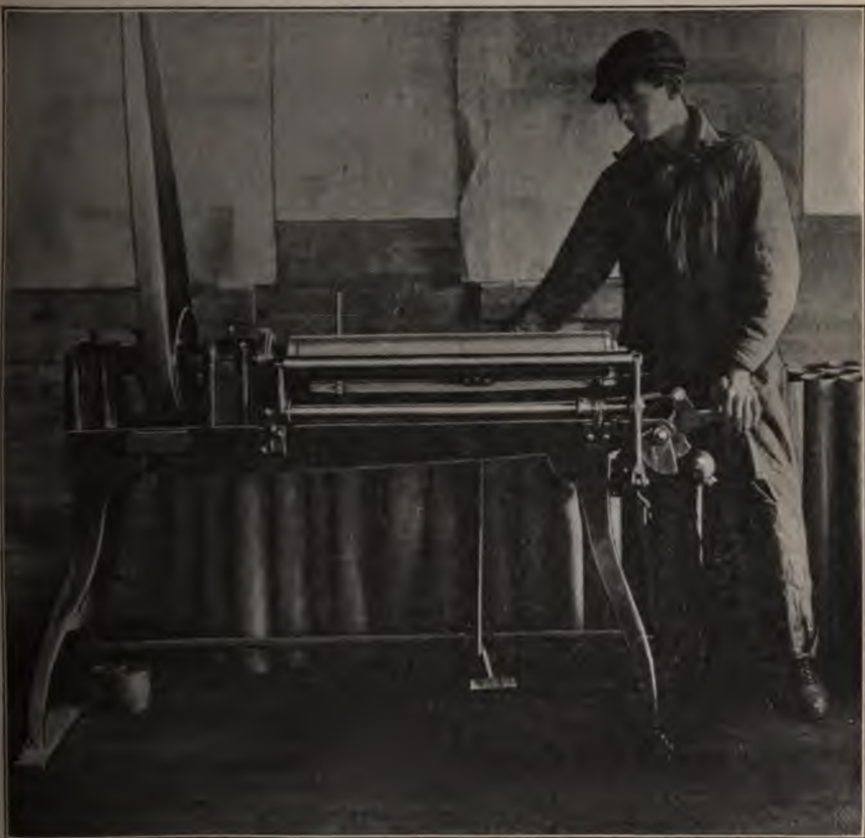


FIG. 90.—Trimming machine.

brake, exerts pressure to form properly the case while it is being wound about the mandrel. The case is now removed from the mandrel with the assistance of a collar. The spiral twist of the slot in the mandrel smoothes the edge of the paper against the inner surface of the carton as it is forced from the mandrel.

Figure 89 shows the operation of removing the case from the mandrel. The man is forcing the case off the mandrel by means of a collar, the case being received by the woman operator.

The cases are stood on shelves in a drying room, where they are kept for a period of time sufficient to dry them very thoroughly. No special provision is made for circulation of air or maintaining a constant temperature, it being the practice of the manufacturer to dry these cases as slowly as is consistent with the demands for their output. Three days is the time usually required to accomplish this drying, which is carried on at room temperature. If the cases are dried too rapidly or if sunlight is allowed to play upon them, they are likely to bulge and thus become unfitted for use. The finished tubes are trimmed on a trimming machine so as to

FIG. 91.—Case and case top.

have smooth ends, the tube being cut to a measure of 28½ inches long. The outside diameter should be 4¼ inches.

The trimming machine is essentially a cut-off lathe which trims both ends of the case to the required length simultaneously. The case is placed on the revolving mandrel by swinging out the headstock and placing the case in position. The headstock is then set and the machine started, the steel cutting wheels revolving at a rate which insures a clean cut.

CASE TOP.

The case top is made of No. 18 gauge galvanized iron and has a staple riveted firmly in the center to which is attached the parachute cable. This cap is shown resting against the side of the light case in figure 91.

Figure 92 shows the case top inserted into the end of the case flush with the end. Eight $\frac{1}{8}$-inch holes are punched through the case and flange of the top by a specially designed punching machine, as shown in the figure, which turns the case $\frac{7}{8}$ of a revolution, punching at each $\frac{1}{8}$ of a turn.

FIG. 92.—Punching machine.

RIVETS AND WASHERS.

Eight copper rivets $\frac{1}{8}$ inch by $\frac{5}{16}$ inch, with $\frac{3}{8}$-inch heads and copper washers, are used to securely rivet the case top to the case. Riveting is done with a specially designed riveting machine as shown in figure 92.

This machine is a combination of a foot-operated punch press and drill press. The rivets are hand assembled in the holes in the case and case top from the inside by means of specially constructed pliers, and the washers are put on each rivet just before the rivet is upset on the riveting machine.

The upset rivets are smoothed off by a die fitted in the chuck of the drill press. This is necessary as otherwise a burr on the rivets would prevent the case from fitting into the shell.

Fig. 93.—Riveting machine.

ILLUMINATING COMPOSITION.

Illuminating composition is one which when ignited by proper means, to be described later, burns slowly, emitting an intense white light. The burning of this composition produces the illumination of the aëroplane flare.

In practice the light composition is made up in batches of 100 pounds by mixing the following chemicals in their respective proportions:

	Per cent.
Barium nitrate ($Ba(NO_3)_2$)	76.00
Aluminum (powdered)	9.75
Aluminum (flake)	8.25
Sulphur (flour)	4.00
Castor oil or vaseline	2.00

The proportions of the above formula are subject to slight changes because of variance in the purity of the various ingredients. In practice the barium nitrate, castor oil or vaseline, and sulphur remain practically constant in amount. The principle variation from the above formula is in the amount of aluminum used in the composition.

The barium nitrate is crushed and ground through a Coggswell mill, to reduce it to a very fine powder. The finer the grinding of the barium nitrate, the more intimate will be its mixture with the other ingredients of the formula and the loading of the charge in the light case will also be more even. The barium nitrate is now taken from the mill and for the purpose of safety is removed to another building where 76 pounds of it is carefully weighed out and placed in the mixing machine, to which 2 pounds of castor oil or heated vaseline is slowly added and mixed. This mixing operation should continue for a period of not less than 4 or 5 minutes. The mixing machine is a combination of a belt-driven shaft with open arms revolving in a horizontal cylindrical trough and a revolving metal screen. The arms of the shaft are designed to thoroughly mix the barium nitrate and binding material. When ready to be screened through the revolving sifter it is only necessary to open the gate at the bottom of the mixer over the sifter and allow the material to run into the hopper above the sifter. The function of the sifter is to eliminate any lumps passing through, and the operator at the completion of each batch forces any accumulation through the sifter with his hand. The sifted material falls into a bin, located above a bucket, shown at the right of the cut.

It is necessary after sifting the material that an accurate weighing should be made. Each can of the mixed barium

FIG. 94.—Mixing machine.

nitrate and oil should contain 78 pounds in order that the final composition shall run uniform. In another building the powder and flake aluminum and sulphur are mixed by rubbing them through a 30-mesh screen by hand into a wooden or fiber tub where the mixture is again mixed by hand and is then passed through the screen a second time. These two mixtures, one of barium nitrate and oil and the other of aluminum and sulphur, are mixed in a wooden or fiber tub and passed twice through a 12-mesh screen. It is

FIG. 95.—Mixing composition by hand.

essential that the mixing be as intimate as possible, as the even burning quality and high candlepower are dependent almost entirely upon an extremely intimate mixture. Various attempts have been made to substitute machinery for the slow and antiquated method of mixing shown in figure 95, which illustrates the manner in which the powder is mixed by hand, but have not met with the approval of the manufacturers.

Powder mixing by hand is an operation where the danger from sparks and electric discharges have been minimized.

Up to the present time the substitution of machine mixers has not been adopted by the manufacturers.

In all operations where there is any compression of the burning compositions, such as the loading of cases with combustible materials, the work should be performed in buildings especially designed for this work and separated from the main part of the plant. There would appear to be little or no danger from explosion occasioned by the mere pressure in forming the compositions into their cases. Manufacturers who have had experience in this art for many years advise that the only source of danger which they seek to provide against is in the igniting of the fine dust that almost invariably occurs with the withdrawal of the plunger as the latter is drawn back from the case after having pressed the composition into form. Any sparking will very readily ignite this fine combustible dust and occasion serious trouble. It is usual to provide for work of this character press buildings separated from the main plant, each building having not more than two presses installed. The other equipment usually provided is a bench 3 feet square and a box 2 by 3 feet to contain the composition. A small scoop, a hardware scale, and a measure that will hold approximately 7 pounds of composition are all the equipment necessary as an adjunct to each press. The press itself consists of top and base sections connected by rods and a movable platform operated by a hydraulic ram controlled by valves at the side and operated by a lever. On the moving platform is a base plate with recess to accommodate the staple of the assembled light case, located at its top, which is called a pilot. Jacket and pilot rest on a metal plate ½ inch thick, which is so arranged that it may be shifted forward and backward on the moving platform of the press so that the case may be carried clear of the rammer.

Fig. 96 shows the loading machine with the jacket moved forward and clear of the rammer. The operator is shown pouring from a scoop a charge of the composition into the case held by the jacket. This charge weighs 7 pounds, the charging being done by successive compressions.

Figure 97 show the jacket, pilot and supporting plate slid back into a position which will permit the rammer to enter and move freely within the jacket.

Figure 98 shows the operation of removing the jacket after these successive charges of composition have been rammed into the case. The operator loosens the six nuts on the jacket, which are shown in the cut, permitting the jacket

FIG. 96.—Hydraulic press; filling case.

to be moved freely away from the case which it has been holding during the process of charging. The lugs on the upper part of the jacket engage hangers which lift the jacket away from the case by sliding it over the rammer. It must be noted that the rammer is always in a fixed position, the operation being accomplished by the upward movement of the platform holding the jacket and case, thus pressing against the fixed rammer. An extension piece is provided

FIG. 97.—Hydraulic press; ramming composition.

for use in ramming the first loading charge. This extension piece is a solid cylinder approximately 8 inches long and of the same diameter as the rammer. It is provided with a hook socket in the head to permit lifting it from the case after the first charge has been rammed home. A tool with a long eye and a hook for lifting out the extension piece is used for removing the solid cylinder from the case after compression. A tin funnel is used as a convenience in loading. The jacket is lowered into position and clamped about

FIG. 98.—Hydraulic press; removing jacket.

the case, the halves making complete contact. The first charge of 7 pounds of composition is then poured in and the extension piece for ramming is placed in position. This assembly of the case jacket, extension piece, etc., is effected when the base plate is in its forward position. By manipulating the lever shown in the foreground of the cut the plate is thrown to the rear of the machine directly under the plunger. Hydraulic pressure is then turned on until 2,500 pounds pressure to the square inch is attained, but for an instant only. After releasing the pressure the plate is brought back to the loading point, the extension piece is removed, and a second charge of seven pounds is loaded in the case. This receives a pressure of 2,200 pounds to the square inch. The remainder of the charge is loaded by filling the case full to the top with composition and ramming down each successive filling until a total of 28 pounds is loaded. The third ramming should be compressed with 1,700 pounds pressure, the fourth with 1,400 pounds, and the remainder with only 1,000 pounds. The jacket is then loosened and by means of an air hoist is lifted clear of the case, so that the latter can be conveniently removed from the machine.

PREPARATION OF THE LOADED CASE TO RECEIVE THE FIRST-FIRE COMPOSITION.

After the loaded case is taken from the press it is removed to another building, where the case is laid upon a table and an operator reams out by a specially designed tool the excess composition to a depth of ⅝ of an inch from the upper edge of the case. This operation is shown in figure 99.

The reaming operation provides room for the first-fire composition which is later rammed into the space so made. The reamed case is shown very clearly in figure 107. After the above operation five ¾-inch holes are drilled to a depth of three-quarters of an inch. The purpose of these holes is to aid in making close contact between the composition and the first fire, by helping to hold the first fire in place and by increasing the contact surface. Shellac is then painted on the inside of the case above the composition and immediately the first-fire composition is loaded into place. The shellac acts as a binder, holding the first-fire composition firmly in position.

FIRST-FIRE COMPOSITION.

The first-fire composition is a quick-burning mixture which is used to insure the ignition of the light composition. It is similar in this characteristic to a quick-burning black powder

FIG. 99.—Reaming excess composition from loaded case.

FIG. 100.—Drilling holes in composition.

	Lbs.	Per cent.
Barium nitrate ($Ba(NO_3)_2$)	4	44.5
Saltpeter (KNO_3)	3	33.3
Sulphur (flour)	1	11.1
Orange shellac (powdered)	1	11.1
	9	100.0

Slightly dampen with wood alcohol.

Barium nitrate used in this operation is the same as that used in making up the composition light mixture and it is ground to the same degree of fineness. The process of mixing the first-fire composition consists of placing the nitrate of barium in a tub or container. Sulphur (flour), saltpeter and powdered orange shellac are now sifted through a 30-mesh screen onto the barium nitrate. The ingredients are thoroughly mixed by hand and sifted twice through a 30-mesh screen to insure uniformity in mixing. Wood alcohol is added to this mixture just prior to its use, and the mixing and screening operations repeated. The office of the alcohol is to act as a cementing agent since it attacks the shellac and forms a binding composition which hardens quickly. The first-fire composition is placed in position by hand and compressed in place by a hand-lever-operated press. The compressed charge fills the case flush with the top.

This operation is shown in figure 101. Figure 107 shows the first fire piled in the case prior to loading and the compressed charge, respectively.

PRIMING COMPOSITION.

The priming composition is a meal-powder quick-burning mixture. Meal powder mixed with gum water sufficient to form a paste constitutes this composition. The gum water is made by adding 2 ounces of gum arabic to 1 quart of boiling water. This priming composition is now painted by hand upon the top of the first-fire composition, as shown in figure 102.

FUSE MATCH.

The object of the fuse or quick match, which is now attached to the priming composition, is to permit a positive and rapid lighting of the priming composition by the expelling charge. The fuse or match for this work is the same as that used for other operations of a similar character. A description of its manufacture is as follows:

FIG. 101.—Loading first fire in case.

Eight-, six-, five, three-, and two-strand matches are all made in much the same manner. In the manufacturer of five ply, shown in the figure, which is used for the aëroplane, flare, strands from five spools of cotton cord are fed through a port at the end of a tub as shown in figure 103.

The strands are carried downward and along the bottom of the tank, and up the opposite end, passing over a roller, and carried back very nearly to their point of entrance where the group of strands is passed through a groove and over a small wooden sheave. A wiping device suspended from the strings swung across the tank consists of a metal tube of a bore sufficient to smooth down and form into proper shape the surface of the match. During this operation a mixture

FIG. 102.—Painting prime on loaded case.

of meal powder, sulphur, charcoal, and starch, made into a thick slurry with water, is introduced into the tank through which the strands pass, thus soaking the cotton with the powder composition, which is as follows:

	Per cent.
Saltpeter	62
Sulphur (flour)	14
Charcoal (powdered)	20.6
Starch	3.4
1 gallon water.	

These are mixed by placing the saltpeter, sulphur, and charcoal together in a tub and thoroughly kneading by hand. The whole is then sifted twice through a 30-mesh screen. Ordinary corn-starch is cooked in water and mixed with the sifted ingredients in the tub until a slurry is formed, whose

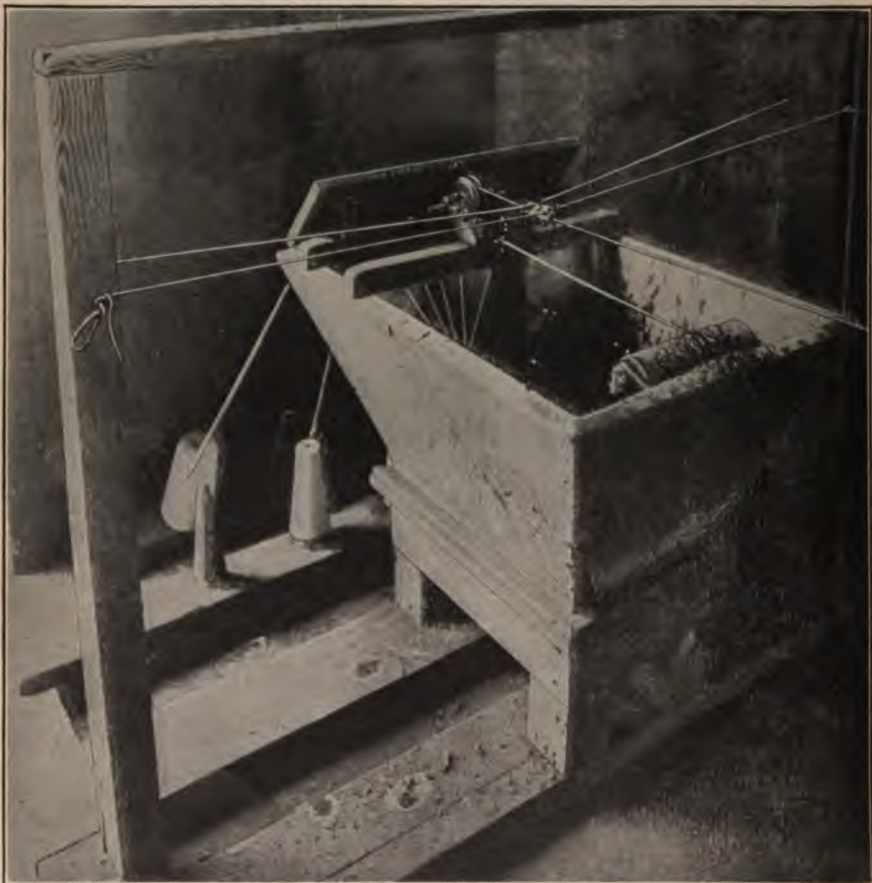


FIG. 103.—Match-making machine.

consistency is such that it is not so thick as to ball up on the strands of the cord as they are passed through and yet thick enough to coat satisfactorily. The match as it is drawn from the dipping or impregnating tank is carried onto a winding frame operated by hand.

This is a simple rack made with suitable grooves at both ends so that the match when fed upon the frame will fall in the several grooves and prevent the contact of one strand with another. The passage of the cotton cord from the spools on their spindles through the dipping tank and onto the

FIG. 104.—Match-holding rack.

frame is done by hand manipulation, the operator slowly rotating and guiding the frame. When the frame is filled the match is cut and attached to the frame, which is then removed from its support and stood up in a drying rack where the match is allowed to dry slowly. The drying may be carried on in the same room as the dipping and winding operation. Twenty-four hours is usually required for drying. The frames before being placed on end for drying are laid in a trough containing dry meal powder which adheres to the wet strands, forming a coating. This makes a quick match out of the otherwise slow match.

MATCH NAIL.

Two pieces of quick match 4 inches long are crossed and secured to the prime on the light case by the match nail.

FIG. 105.—Setting match and match nail.

This nail is an ordinary iron shingle nail and when driven home is covered with a daub of prime, the same prime as is used in coating the first-fire composition.

CASE BOTTOM.

The case bottom is formed by two disks of No. 50 strawboard. These disks are 3⅜ inches in diameter and are perforated in the center with an orifice $1\frac{1}{8}$ inches in diameter. These disks are punched by hand, usually at the factory. This strawboard case bottom is placed over the prime, serving as a means of holding the prime and first fire in place, and it prevents the flaking off of the prime. The case bottom is held in place by means of a drumhead.

FIG. 106.—Assembling case bottom.

DRUMHEAD.

The drumhead consists of a piece of muslin 6 inches square, in the center of which has been cut a round hole $1\frac{1}{8}$ inches in diameter. The square of muslin or drumhead is first given a coat of common starch paste and securely attached to the case in such a manner that the hole in the center of the square registers with the hole in the case bottom through which the matches pass. This drumhead in position is shown as figure 107.

BOTTOM FINISHING BAND.

This consists of a strip of No. 30 Kraft paper 3 inches wide by 18 inches long. The strip is pasted around the end of the case holding the drumhead in place and prevents the tearing off or dislodgment of the muslin laps of the drumhead. This is shown in figure 107.

CONNECTING CABLE.

This connecting cable is a steel wire, one end of which is attached to the strings of the parachute, the other to the staple of the case containing the illuminating material. As this case weighs in the neighborhood of 30 pounds, and as it falls freely before coming to rest, swinging from the para-

FIG. 107.—Successive stages of heading case.

chute, it is necessary that a strong wire be used to hold the case, wire being preferred to rope, as it is not so bulky. This connecting cable is of seven-ply 42-gauge steel wire of six strands, made with a cotton center. These cables are cut in 36-inch lengths. A method in use for testing the strength of the cable and the staple in the head of the illuminating case is shown in figures 108 and 109.

In figure 108 the operator has hooked the cable to an eye which is hung from a stout rope attached to one of the roof girders. The other end of the cable is attached to the staple in the light case. A sack loaded with straw acts as a cushion to break the fall in the event of the snapping of the cable or pulling out of the staple. The case containing the illuminating mixture is allowed to fall a short distance, coming to rest with a clearance of about a foot above the mat.

The latter figure shows the case hanging freely, having withstood the strain and snapping test of the fall.

WAD.

The wad is a felt disk $4\frac{19}{64}$ inches in diameter by $\frac{1}{4}$ inch thick which has been perforated by a port in the center $\frac{7}{8}$ inch in diameter. This disk is riveted between two steel

FIG. 108.—Making strain test.

FIG. 109.—Showing satisfactory strain test.

disks $4\frac{1}{8}$ inches in diameter with a center orifice $\frac{7}{8}$ inch in diameter, which registers with the $\frac{7}{8}$-inch hole in the felt disk. Four $\frac{1}{8}$-inch rivets are used to hold the felt firmly between two steel disks. This wad fits snugly against the inside walls of the shell and serves as a buffer against the flame of the expelling charge. The expelling charge throws the

parachute and case containing the illuminating composition from the shell. Some protection should prevent the flame from reaching to the parachute, which is easily inflammable, and the wad fulfills this function.

FIG. 111.—Parachute rolled.

PARACHUTE.

Figure 110 shows the parachute distended. This picture gives an excellent idea of the size of the parachute and its sustaining power. It measures 18 feet 8 inches in diameter, and is made of a very light Japanese silk. The lightness of the parachute and the compactness with which it may be rolled and folded are shown in the succeeding picture of the parachute rolled compactly into a cylindrical form.

FIG. 112.—Introducing case in shell.

Figure 111 shows on the table a wrapped and bound package. It is in this form that the parachute comes to the pyrotechnic manufacturer. The same picture shows a package which has been opened, the parachute appearing in the form of a roll. The folding or rolling of the parachute has been done with great care by the maker, so that when thrown from the aëroplane shell it will not become tangled and fail to open properly. These rolled packages are left in their original condition and are only unrolled enough to allow their being tied to the cable attached to the light case.

TIE STRING.

In the foregoing picture the operator has drawn the string of the parachute through the eye at the end of the cable, previously referred to and described. The strings, after hav-

FIG. 113.—Inserting parachute in shell.

ing been threaded twice through the eye, are brought together to form a loop and are tied down firmly by means of a tie string. The tie string takes the place of splicing and holds the strings firmly in place.

Figure 112 shows the operator slipping the case containing the illuminating composition into the shell of the aëroplane flare. The staple is clearly seen in the center at the end of the case. To this staple has been attached the connecting cable, to the other end of which is attached a parachute.

Figure 113 shows the operator inserting the parachute into the shell, into which the illuminating case, the cable and wad have already been introduced.

PADDING.

Before putting on the cap of the shell it is desirable, in order to insure firm packing of the contents of the shell, that

FIG. 114.—Inserting protective padding.

the space between the parachute and outer cap should be filled in with some form of padding.

Figure 114 shows the operator forcing in the padding on top of the parachute. The padding used is the wrapper covering of the parachute package, which answers the purpose very well, being about the size necessary to fill the cavity. The

FIG. 115.—Capping cylinder.

cylinder is capped and crimped at four points, as shown in figure 115.

FIRING MECHANISM.

The firing mechanism is essentially a firing pin and detonating cap. The parts in detail are described as follows:

PROPELLER AND SHAFT.

The accompanying figure 116 shows a firing mechanism consisting of a brass shaft to the end of which is attached a stamped-steel propeller in the shape of a pin wheel. The

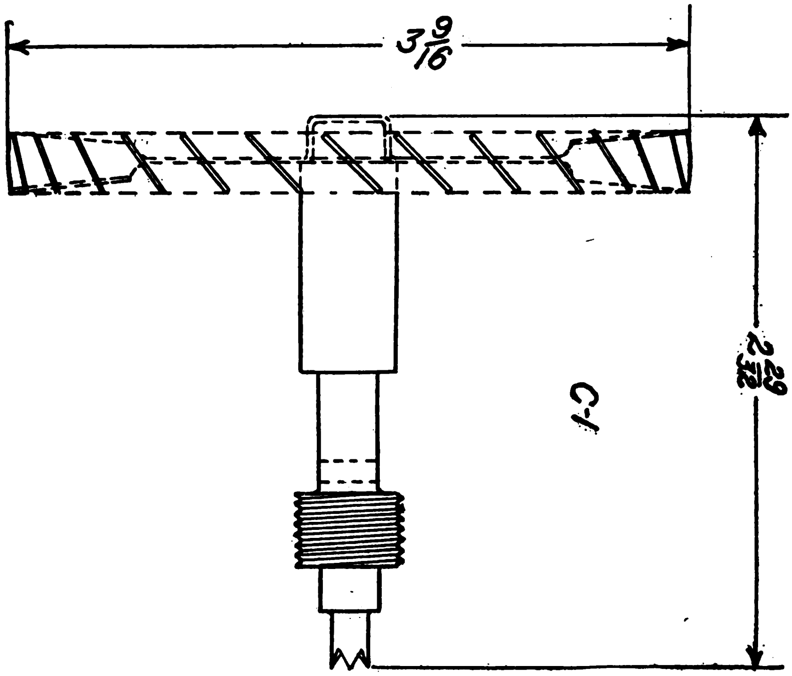


FIG. 116.—Igniting mechanism; propeller and shaft.

forward end of the shaft terminates in a four-prong firing pin. The shaft is shouldered and threaded for a distance of ⅜ of an inch, having a pitch of 24 threads to the inch. The threads of the shaft engage corresponding threads cut for a distance of $1\frac{3}{16}$ inches in the inner surface of the cylindrical brass barrel in which this shaft rotates. The shaft is guided by means of the engagement of these threads in such a manner that the rotating of the pin wheel requires a certain definite period of time for the shaft to move forward through the barrel. The threads in the barrel are of such a number and occupy such a length that they permit a positive forward movement of the shaft to a position $\frac{3}{16}$ of an inch from the detonating cap. When this point is reached the threads disengage, allowing the shaft to be forcibly plunged forward, and causing the firing pin to come in contact with the detonating cap.

Referring to figure 117, the propeller is shown with its area of flat surface against which the force of the air due to the downward motion of the aëroplane flare exerts a pressure that aids in causing the shaft to be driven in the manner described.

FIG. 117.—Igniter-mechanism parts.

On the shank of the propeller shaft, shown in figure 118, appear two milled flat surfaces that serve to accommodate a safety fork, which is part of the mechanism of the aviator's releasing control. This serves as a means of preventing the propeller from turning until it has been released from the aëroplane. In this regard the cotter pin seen in figure 117 prevents such rotation during shipment and handling, and this pin must be removed when the flare is attached to the aëroplane in order to permit functioning.

BARREL.

Figure 119 shows the brass barrel in which the shaft is driven by the propeller. The outer threads fit the tapped opening in the nose of the aëroplane shell as shown in figure

85 and are cut six threads per inch for a distance of $\frac{1}{2}$ inch. The inner thread (24 threads per inch) extends for $1\frac{3}{16}$ inches. These threads register with the corresponding

FIG. 118.—Igniter mechanism assembled.

threads on the shaft, and as already described become the timing mechanism. The forward movement of the shaft driven by the rotation of the propeller is thus made positive by the traverse of these fine threads.

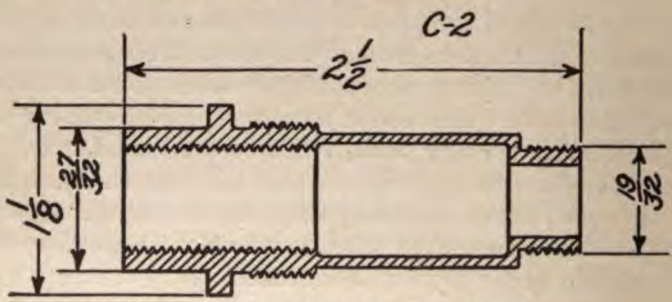


FIG. 119.—Dimensional drawing of barrel.

A dimensional cut of the brass detonating cap is given in figure 120. There is a $\frac{1}{16}$ of an inch hole in the center, making a connection with the expelling-charge chamber. The cap is held in place between barrel and expelling-charge container. Care must be exercised to see that the container is tightened sufficiently to hold this cap so that it will not loosen.

DETONATING CAP.

The cap is designed to fit into the forward end of the barrel, the shoulder of the cap resting against the top of the barrel. In this position the cap projects $\frac{5}{32}$ of an inch into

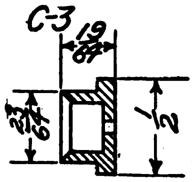


FIG. 120.—Dimensional drawing of detonating cap.

the barrel. The detonating mixture is carried in the recess of the cap, which is ¼ of an inch deep by ¼ of an inch in diameter.

DETONATING-CAP COMPOSITION.

The composition consists of—

	Per cent.
Potassium chlorate	50
Antimony sulphide	25
Red phosphorus	6
Gum arabic	13
Powdered glass	6

This formula is not strictly adhered to, but is variable according to the sensitiveness desired.

The storage of the detonating caps is very important. They must be stored in a separate building located at a distance from the plant. Such a building is shown in figure 121. The caps are placed on small wooden trays, holes being bored to accommodate 28 caps, so that each cap is separated from the others. Figure 122 shows the method in use.

Tests are made of each lot of detonating caps, in order to determine the sensitiveness of the composition, which is subject to variation due to changes in the quality of the ingredients, atmospheric conditions, etc. The apparatus shown in figure 123 is used for this purpose. It consists of a 3-foot length of 2-inch pipe, flanged to a floor plate and perforated with six ¾-inch holes and terminating in a plate drilled and tapped to fit the outer thread of the igniter barrel. A testing detonating mechanism, shown on the table in the figure, is used, and is a standard outfit, save that the barrel is perforated to allow the free exit of the gases from the exploded cap. The operation of testing consists in as-

FIG. 121.—Exterior view of detonating-cap storage shed.

sembling a cap to be tested in the igniter mechanism and screwing the latter into the pipe stand. The pin wheel is then rotated by compressed air, and as the shaft is fed into the barrel, by the rotation of the wheel, the cap should be fired, resulting in a subdued explosion.

The general manipulation of loading composition into brass container is as follows:

A light paper cover is pasted on the flat surface opposite to the opening that receives the composition. The composition is in a plastic semifluid state and when loaded into the container is set aside in a hot room to dry, great care being taken to avoid friction after drying.

FIG. 122.—Interior view of detonating-cap storage shed.

DETONATING-CAP COVER.

This consists simply of a piece of tissue paper 3/8-inch outside diameter, which is pasted on the detonating cap to cover the hole in the center.

FIG. 123.—Apparatus for testing detonating caps.

EXPELLING-CHARGE HOLDER.

The expelling-charge holder is of brass, with inside thread to fit over the end of the barrel of the firing mechanism, with four small prongs on the opposite end, used to bend over and secure the returning wad. The $\frac{3}{16}$-inch hole through the base of the holder registers with the $\frac{1}{16}$-inch hole through the detonating cap when assembled and allows the firing of the charge by detonation. A dimensional cut is shown in figure 124 and an illustration of this part is seen in figure 125.

EXPELLING CHARGE.

The expelling charge consists of 70 grains 5F grain gunpowder, completely filling the expelling-charge holder. Figure 125 shows the operation of hand-loading expelling charge into its container. Prior to filling the charge into the container a light disk of ordinary Kraft paper is placed in the bottom of the charge holder. This paper prevents the

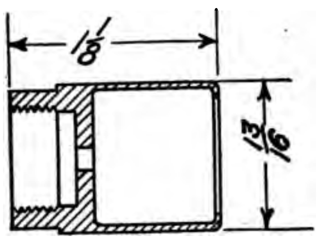


FIG. 124.—Dimensional drawing of expelling-charge holder.

powder from sifting through the central orifice. After the powder charge has been rammed home and covered by the wad the paper disk is perforated by inserting a wire nail through the hole, the tip of the nail being wet with prime. The prime serves a dual purpose, first to close the hole just made, second to provide a first fire for the expelling charge. The figure shows the operator in the background engaged in this performance.

WAD.

This wad, which is of thin cardboard, $\frac{23}{32}$ of an inch outside diameter, is placed on top of the powder charge and is held in place by bending over the four light prongs on the end of the charge container. This is done by pounding the prongs in place by means of a hand mallet and former.

SAFETY PIN.

This is an ordinary cotter pin $\frac{3}{32}$ of an inch diameter and serves a twofold purpose: one to prevent the accidental driv-

FIG. 125.—Loading expelling charge.

ing of the firing pin on to the detonating cap, and the other to register correctly the forward movement of the driving pin, so that at no time prior to preparing the mechanism for functioning shall the driving pin have traversed any part of its journey forward through the barrel.

DETONATING-CAP PACKING TUBE.

The detonating cap is placed in the packing tube and tightly packed in place with cotton wadding so as to thoroughly protect it. After the cap is packed the tube is wrapped in a paper wrapper.

FIG. 126.—Packing detonating cap.

DETONATING-CAP PACKING-TUBE WRAPPER.

This consists of a paper wrapper, 4 by 6 inches, of 30-pound Kraft stock. Before encircling the packing tube with this wrapper, which is pasted on, a string is placed across the packing tube with the end of the cord protruding to facilitate unwrapping.

TIE CORD.

The entire package is then waterproofed, being dipped in melted parafin and attached to the shaft of the firing mechanism by means of the tie cord. This cord is an ordinary piece of hemp twine about 12 inches long, with two

FIG. 127.—Attaching wrapped detonating cap.

turns around the package. This operation is shown in figure 127.

BOXING.

The flares are packed two in a tin-lined box and are held firmly by collars made from ⅞-inch pine board formed by cutting a ½-inch circle, the same size as the outside of the case, which fits snugly around the case against the carrying bands, one on each end. The collars are bolted firmly together by the aid of cleats extending the full height of the completed box. These cletes aid in holding the flares apart. A bolt ¼ by 2¾ inches is used. Blocks ¾ inch thick and the

FIG. 128.—Boxing completed aëroplane flares.

full depth of the box are used at each end, holding the flares firmly in position. A tin lid with a hand-hold attachment is soldered on with soft solder. The wood lid is nailed on very firmly.

AEROPLANE FLARE FLOW SHEET

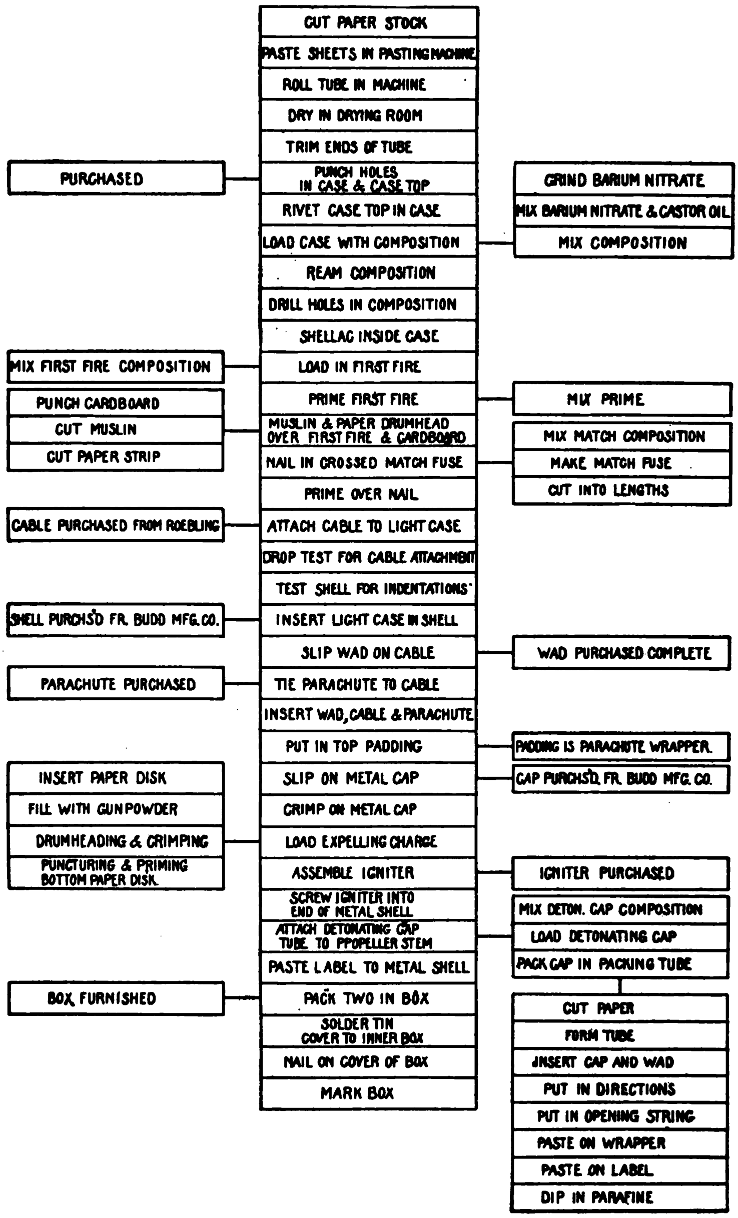


PLATE 6.

AEROPLANE FLARE MATERIAL CHART

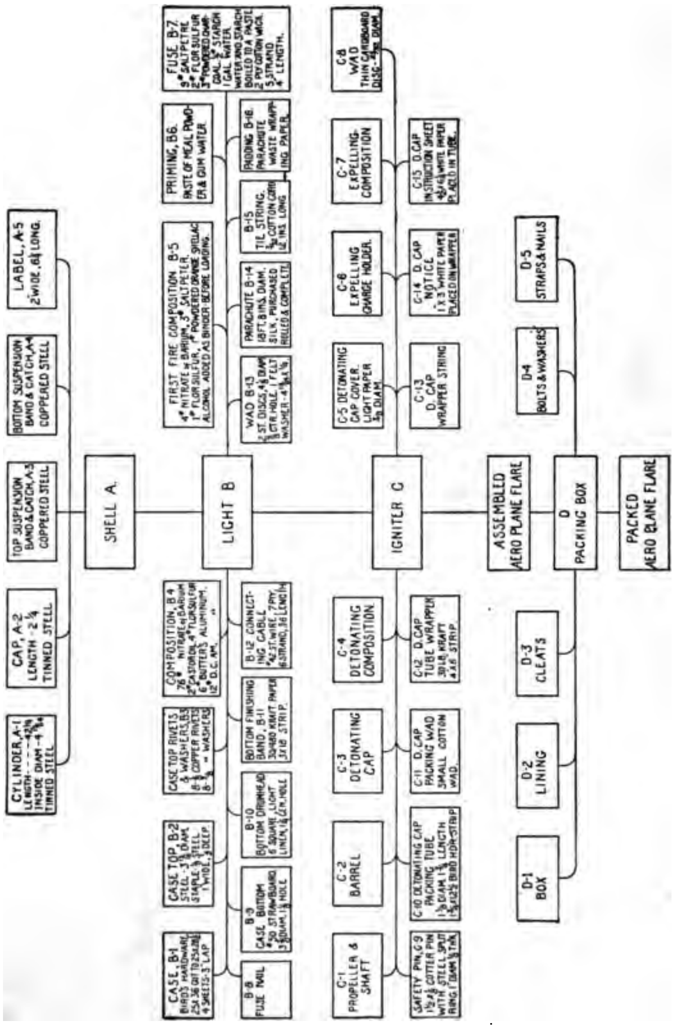


PLATE 7.

CHAPTER III.

PARACHUTE RIFLE LIGHT.

The rifle light is a pyrotechnic device developed during the World War. The rifle light performs a dual function. It is used for lighting purposes, when the illuminating device is swung from a small parachute projected into the air, or it is used for signaling in which case a parachute may or may not be used. If used for illumination, white or colored lights are suspended from a parachute; and if used for signaling, small briquettes of composition are used which will burn with a brilliant light and produce a meteor effect. By reason of the fact that the rifle light is more scientifically designed and by reason of its size, approximately 6⅝ inches long and 1¾ inches in diameter, it is capable of quantity production, an important feature, which has resulted in the standardizing of the compositions used and the methods of manufacture to such an extent that the rifle light is a rather well-developed pyrotechnic device. When the light is used for signaling purposes it is usually fired to a height of 500 feet. When used for illuminating purposes a lower altitude is attained. The rifle light is fired from a mortar or discharger, which device is attached to the muzzle of a rifle barrel. The light is shot out by means of the explosion of a blank cartridge in the rifle barrel. The special mortarlike fitting is portable and may be attached to any standard type of rifle barrel. Due to the rather high recoil, it is not usual

FIG. 129.—Parachute rifle light.

to hold the butt of the rifle against the body at the time of discharge, the butt being placed upon the ground and the desired angle obtained which will project the light either for signaling or for illuminating purposes. The explosion of the blank cartridge in the rifle barrel causes the expulsion of the

FIG. 130.—Rifle-light discharger.

light from the mortar and at the same time detonates a sensitive cap. The cap in turn ignites a time fuse in the light, and the fuse is regulated to fire the expelling charge which subsequently lights the illuminating or signal composition.

Figure 130 shows the rifle-light attachment and at the attachment in place on the rifle barrel.

The picture shows very clearly the method of making this attachment, which is not unlike the fixing of a bayonet to the

FIG. 131.—Placing rifle light in discharger.

rifle barrel. In the same picture is shown the rifle light, and a light after having been inserted into the fixture. The operation of firing is shown in figures 131 and 132.

Figure 131 shows an officer slipping the rifle light into the fixture.

FIG. 132.—Firing rifle light.

Figure 132 shows the position in which the rifle is held at the time of discharge.

RIFLE LIGHT WITH PARACHUTE.

Figure 133 shows an exposed longitudinal section of the rifle light with parachute.

FIG. 133.—Sectional view of parachute rifle light.

PARACHUTE RIFLE LIGHT.

1. Shell.
2. Wood plug.
3. Shell nail.
4. Time fuse.
5. Prime.
6. Detonating-cap plate.
7. Detonating cap.
8. Protecting disk.
9. Protecting-disk nail.
10. Expelling-charge holder.
11. Expelling charge.
12. Expelling-charge, muslin cover.
13. Expelling-charge, muslin prime.
14. Light case.
15. Bottom disk.
16. Bottom band.
17. Outer disk.
18. First-fire composition.
19. Light composition.
20. Quick match.
21. Quick-match prime.
22. Top disk.
23. Top-finishing band.
24. Tie cord.
25. Wad.
26. Asbestos cord.
27. Parchute.
28. Packing wad.
29. Cork cap.
30. Identification cap.
31. Blank cartridge.
32. Protecting band for cartridge.
33. Cartridge tape.
34. Directions label.
35. Packing carton.
36. Tearing cord.
37. Directions label.
38. Shipping carton.
39. Identification label.

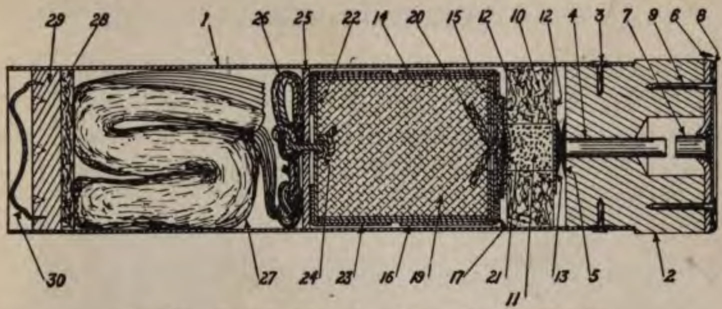


FIG. 135.—Sectional drawing of parachute rifle light.

Figure 134 shows the parachute with an illuminating star attached, suspended in the air.

FIG. 134.—Parachute functioning.

SHELL OR TUBE.

The shell consists of a tinned tube with lapped seams of an inside diameter of $1\frac{3}{4}$ inches and length of $5\frac{5}{8}$ inches. The shells are purchased from a tube manufacturer, and are shipped cut to length ready for assembly.

WOOD PLUG.

The wood plug which fits into the lower end of the shell is made of hardwood. It is $1\frac{1}{2}$ inches long, having a diameter of $1\frac{3}{4}$ inches for one-half of its length, the balance shouldered having an increased diameter of $1\frac{7}{8}$ inches. A $\frac{3}{16}$-inch hole is drilled through the center, in order to accommodate a time fuse, and a $\frac{5}{8}$-inch hole is drilled in the large end to accommodate the detonating cap. This plug is manufactured and shipped to the plant ready for assembly.

FIG. 136.—Rifle-light shell and plug.

Figure 136 shows the shell and wood plug. The plug is fitted into the shell and secured to it by four nails $\frac{3}{8}$ inch long, which are driven through the shell at a distance $\frac{3}{8}$ inch from the bottom of the tube. This operation is performed by a specially designed machine, the shell being turned by hand through an arc of 90° and a nail driven in at the conclusion of each turn.

PAINTING OF CASE.

The shell and wood plug forming the case are painted on the outside by means of an air brush. The air brush consists of a spray-atomizing machine not unlike a "whitewash gun."

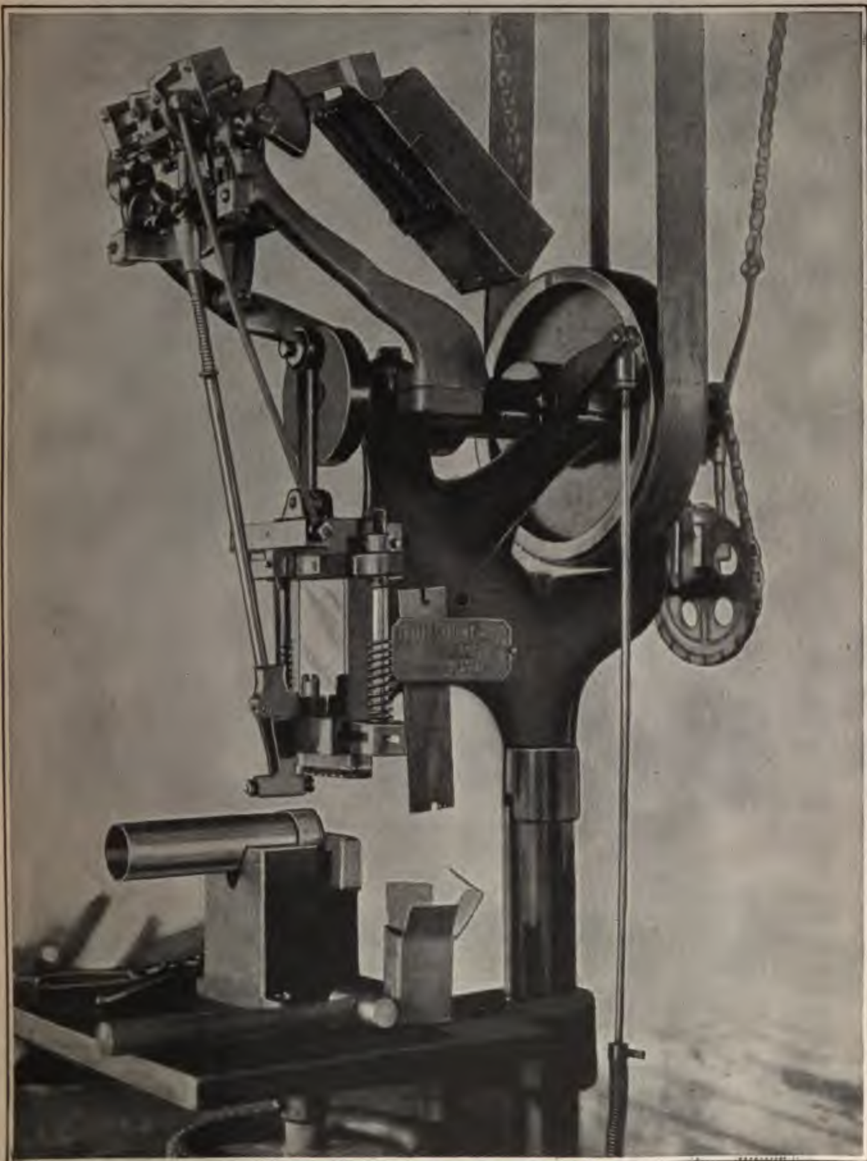


FIG. 137.—Machine used for nailing plug to shell.

Figure 138 shows a battery of shells which revolve on spindles, the whole being covered by a hood equipped with an exhaust fan. The operator atomizes the paint, directing the flow against the walls of the tubes, and rapidly gives them a light coating.

FIG. 138.—Shell-painting machine.

TIME FUSE.

The time fuse is a tubular fuse purchased from the standard manufacturers, $\frac{3}{16}$ of an inch in diameter by $1\frac{1}{4}$ inches long. This fuse is forced through the $\frac{3}{16}$-inch hole drilled into the wood plug and is pushed up until the end protrudes into the $\frac{5}{8}$-inch hole in the lower part of the plug. The fuse is now cut off flush with the top of the plug. This time fuse is necessary in order to delay the ignition of the prime and expelling charge until the light has reached the desired altitude.

PRIME.

This is a meal-powder and gum-water prime of similar specifications to those mentioned in preceding chapters. A blob of prime is placed over the end of the fuse which has been cut even with the top of the wood plug.

DETONATING-CAP PLATE.

This consists of a steel disk 1⅞ inches diameter of 16 metal gauge. There is a hole drawn in the center to hold the detonating cap, the head of which lies in the depression in such a manner that its surface is just beneath the top of the plate.

DETONATING CAP.

Before placing the protecting disk on top of the detonating-cap plate and attaching the whole firmly to the wood plug, a detonating cap is set in place, the head of the cap taking the position described above. These caps are 22 caliber rim-fire cartridge, loaded with a standard detonating mixture.

PROTECTING DISK.

The protecting disk is cut from 24-gauge tin sheet and is 1⅞ inches in diameter. This disk fits over the detonating-cap plate and is held in place by four small nails, which are driven through the protecting disk and detonating-cap plate into the bottom of the wood plug.

Figure 139 shows the machine used for driving home these nails. The protecting disk is placed over the detonating-cap plate for the purpose of preventing sparks or flames from issuing through the hole in the wood plug occupied by the time fuse, and thus showing the course taken by the rifle light during its flight.

Figure 140 shows first the plug on the extreme right with the fuse ready to be inserted in the hole in the center. Next to it on the left is the plug with the fuse cut off level with the top, then the plug with a blob of prime covering the end of the time fuse. The last two plugs show the detonating-cap plate and the protecting disk ready to be nailed together on

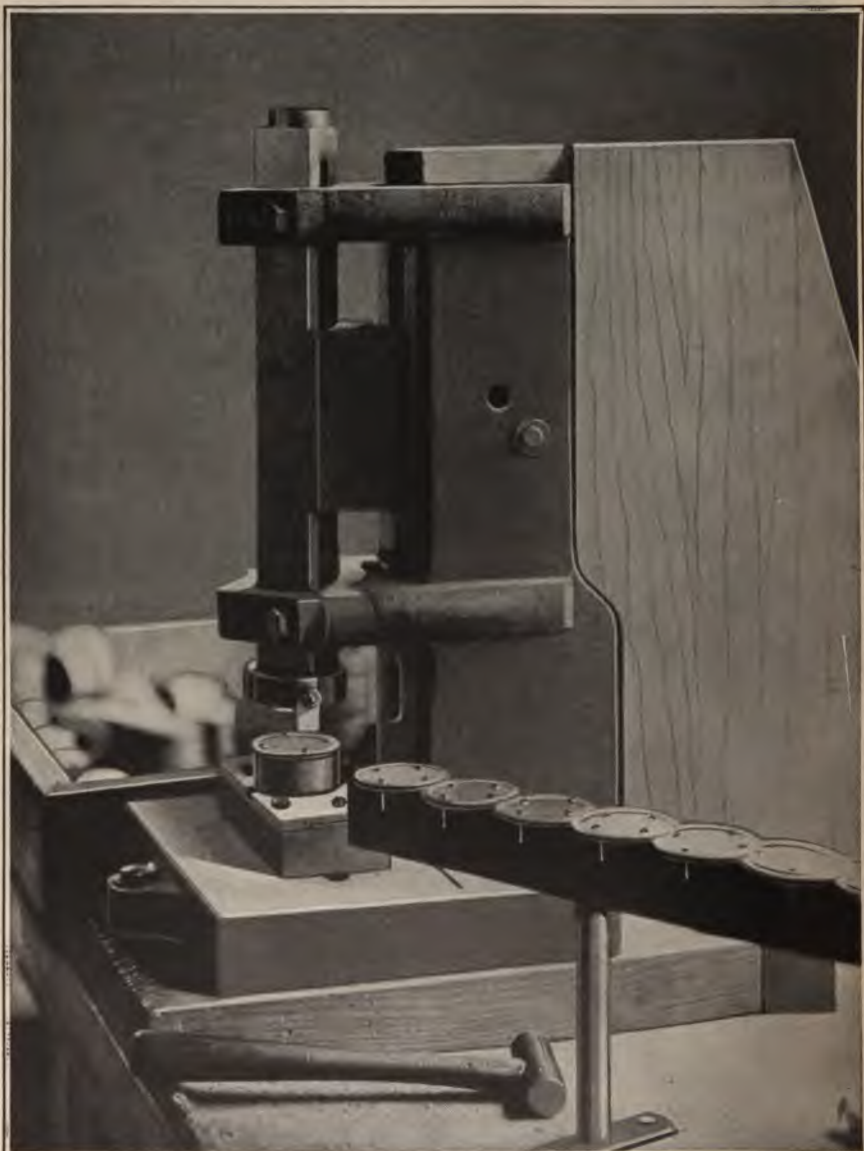


FIG. 139.—Machine nailing plates to plugs.

the plug. In the foreground on the left is shown the detonating cap set in position; to the right the protecting disk.

FIG. 140.—Details of plug and igniter.

EXPELLING-CHARGE HOLDER.

This consists of a felt disk 1¾ inches diameter by ½ inch thick, which has a half-inch hole in the center and a cotton disk glued to the bottom.

Figure 141 shows the expelling-charge holder on the right, in the center the loaded holder covered with a disk of cotton, and on the left the holder with the cotton disk painted with a daub of prime.

FIG. 140.—Details of plug and igniter.

EXPELLING-CHARGE COMPOSITION.

The expelling-charge holder is loaded with 5F gunpowder, which fills the hole in the felt disk. In order to hold the charge of powder in place muslin disks are pasted on each side of the felt washer. One of these has a daub of prime in the center. When assembled this disk abutts the wood plug and the primed time fuse.

LIGHT.

CASE.

This is a carton, formed from a single sheet of two-ply Bird's hardward paper, cut 12 by 20 inches. It is rolled in a cylindrical form on a mandrel to a diameter of 1½ inches, and a length of 12 inches. It is then cut in 2-inch lengths, the carton or light case being 1½ inches in diameter and 2 inches long.

BOTTOM DISK.

This is composed of two thicknesses of hardware paper, 1⅝ inches in diameter, through the center of which is punched a hole ½ inch in diameter. This disk is glued in place and serves as a bottom to hold the light composition in the case.

FIG. 142.—Light case and cable.

BOTTOM BAND.

Muslin cut in strips 8 inches long by 1½ inches wide encircles the case with ½ inch projecting. The projecting part is pasted over the bottom disk, holding it securely in place.

Figure 142 shows the bottom band attached to the case.

OUTER DISK.

A piece of 30-pound Kraft paper is cut circular in form 1⅝ inches in diameter. It is pasted over the bottom disk and edge of the muslin band, completely covering the hole in the bottom disk.

FIRST-FIRE COMPOSITION.

This composition consists of—

	Per cent.
Saltpeter	54.5
Sulphur	36.4
Charcoal	9.1

It is mixed by weighing 6 pounds of saltpeter, 4 pounds of sulphur, and 1 pound of charcoal, and screening each ingredient separately through a 24-mesh sieve into a tub. The ingredients are mixed thoroughly by hand, then screened through a 16-mesh sieve. The amount used per light is about 10 per cent. of the total weight of the composition. This first-fire composition is pressed into the light case or carton until it occupies a space equivalent to approximately $\frac{1}{10}$ of the volume of the case.

LIGHT COMPOSITION.

There may be either a white, green, or red light composition loaded into the case, depending upon the particular color desired. These compositions will be taken up separately and discussed.

WHITE-LIGHT COMPOSITION.

This is a mixture of—

	Per cent.
Barium nitrate	70.6
Powdered aluminum	19.6
Flake aluminum	9.8

A batch consists of first 18 pounds of barium nitrate screened through a 24-mesh sieve into a fiber tub. Then 5 pounds of powdered aluminum and 2½ pounds of flake aluminum are passed through a 24-mesh sieve into the same tub and all are thoroughly mixed by hand and then screened through a 24-mesh sieve. One pint of ordinary gum water is then added, mixed, and the whole is rubbed and screened twice through a 12-mesh sieve. The case is first charged with first-fire composition and then the light composition is loaded into the case by hand with mallet and tamping tools in four separate charges so that the final compressed charge is even with the top of the case. It is allowed to dry for 24 hours before being assembled in the shell. The quantity and character of the composition are designed to burn for 30 seconds.

FIG. 143.—Method of mixing composition by hand.

GREEN-LIGHT COMPOSITION.

This is a barium-chlorate and shellac mixture made up in the proportions of 90 per cent. barium chlorate and 10 per cent. orange shellac. It is a very simple mixture to make up and is effectively mixed by one or two screenings through a

24.-mesh sieve. The quantity of this composition is designed to burn 30 seconds.

RED-LIGHT COMPOSITION.

This is composed of—

	Per cent.
Potassium chlorate	72.7
Strontium carbonate	15.2
Orange shellac	12.1

It is made up in batches by mixing 75 pounds of potassium chlorate with 15 pounds of strontium carbonate and 12 pounds of orange shellac. The constituents of this composition are compounded in a similar manner to the compositions described above. The usual practice, in order to insure uniformity and a homogeneous mixture, is to screen twice through a 12-mesh sieve. It will be noted that a gum mixture is used to act as a binder in compounding the white-light composition. In compounding the green-light composition and the red-light composition, powdered orange shellac is used, but no gum water.

The shellac performs two functions: one, supplying the means for a high temperature of combustion to the composition; the other, acting as a binder, due to the slightly tacky character of the powdered shellac which holds the mass together when pressed into the carton. This composition is designed to burn between 30 and 35 seconds.

QUICK MATCH.

This is comprised of two pieces of two-ply match 1½ inches long. Each piece is inserted through a separate hole in the bottom disk so as to cross and leave 1 inch of the match exposed outside of the case. The junction of the matches is primed with a small quantity of prime. Figure 145 shows the quick match placed in position and Figure 146 shows it sealed by means of the prime.

TOP DISK.

This consists of a black hardware-paper disk 1⅝ inches in diameter through which a tie cord passes. The tie cord is held to the top disk by being knotted on the inner side of the disk.

TOP FINISHING BAND.

This is a paper strip 1½ by 6 inches, of 20-pound Kraft paper, pasted around the case and over the edge of the top disk to hold the disk firmly in place.

FIG. 144.—Hand loading of light case.

TIE CORD.

This tie cord is used to attach the strings of the parachute to the light case and is of cotton $\frac{1}{16}$ of an inch in diameter and 24 inches long.

WAD.

The wad, which is used to prevent the flame of the expelling charge from burning the parachute and parachute strings, is made of 50-pound strawboard, cut 1¾ inches in

FIG. 145.—Position of quick match on light case.

diameter, with a central hole large enough to permit the threading of the tie cord through it. The string is then knotted to prevent the wad from riding.

FIG. 146.—Quick match sealed with prime.

ASBESTOS CORD.

In order to prevent the flame of the expelling charge from burning the cord which holds the light suspended from the parachute, an asbestos cord is used as an auxiliary. This is tied firmly to the cord and spans the distance between the wad and the point at which the strings of the parachute are attached. The length of this cord is shown in figure 147.

FIG. 147.—Asbestos cord and protecting wad.

This figure shows also the parachute folded on the table ready to be inserted in the case.

PARACHUTE.

The parachute is made of light, tough Japanese paper. The thickness of the paper is not unlike that of the rice paper used for cigarettes. The parachute is composed of seven sectors, the length of a sector being 16 inches with an arc approximately 12 inches. These sectors are sewn together with a fine cotton or fiber thread. The parachute strings are tied to the ends of the seam. When completely assembled the parachute has a form not unlike that of an open umbrella; often with an inverted cone at the center, due to the drawing forward of the central parachute strings which are attached to the apex of the parachute. There are eight parachute strings, seven of them extending from the seams where the sectors are sewn together and the eighth being attached to the center or focus of these seams. The strings are knotted

FIG. 148.—Introduction of light into shell.

together at a distance permitting the free opening of the parachute.

Figure 134 shows a parachute which has opened and is functioning properly, having been expelled from its case.

It is obvious that careful and delicate manipulation in packing is necessary in order to insure the opening of the parachute in a proper manner so that the strings will not become entangled, thus preventing the proper functioning of the article. There is no standard method of folding the parachute, each manufacturer following his own plan, which ac-

FIG. 149.—Plaiting folds of parachute.

cording to his experience has given the best result. There is, however, a general procedure which is shown in figures 149 and 150.

First the parachute is inspected for imperfections. This is done by the operator's drawing the parachute quickly through the air by means of the strings, thus inflating it and giving it a test. The perfect parachutes are then rubbed thoroughly inside and out with pulverized pumice stone.

This is necessary in order that the parachute shall open smoothly when expelled from the container.

The next operation is to tie the parachute strings to the asbestos cord. The operator before tying the strings again

FIG. 150.—Folded parachuate.

inspects the parachute in a manner similar to that which has been described above. The asbestos cord is now tied to the parachute strings by simple knots. The parachute is then ready for folding and the operator doing this work again inspects it in the same manner as above.

The operator holds a parachute at its apex, and first runs his fingers as a comb downward through the strings to see that they are not entangled. The seams of the various segments are drawn and accordeon plaited, very much in the manner of an umbrella folded before being rolled.

The parachute is encircled by the hand and the folds smoothed down into a cylindrical form and then folded double. The strings are now caught up and coiled around three fingers of the hand and the coil is placed against the side of the folded parachute. After the strings have been carefully arranged the bundle is again folded over the strings, making a compact package, which is shown in figure 150, ready to be inserted into the case.

CORK CAP.

This is a compressed cork disk 1¾ inches in diameter by ⅜ inch thick, which is forced into the top of the shell to hold the contents in place.

FIG. 151.—Cork cap.

IDENTIFICATION CAP.

This is a stamped-tin disk with several prongs which are forced into the cork cap after it has been inserted into the

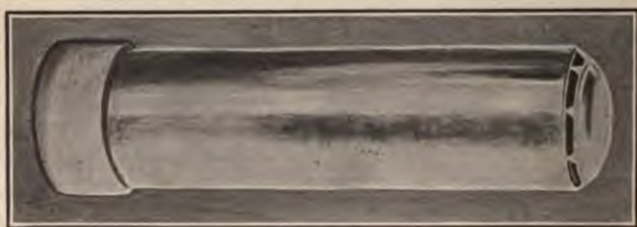


FIG. 152.—Identification cap assembled.

container. This disk is shaped and painted to designate the color of the light as follows:

Indented indicates white; smooth crown shape, green, and corrugated, red.

BLANK CARTRIDGE.

The blank cartridge used for the rifle light consists of the ordinary 30-caliber supplied with a reduced charge. Each rifle light has a blank cartridge attached to its side, so that men in the field do not have to be supplied with a special cartridge in order to fire the rifle lights. Figure 129 shows the arrangement of cartridge banded to the side of the rifle light.

PROTECTING BAND FOR CARTRIDGE.

This consists of a 1¼- by 1¾-inch strip of 30-pound Kraft paper, which encircles the cartridge to protect it from becoming gummed up with the adhesive tape used to bind it to the rifle light.

CARTRIDGE TAPE.

This consists of ½-inch-wide electrician's adhesive tape, 8 inches long, and serves to hold the cartridge to the light-case shell.

PACKING CARTON.

Rifle lights are packed in cardboard cartons, six lights per carton. Figure 153 shows the method of packing the carton. These cartons when filled are sealed with gum paper and dipped in molten low-grade paraffin. Five cartons are dipped per charge.

SHIPPING CARTON.

The packing cartons are then packed in a shipping carton, measuring 6 by 6¾ by 23 inches and carrying five packing cartons, it, too, being sealed with gum paper and dipped in molten crude paraffin.

FIG. 153.—Packing carton and designating caps.

PARACHUTE RIFLE LIGHT FLOW SHEET

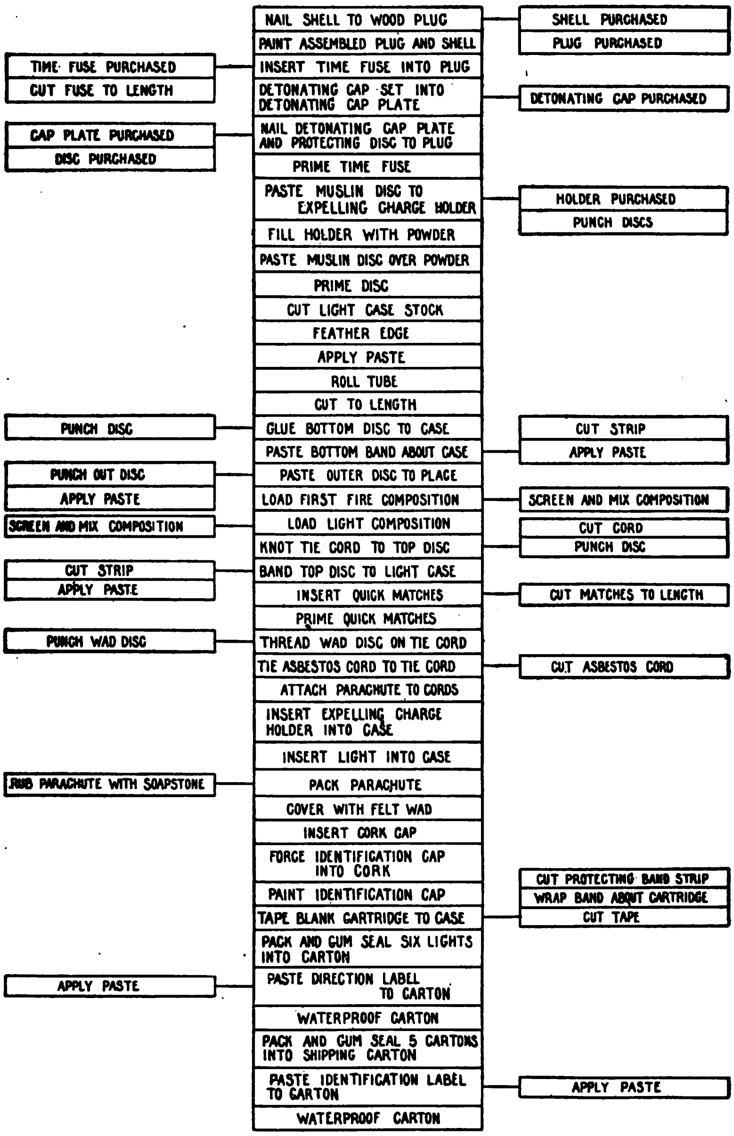


PLATE 8.—Parachute-rifle-light flow sheet.

PARACHUTE RIFLE LIGHT MATERIAL CHART

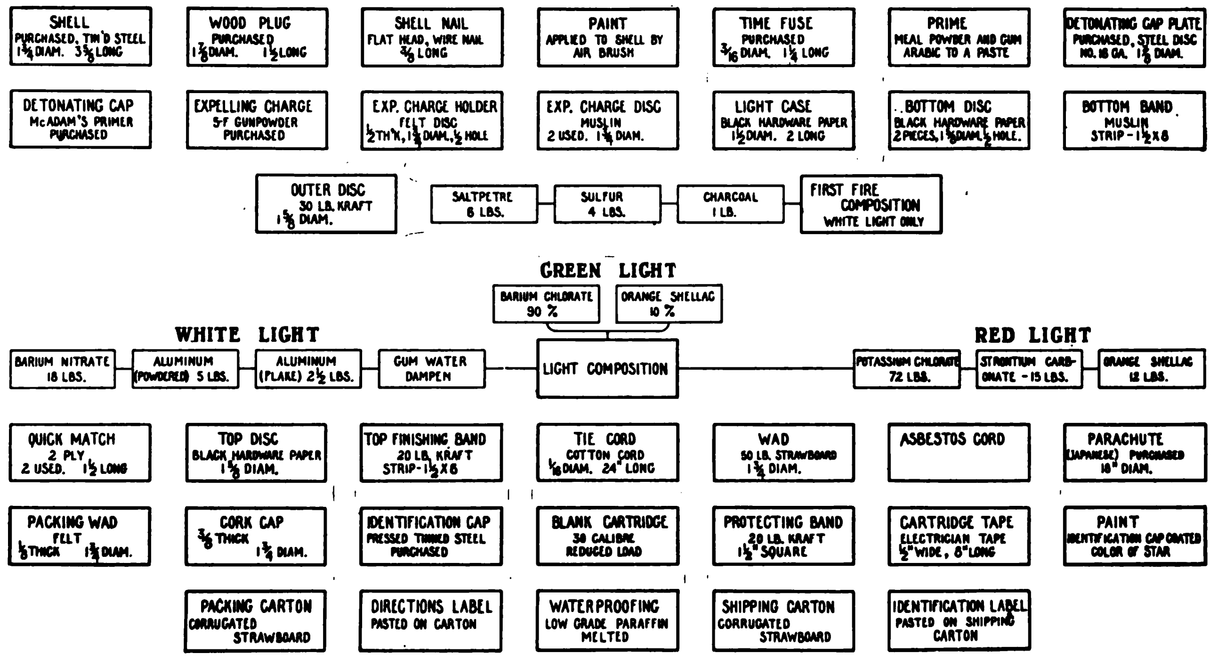


PLATE 9.—Parachute-rifle-light material chart.

FIG. 154.—Star rifle light.

CHAPTER IV.

STAR RIFLE LIGHT WITHOUT PARACHUTE.

This is a pyrotechnic article very similar to the rifle light with parachute. It has attained much popularity by reason of the fact that its efficiency in functioning is very high. Also, its ease of transportation, convenience in firing, and large production in manufacture make this one of the most valued in use.

Figure 155 shows a six-star rifle light with case partially removed. The star rifle light is very similar to the parachute rifle light, differing mainly in that there is no parachute to hold the lights suspended in the air when burning.

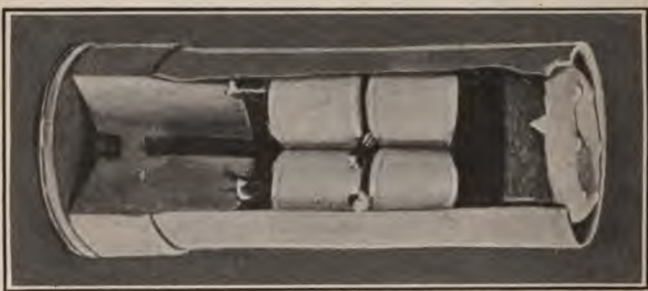


FIG. 155.—Sectional view of six-star rifle light.

The figure shows the arrangement of stars in the case. Two of the six occupy positions immediately adjacent to and behind the two rows of stars shown in the picture. Again, the star rifle light differs from the parachute rifle light, in that the stars are not connected one to another, and when expelled from the case take their own direction. Consequently a chain of stars in the form of a caterpillar, where the stars are connected, is not used in this type of light.

The rifle-light star is fired from the rifle in a similar manner to that of the parachute rifle light. An expelling charge after the light has reached the desired height blows the stars out of the container, lighting them at the same time. These stars travel through the air much in the manner of meteors,

FIG. 156.—Sectional view of three-star rifle light.

and during their flight flame brilliantly. They can be readily seen at a distance, as they burn with intense light for a period ranging from 6 to 10 seconds, depending upon the number of stars. The star rifle light measures 1¾ inches in diameter. The stars are made with white, green, or red compositions. Consequently a variety of signals is possible with the use of this type of pyrotechnic article.

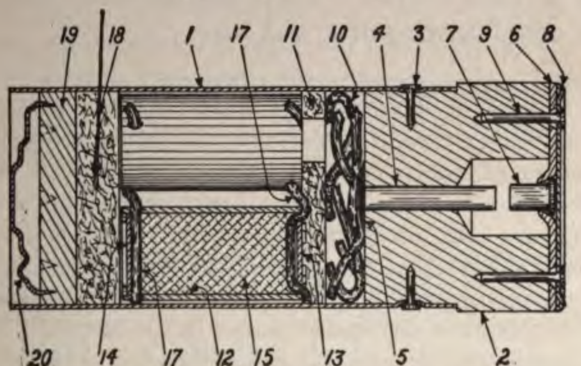


FIG. 157.—Sectional drawing of three-star rifle light.

STAR RIFLE LIGHT.

1. Shell.
2. Wood plug.
3. Shell nail.
4. Time fuse.
5. Prime.
6. Detonating-cap plate.
7. Detonating cap.
8. Protecting disk.
9. Protecting disk.
10. Expelling charge.
11. Expelling disk.
12. Light case.
13. Bottom disk.
14. Top disk.
15. Light composition.

*16. Wet prime.
17. Quick match.
18. Packing wad.
19. Cork cap.
20. Identification cap.
*21. Blank cartridge.
*22. Protecting band for cartridge.
*23. Cartridge tape.
*24. Directions label.
*25. Packing carton.
*26. Tearing cord.
*27. Directions label.
*28. Shipping carton.
*29. Identification label.

THE SHELL.

The shell for the star rifle light is a tin cylinder with a soldered lap seam 1¾ inches in diameter by 3⅝ inches long. The size of the shell is unchanged whether a one-, three-, or six-star signal is assembled. Several of the parts are identical with those used in the parachute rifle light described in the previous chapter. These are the wood plug, detonating cap, protecting disk, and fuse.

EXPELLING CHARGE.

The expelling charge in the star rifle light, irrespective of the number of stars, consists of ten one-inch quick matches, placed in the bottom of the shell and resting on the wood plug. The quick match used is similar to that previously described. Through the center of the wood plug, as shown in the description of the parachute rifle light, is a time fuse which functions in the same manner in the star rifle light as in the parachute rifle light. Since the star rifle light does not require so heavy an expelling charge as the parachute rifle light, the quick matches supply the necessary power to drive the signal out of the case when the latter has reached the desired height, and also supply a flame which readily ignites the fuse attached to each of the lights.

* Not shown.

EXPELLING DISK.

In the one- and three-star rifle light the expelling disk is made of cotton felt 1/8 inch thick and 1 3/4 inches in diameter. This disk rests upon the quick match. It is upon this disk that the stars rest, the disk being forcibly expelled by means of the explosion of the matches, thus expelling the lights from the shell. In order that there may be a free access of the flame from the burning matches into the compartment occupied by the lights, thus causing ignition of the fuses of the lights, perforations are made in the expelling disk. In the one-star light there is a 3/8-inch-diameter hole in the center, in the three-star light there are three 3/8-inch-diameter holes spaced equally distant. When the six-star light is assembled this propelling disk is of strawboard 3 3/8 inches in diameter, and the holes cut through the disk are similarly arranged to those of the three-star-light.

LIGHT CASE.

The light case may be made of black hardware paper or aluminum. When made of hardware paper it is rolled in a similar manner to that described under the parachute rifle light, a single thickness of black hardware paper 12 by 20 inches being rolled to an internal diameter of 1 1/2 inches. This tube is then cut into lengths of 1 5/8 inches which is deemed the proper length for the light case. It is the custom to use the paper case where colored stars are used, the aluminum case being used for the white light or white stars, the reason being that the burning of the case, where the latter is of cardboard, does not materially effect the color of the lights, whereas the burning of the case when made of aluminum is noticeable. One-star white light, however, is usually assembled in a light case of cardboard.

For the three-star white light the case is made of expanded aluminum, 3/4 inch in diameter by 1 1/2 inches long. One end of the case is open and is provided with four projections, which can be seen in figure 158.

The bottom of the case is crimped over, leaving an opening approximately 5/8 inch in diameter. The crimping serves as a bottom to hold a disk.

Referring again to figure 158, a hole is shown close to the bottom for the purpose of inserting a quick match which rests on top of the disk. In the six-star white light also the case is of aluminum. This case, however, has not a crimped bottom, as does the case previously described, but has a solid bottom. The case is ¾ inch in diameter and ¾ inch long. The open end is likewise provided with four small projections which serve the same purpose as outlined in the description of the case previously mentioned.

FIG. 158.—Successive stages of loading three-star light case.

For the red or green lights paper cases are used. In the one-star light the paper tube is 1½ inches long. For the three-star red or green lights the case is made of black hardware or Kraft paper $\frac{11}{16}$ inch inside diameter and 1⅝ inches long, and for the six-star red or green light a similar case is used, with the exception that it is only ¾ inch long.

BOTTOM DISK.

This is used only for the one-and three-star white lights. For the one star it consists of a 1½-inch-diameter disk of strawboard with a ⅞-inch hole in the center. For the three-star light it is simply a solid strawboard disk, $\frac{11}{16}$ inch diameter.

MUSLIN WRAPPER.

This wrapper is used only for the one-star white light. It is identical with that used in the rifle light with parachute, being a piece of muslin 1½ by 8 inches, pasted around the bottom of the light case with ½ inch projecting and pasted over the bottom disk.

OUTER DISK.

This, too, is used only in the one-star white light and does not differ from that used in the parachute light. It consists of a 1⅝-inch-diameter piece, 30-pound Kraft paper, and is pasted over the bottom disk and edge of muslin wrapper, covering the hole in the center of the bottom disk.

WHITE-LIGHT COMPOSITION.

It is to be noted that in the stars no first-fire composition is used, for the stars are designed to burn as meteors. For the one-star white light the composition consists of—

	Per cent.
Barium nitrate	68
Aluminum (flake)	25.2
Aluminum (powdered)	6.8

This is made up in practice by weighing 15 pounds of barium nitrate, 5½ pounds of flake aluminum and 1½ pounds of powdered aluminum, mixing by hand and screening twice through a 24-mesh sieve. Twelve ounces of castor oil are then added to the batch and mixed well, the whole passing twice through a 12-mesh sieve. This composition burns from 10 to 12 seconds. After assembling the bottom-disk muslin wrapper and outer disk, the composition is loaded into the case in the following manner:

A small quantity of wet prime is dropped on the bottom disk and the case is filled with the white-light composition. A wood plunger and mallet then tamp this material down and the case is again filled with composition, until it is packed to within ⅛ inch of the top. This is the hand operation that some manufacturers hold gives the best result. The three-star-white-light composition is the same as the one-star light, but the loading of the case differs in that the light case when assembled has a quick match 1½ inches long inserted through the side hole. A small quantity of wet prime is dropped on the bottom disk and the composition is loaded with mallet and plunger, similarly to those used in loading the one-star light. The candlepower of the three-star light is the same as that of the one star, but it burns only from 8 to 10 seconds. In the six-star light the composition and method of loading are quite similar to those of the three-star light, but it burns only from 6 to 8 seconds.

FIG. 159.—Filling light case.

ONE-RED-STAR RIFLE LIGHT.

CASE.

The case is usually made of a very cheap cardboard, such as Bogus 0.013. The inside diameter of the case is 1½ inches and the height 1½ inches. This case is similar in its manufacture to the case previously described.

COMPOSITION AND LOADING OPERATION.

The composition of the one-red-star rifle light consists of—

	Per cent.
Potassium chlorate	72.7
Strontium carbonate	15.2
Orange shellac	12.1

FIG. 160.—Ramming charge in light case.

This mixture is made up in batches of 72 pounds of potassium chlorate, 15 pounds of strontium carbonate, and 12 pounds of powdered orange shellac. The customary method of hand mixing and hand screening through a 12-mesh sieve is used to insure uniformity of the mixture. The loading is done by hand. The operator fills the case to the brim with the composition and tamps it firmly into place by means of a mallet and wooden tool, repeating the operation until the case is completely filled. The orange shellac in this composition has a sufficient amount of moisture content to amalgamate the mass, which later on drying sets firmly. When drying is partially complete the composition is given a coating of wet prime which is painted over each end. It is to be noted here that the case is a cylinder open at both ends, which permits the application of the wet prime as stated.

Figures 162 and 163 show the operation of loading.

FIG. 161.—Red-star light case.

WAD.

A felt wad 1¾ inches in diameter and ⅜ inch in thickness is now placed on top of the light which has been placed in the container. On top of this felt disk is placed a cork wad of the same diameter and ⅜ inch thick.

TIN IDENTIFICATION CAP.

This is a stamped-tin disk with eight prongs which are forced into the cork wad. It is painted, and by its form designates the color and number of lights. With the one-red-star rifle light the cap is stamped with graduated concentric rings, the innermost ring protruding and having one small projection like a wart expanded on its rim.

BLANK CARTRIDGE.

There is a 30-caliber blank cartridge with a reduced load attached to the outside of the case for the purpose of discharging the light from the rifle fixture. This is the kind of cartridge that has been previously described in connection with the discharging of the parachute rifle light. A small

FIG. 162.—Filling red-star light case.

strip of 20-pound manila paper, $1\frac{1}{2}$ by $1\frac{1}{2}$ inches, is placed around the cartridge to protect it from the adhesive-tape binder holding it to the tin case. The adhesive-tape binder is a strip of electrician's tape, $\frac{1}{2}$-inch wide by 8 inches long.

PAINTING.

An operator gives the tin identification cap a coat of paint designating the color of the star.

Fig. 163.—Charging red-star light case.

PACKING CARTON.

The packing carton is a corrugated strawboard carton with corrugated strawboard dividing strips, the carton being 4¼ by 5 by 6¼ inches to accommodate six lights. It is closed and sealed with gum paper and then dipped, five cartons on a tray being dipped at the same time in molten low-grade paraffin.

SHIPPING CARTON.

This is a container used to hold the packed cartons and is made of corrugated paper, measuring 6 by 6¾ by 23 inches. Five packing cartons are contained in this package, which is sealed with gum paper properly labeled and then dipped into molten crude paraffin. It may be noted here that for use this crude paraffin is better than the refined paraffin by reason of the fact that the crude article contains as an impurity a certain amount of petrol, which gives to the paraffin an adhesive quality not obtained in the refined product.

THREE-RED-STAR RIFLE LIGHT.

CASE.

This case is made of black hardware or Kraft paper $\frac{11}{16}$-inch inside diameter and 1⅝ inches high.

COMPOSITION AND LOADING.

The composition of the three-red-star rifle light consists of—

	Per cent.
Potassium chlorate	72.7
Strontium carbonate	15.2
Orange shellac	12.1

This is identically the same composition as is used in the one-red-star light, the batches being made of 72 pounds of potassium chlorate, 15 pounds of strontium carbonate, and 12 pounds of powdered orange shellac. The loading operation is identical with that described in the one-red light and consists of filling the case and tamping by hand.

MATCH.

Before the composition is tamped into the case a 4¼-inch match is threaded through the case from top to bottom and bent over the edges, the match lying snugly along one side of the case. The composition when tamped into place holds this match firmly in position.

WAD.

The wad of this case is the same as that used in the one-red-star light and consists of a felt disk 1¾ inches in diameter and ⅜ inch in thickness.

CORK WAD.

A cork wad of the same diameter $\frac{5}{16}$ inch in thickness is placed on top of the felt wad, as is done in the assembly of the one-red-star light.

CANDLEPOWER.

The prescribed candlepower for the three-star light is from 300 to 400.

BURNING TIME.

The burning time of these lights should be from five to six seconds.

TIN IDENTIFICATION CAP.

The shape and size of this tin identification cap have been described in detail under the heading of "One-Red-Star Light," with the exception that the cap for the three-star light has three small warts or projections expanded on its rim.

BLANK CARTRIDGE.

The same blank cartridge is used to discharge these lights as has been described under the one-red-star light. The assembly and painting are similar to those of the one-star light as are also the packing carton and shipping carton.

SIX-RED-STAR RIFLE LIGHT.

CASE.

The case for these lights is made of similar material, namely, black hardware paper, as previously described in the one-red-star light, the diameter of the case being $\frac{11}{16}$ inch and the height of the case being ¾ inch.

COMPOSITION AND LOADING OPERATION.

The composition as well as the loading operation is identically the same in making up the stars for the six-red-star light, as previously described under the one-red-star light.

MATCH.

The same kind of quick match is used for these lights as for the three-red-star light. The match, however, is cut 2¼ inches long and is threaded through the case and held in position by the packing in of the composition as previously described.

CANDLEPOWER.

The prescribed candlepower for the six-star light is from 180 to 250.

BURNING TIME.

The burning period is from 4 to 6 seconds.

WADS AND IDENTIFICATION CAP.

The wad and cork wad are the same as previously described. The tin identification cap, also, is the same, with the exception that there are six small warts or projections expanded on the rim of this cap.

BLANK CARTRIDGE.

The blank cartridge is similar to that used for the one-red-star light and the three-red-star lights, and is assembled in the same manner.

PAINTING OF THE CAP.

The painting of the cap is the same for all of the red lights.

PACKING CARTON.

The packing carton, as well as the shipping carton, is the same as in the previously described red lights.

ONE-GREEN-STAR LIGHT.

The only difference between the one-red-star light and the one-green-star light is in the composition and in the form of the tin identification cap. The composition for the one-green-star light consists of—

	Per cent.
Barium chlorate	90
Powdered orange shellac	10

The tin identification cap has a smooth convex contour with one small projection expanded on its surface.

THREE-GREEN-STAR LIGHT.

This is similar to the three-red-star light, with the exception that the composition is—

	Per cent.
Barium chlorate	90
Ground orange shellac	10

The identification cap has a convex container with three small projections expanded on its surface.

SIX-GREEN-STAR LIGHT.

This is similar to the six-red-star light, with the exception that the composition consists of—

	Per cent.
Barium chlorate	90
Powdered orange shellac	10

The tin identification cap resembles that of the three-star green and has six projections.

CANDLEPOWER.

The candlepower of the one-green-star light should be 350 to 400; the three-green-star light should be 225 to 300, and the six-green-star light should be 150 to 200.

BURNING TIME.

The burning time of the one-green-star light should be 10 seconds; of the three-green-star light, 5 to 6 seconds; of the six-green-star light, 5 to 6 seconds.

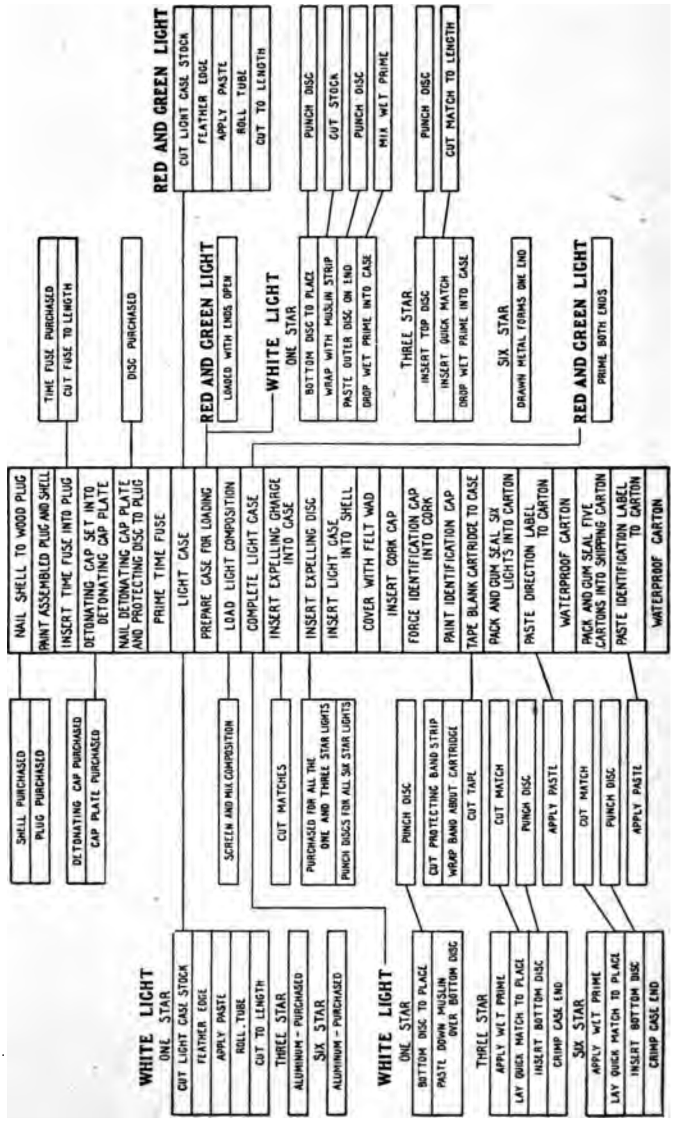


PLATE 10.—Star-rifle-light flow sheet.

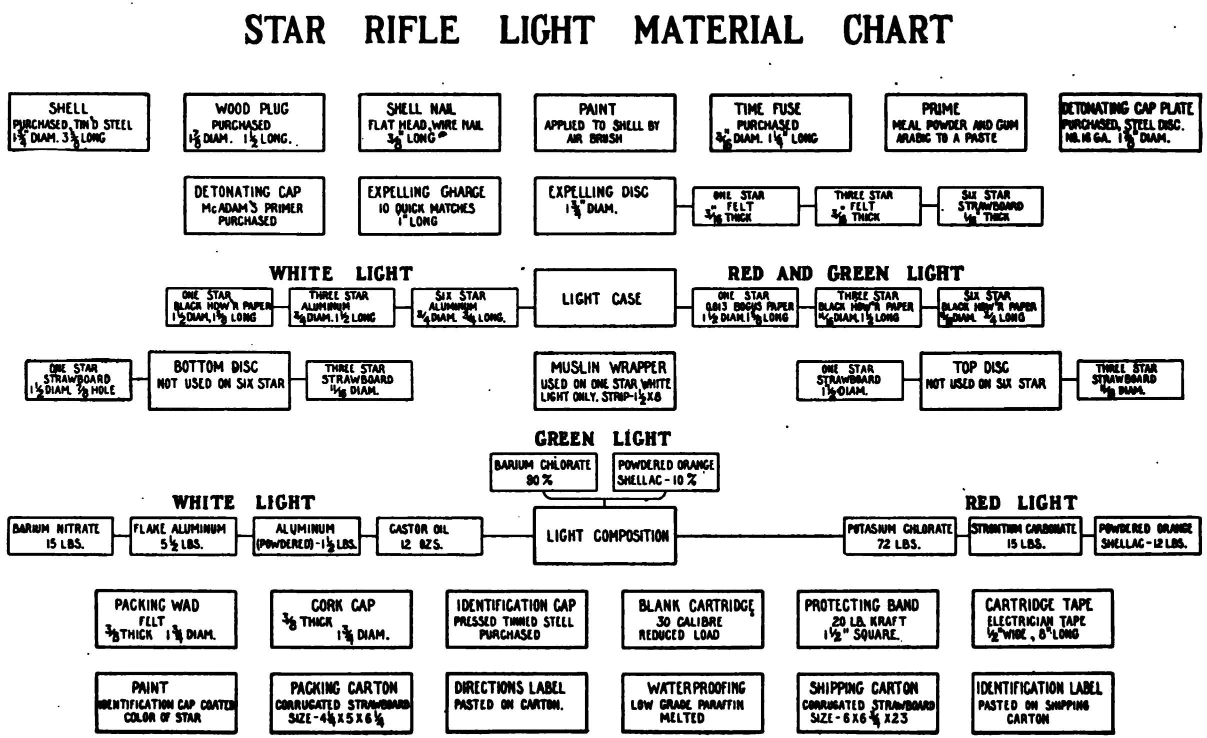


PLATE 11.—Star-rifle-light material chart.

CHAPTER V.

VÉRY SIGNAL (25 MILLIMETER).

The Véry signal is a pyrotechnic device which is fired from a specially designed pistol. A cartridge similar to a shotgun cartridge holds the signal star which is propelled about 300 feet, burning for from 6 to 8 seconds, the ignition taking place about 50 feet from the muzzle of the pistol.

FIG. 164.—Véry-light cartridge and signals.

CASE.

The case consists of the ordinary shotgun shell, which is made by the Winchester Repeating Arms Co., with firing cap already inserted in the base of the shell. The length of the shell is $3\frac{7}{8}$ inches, and its diameter 1.04.

CARDBOARD LINING.

A ring of Bird's hardware paper, which is the same material used for making the rocket carton, is set in the case, acting as a spacer, forming a seat for the wads to rest on and also serving as a brace for the sides of the shell when the blowing charge is fired. This cardboard lining is $\frac{45}{64}$ inch in its inside diameter, $\frac{15}{16}$ inch outside diameter, and $\frac{3}{8}$ inch in length.

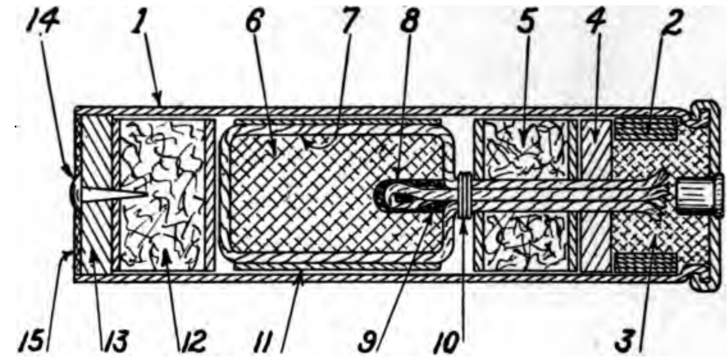


FIG. 165.—Sectional drawing Véry light.

VÉRY SIGNAL LIGHT.

1. Case.
2. Cardboard lining.
3. Powder charge.
4. Strawboard wad.
5. Felt wad.
6. Star.
7. Match.
8. Match.
9. Wet prime.
10. Tie string.
11. Wrapper.
12. Holding wad.
13. Identification wad.
14. Tack.
15. Paraffin seal.

POWDER CHARGE.

The powder charge consists of from 25 to 30 grains of black powder No. 20 to 36, which is introduced into the empty shell and pressed home by means of a strawboard wad.

STRAWBOARD WAD.

This strawboard wad is $\frac{3}{16}$ inch in thickness and has a diameter of $\frac{59}{64}$ inch. Through the center of the wad is a port $\frac{3}{16}$ inch in diameter. This hole in the center permits the threading of the match, which is ignited by the powder charge used for expelling the star, and carries the ignition to the light.

FELT WAD.

Resting upon the cardboard wad is a felt wad $\frac{59}{64}$ inch in diameter, $\frac{5}{8}$ inch in thickness, with a port through the center having a diameter of $\frac{3}{16}$ inch. The port, as in the case of the port in the wad, is for the purpose of allowing the match to pass through. This felt wad is faced with cardboard and is the customary shotgun-shell wad.

STARS.

The Véry light may have either white, red, or green stars. If for a white star, the composition is—

	Per cent.
Saltpeter	65.9
Black antimony	16.5
Sulphur (flour)	16.5
Meal powder	1.1

For the red star, the composition is—

	Per cent.
Chlorate of potash	71.9
Strontium carbonate	18
Powdered orange shellac	9
Lampblack	1.1

For the green star, the composition is—

	Per cent.
Barium chlorate	90
Powdered orange shellac	10

These compositions are mixed in the usual manner, by hand mixing and screening through a 40-mesh sieve, the mixture being passed through three successive times. After each screening it is mixed thoroughly by hand. A binder consisting of gum water is used to dampen slightly the several different compositions in order that the light when loaded shall hold its form. The stars are molded in a hand arbor press, equipped with a special brass mold.

MOLD.

Figure 168 shows the type of mold used and the form into which the composition or star is compressed.

These lights are now placed in a drying room where they are dried at 100° F. for four or five days.

QUICK MATCH.

The ordinary quick match described previously is cut 8 inches long and is looped longitudinally around the light, fitting snugly into the grooves with the ends even and protruding beyond the light. This match is held firmly in place by means of a strip of Kraft paper 6½ by 1½ inches which is pasted around the star. A second match is now inserted into the hole in the end of the star and held in place by

FIG. 166.—Briquetting equipment.

means of a blob of prime, consisting of meal powder and water. These matches are next threaded into the felt and strawboard wads and protrude into the propelling charge of black powder at the base of the case.

After the star is in place in the shell with the matches in position, a wad is forced into the shell to hold it in place.

FIG. 167.—Briquette press.

HOLDING WAD.

The holding wad is of felt, being $\frac{59}{64}$ inch in diameter and ⅝ inch in thickness, faced with paper, and is the customary shotgun-shell wad.

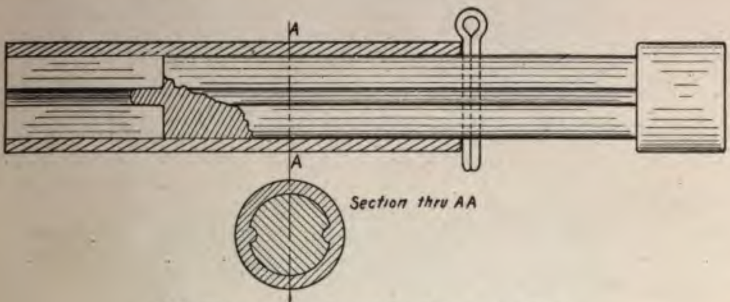


FIG. 168.—Briquette mold and cross section.

IDENTIFICATION DISK.

This disk is made of strawboard $\frac{3}{16}$ inch in thickness and $\frac{59}{64}$ inch in diameter. The face of the disk is lettered in raised letters as shown in figure 169.

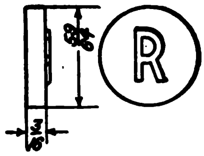


FIG. 169.—Designating disk.

The face is painted to designate the color of the star. This disk is held in place by means of a $\frac{3}{8}$-inch tack with a round head which is driven through the disk and into the felt-holding wad.

TYPES OF VÉRY PISTOLS USED IN 1918.

FIG. 170.—Véry-light pistol A.

FIG. 171.—Véry-light pistol B.

FIG. 172.—Véry-light pistol C.

FIG. 173.—Véry-light pistol D.

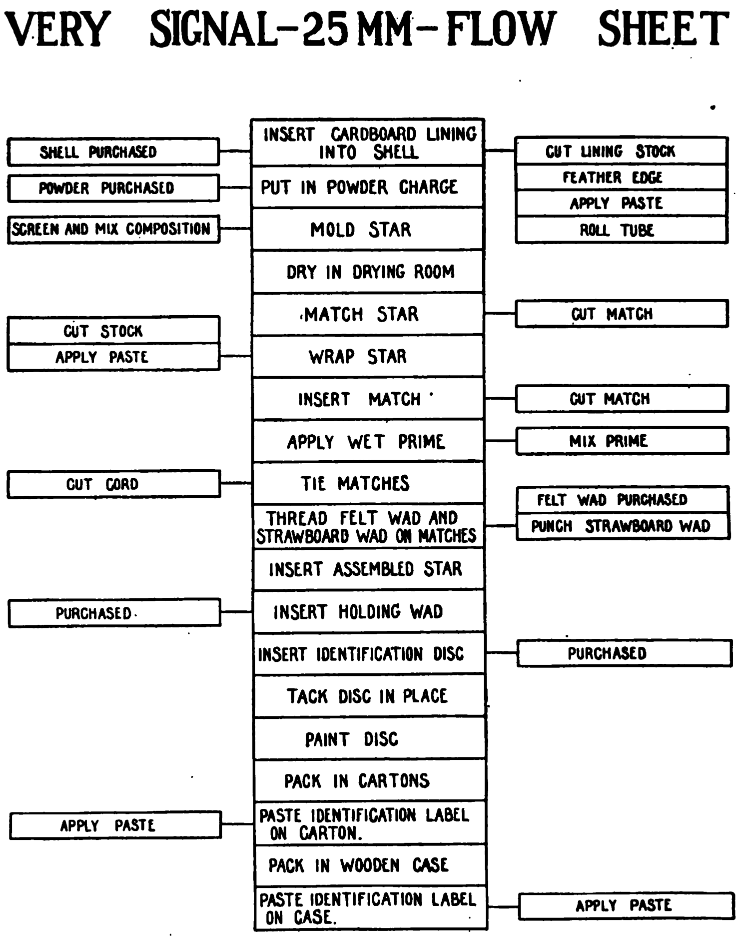


PLATE 12.—Véry-light flow sheet.

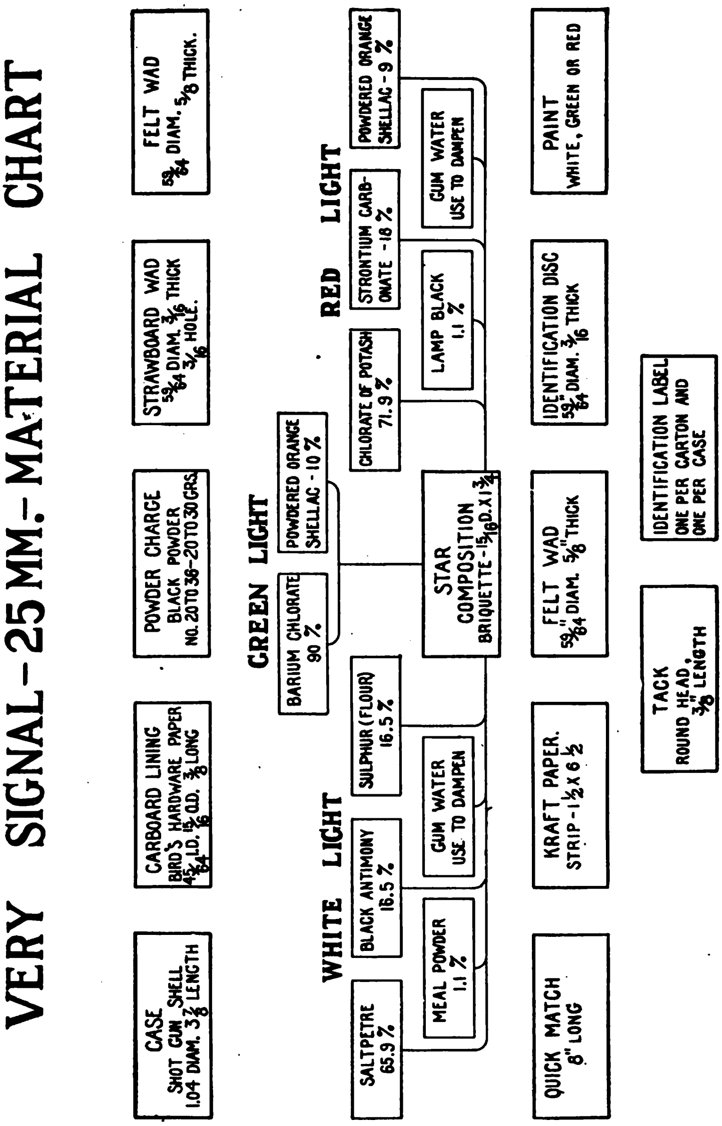


PLATE 18.—Véry-light material chart.

FIG. 174.—Position light.

CHAPTER VI.

POSITION LIGHT.

There are various types of position lights, often called Bengal lights.

The position light is commonly used to indicate the location of trenches to aërial observers. But it is available also for other purposes. The light is made to burn with a white illumination, a red illumination, or a green illumination. These pyrotechnic articles are relatively small; can be transported with ease and are extremely efficient for illuminating purposes as well as for signaling.

The position light is small, cylindrical in form, 2½ inches high by 1½ inches inside diameter, loaded with an illuminating composition and resembling closely the rifle light. The method of firing it is very similar to that used for the smoke torch.

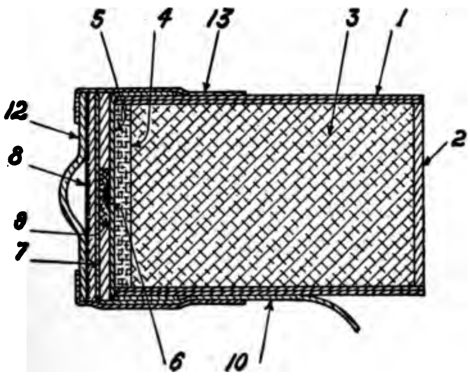


FIG. 175.—Sectional drawing of position light.

POSITION LIGHT.

1. Case.
2. Case-bottom disk.
3. Composition.
4. First-fire composition.
5. Drumhead.
6. Prime blob.
7. Protecting disk.
8. Striker disk.
9. Cotton batting.
10. Opening tape.
11. Staples (not shown).
12. Identification disk.
13. Binding band.
14. Waterproofing.
15. Label.
16. Tearing cord.
17. Inside wrapper.
18. Outside wrapper.
19. Drumhead.
20. Identification tag.
21. Outside label.
22. Packing.

CASE.

The case is a small paper cylinder rolled by hand on a mandrel in the method previously described. The paper used being Bogus 0.013. The case should have an inside diameter of 1½ inches and a height of 2½ inches. Bogus paper is used, because this paper burns readily and will not produce a chimneying effect.

CASE-BOTTOM DISK.

The case-bottom disk is stamped out of 50-pound strawboard and has a diameter of 1½ inches. In assembling the disk in the bottom of the case, the inside of the case is first wiped with glue close to the bottom, and while the glue is still wet, the bottom disk is dropped in at the other end and forced into place flush with the bottom. The article is allowed to dry before the composition is added.

COMPOSITION FOR WHITE LIGHT.

This composition is—

	Per cent.
Barium nitrate	66.9
Sulphur (flour)	16.7
Flake aluminum	15.5
Black antimony	.6
Stearin	.3

Twenty-eight pounds of barium nitrate and 7 pounds of sulphur are mixed by hand and rubbed through a 16-mesh sieve. After screening they are again well mixed by hand; 6½ pounds of flake aluminum and ¼ pound of black antimony are now added to the mixture, which is again sifted through a 16-mesh sieve, and 1/8 pound of stearin is added. The whole mass is thoroughly mixed by hand, and screened through a 12-mesh sieve. It is then given a final thorough mixing by hand. It is to be noted here that no powdered orange shellac is added to the mixture as in the case of the rifle light, the stearin acting as the binder. This mixture may be loaded in the case by hand, in a manner similar to that previously described, by using a mallet and wooden plunger, which drive the charge home to within 1/8 inch from the top of the case. Or a machine may be used for loading.

MACHINE FOR LOADING.

This is a simple hand-lever-operated machine or press used for charging position-light cartons. It consists of a movable platform on which are placed cases to be loaded, and a stationary head which carries the plungers or rammers. The principle of this machine is analogous to that used in charging the rocket bodies, except that hand power is substituted for hydraulic.

Before being placed under the plungers for pressing, the light cases are assembled on a jig, consisting of a wooden base block with a rack or frame having 10 brass cylinders.

The assembled cases are shown in figure 177.

This operation is accomplished by removing the rack of cylinders from the base block, inverting it and placing the paper cartons in the cylinders, and then setting the base block on the support of the rack and turning the whole to its normal position as shown in figure 177.

The brass cylinders are 2¼ inches long, and have for ⅜ of an inch an internal diameter of 1⅝ inches, that being the outside diameter of the case to be charged. The balance of the length of the cylinder has the same diameter as the inside of the case, which is 1½ inches.

Figure 177 shows the measuring tray, which consists of a sliding frame approximately 3½ inches in thickness, through which are bored 10 holes, as shown in the picture. This 1¾-inch board may be moved by hand forward and backward across the face of a supporting board or plank, which is 1¾ inches in thickness and acts as a shutter, closing

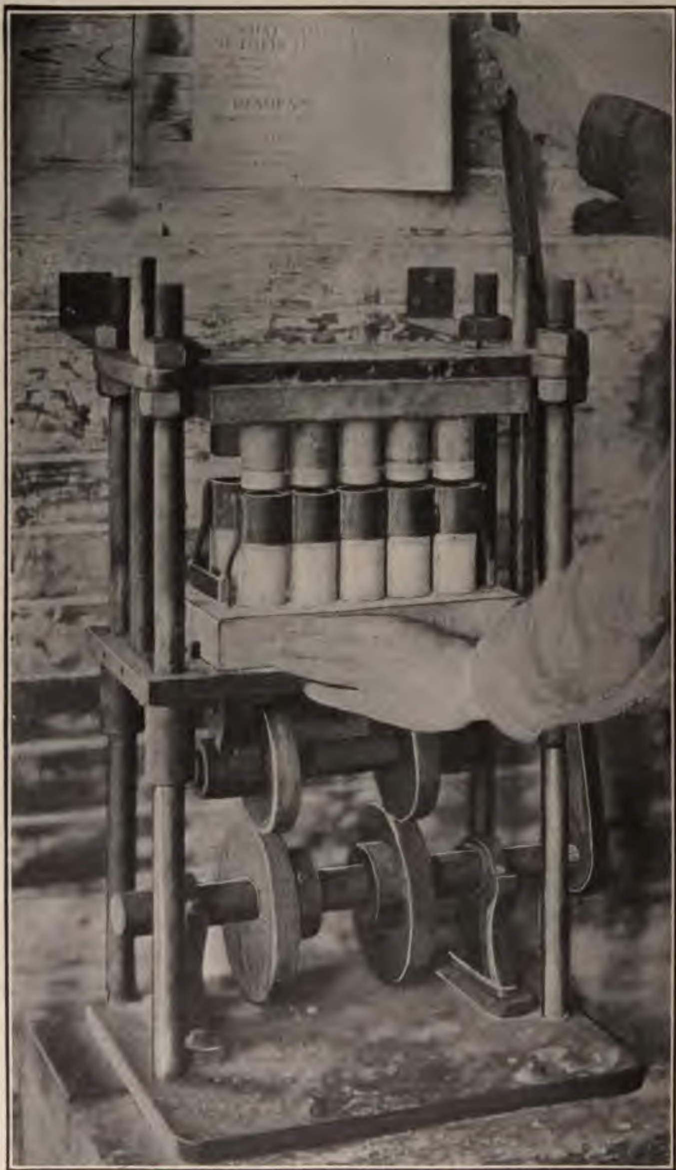


FIG. 176.—Light cases assembled on loading machine.

and opening the several orifices. The holes in the upper plank, when in position as shown in the photograph, register with the holes in the lower plank, thus permitting a measured charge to be introduced into the carton.

Figure 178 shows the operation of filling the loading frame with composition by hand.

Figures 178, 179, 180, and 181 show the hand operation of filling the cavities in the board to their brim with composition.

Figure 179 shows the operator removing the excess composition.

FIG. 177.—Loading rack and measuring tray.

Figure 180 shows the measuring frame in position to discharge its several charges into the cartons.

Figure 181 shows the top block after the charges have been discharged, the operator having manipulated the sliding frames into a position where the orifices in each register, so that the contents are allowed to fall through and into the carton. One charge of composition is measured into the cartons in this manner, then the loading block is placed in the pressing machine.

Figure 176 shows the introduction of the cartons under the plungers of the hand press. The loading block is taken from the press, and a second charge is measured and pressed into the cases, in the same manner as before.

Figure 182 shows the position of the plungers after the operator has driven them home, thus pressing the charge into the cartons. The pressure exerted by the operator is magnified by means of the two cams beneath the loading block of the machine, as shown in the photograph. When the charges are rammed home in the cartons they fill the

FIG. 178.—Charging measuring frame.

cartons to within ¼ of an inch of the top. In removing the cartons from the press, the base block, holding the loaded cartons and their brass guides, is removed from the machine and the guides are lifted off from the cartons. The topping charge is then added to the case in the same manner as in the hand-loading operation.

FIRST-FIRE COMPOSITION FOR THE WHITE LIGHT.

There are two different compositions used. One of them consists of—

	Per cent.
Saltpeter	57.2
Sulphur (flour)	19
Antimony	19
Dextrin	4.8

FIG. 179.—Removing excess from measuring frame.

The saltpeter and sulphur are first well mixed by hand and rubbed through a 15-mesh sieve. Antimony is added and mixed. Dextrin is added, and, after being well mixed by hand, the mass is screened through a 12-mesh sieve and then again thoroughly mixed. The case, loaded with the color composition to within 1/8 inch of the top, is then filled to the brim with the first-fire composition described above, and capped. This latter operation consists of forcing a cardboard disk into the open end of the case with the loaded composition and the first-fire composition and lightly tapping it into place.

FIG. 180.—Measuring frame in unloading position.

FIG. 181.—Measuring frame unloaded.

POSITION LIGHT—RED.

The difference between the white and red lights is that the latter has a composition consisting of—

	Per cent.
Chlorate of potash	37.5
Nitrate of strontium	50.
Powdered orange shellac	12.5

FIG. 182.—Compressing composition.

This composition is made up in the manner heretofore described, and is screened in order to get a homogeneous mass.

POSITION LIGHT—GREEN.

The green differs from the white position light only in the composition, which consists of—

	Per cent.
Barium chlorate	23.3
Barium nitrate	59.2
Powdered orange shellac	10.5
Potassium chlorate	6.4
Stearin	.6

A batch consisting of 47½ pounds is mixed in a manner similar to that described under the white-light composition.

DRUMHEAD.

In assembling either the white, red, or green light the same drumhead is employed. The red and green lights have no quick fire as the composition is easily ignitable. A muslin drumhead is put over the top of the case and pasted down on the sides in the manner previously described.

Fig. 183.—Case with drumhead.

Fig. 184.—Prime on drumhead.

PRIME BLOB.

This consists of—

	Per cent.
Black antimony	23.
Potassium chlorate	46. 3
Strontium carbonate	30. 7

The three constituents are thoroughly mixed and screened in the customary manner and the powder wet down to a paste by the use of gum water made by mixing 2 ounces of gum arabic dissolved in a pint of water. A puddle of this prime about ½ inch in diameter is formed on the muslin drumhead in the center, where a hole has been punched through.

PROTECTING DISK.

The protecting disk is made from 50-pound strawboard cut 1½ inches in diameter, with a hole in the center ¾ inch in diameter.

FIG. 185.—Protecting and striker disks.

Figure 185 shows this disk at the right of the case.

STRIKER DISK.

The striker disk is cut from a piece of 50-pound strawboard 1½ inches in diameter. This disk is given a coating of composition consisting of—

	Per cent.
Powdered glass	80
Red phosphorous	20

This is thoroughly mixed and made into a paste by adding gum water. The striker is related to the blob in the same manner as the surface on our safety match box is to the head of the match.

COTTON BATTING.

A small wad of cotton batting is formed into the hole in the protecting disk and acts as a protection to the prime blob.

OPENING TAPE.

Cotton tape ½-inch wide and 5 inches long is placed between the protecting disk and the striker disk. Two staples hold the two disks firmly together with the tape between. The cotton in the protecting disk prevents an abrasion on the blob. Figure 185 shows the assembly. The tape protrudes beyond the lower edge of the band as shown in figure 186.

STAPLES.

The staples are small wire staples of $\frac{7}{16}$-inch No. 14 semi-spring wire used in assembling the striker and protecting disk. A stapling machine is employed to clinch them.

FIG. 186.—Binding band in place.

IDENTIFICATION DISK.

This disk is placed upon the top of the light and is made of 50-pound strawboard cut to a diameter of 1½ inches. Three different types of embossing characterize the three different lights, namely, the red, white, and green. Corrugations signify red; a concave surface signifies white and a convex surface signifies green. This identification disk is held in place by a binding band.

BINDING BAND.

This binding band is used to hold together and firmly attach to the case the several disks previously described. The band is a strip of rope manila, 20-pound stock, cut in strips 6 inches long by 1½ inches wide. This strip is pasted on, encircling the case and overlapping with a sufficient margin to hold the identification disk firmly in place.

WATERPROOFING.

When fully assembled the light is dipped into a shellac paint, composed of lampblack, shellac, and wood alcohol, care being taken that the top of the light is brushed off carefully in order to prevent any confusion with regard to the identification disk. The end of the tape also is conspicuously in evidence, to facilitate the separating of the striker disk. Figure 187 shows the light after dipping.

FIG. 187.—Light waterproofed.

LABEL.

A label is now pasted around the light, giving directions how to ignite the same. These directions are printed in English and French. The red light has a red label; the green light, a green label, and the white light, a white label. This is shown in figure 174.

TEARING CORD.

This is a piece of strong cotton cord about 16 inches long, firmly tied to one of two lights, which are packed together.

FIG. 188.—Lights on wrappers showing tearing cord.

FIG. 189.—Inner wrapper assembled.

The cord is used to facilitate the opening of the two lights as is shown in figures 188 and 189.

INSIDE WRAPPER.

The inside wrapper is a piece of Bogus paper 0.013 cut in a strip 2½ by 12 inches. This is wrapped around one of the lights and encircles its neighbor also, binding the two together.

OUTSIDE WRAPPER.

The outside wrapper is a piece of Kraft paper, 20-pound stock, 5 by 12 inches, used to pack two lights together. The tearing cord previously mentioned protrudes from one of the edges of the package.

DRUMHEADS.

These drumheads are of 20-pound Kraft paper, cut in rectangles 4½ by 6 inches, with an inch cut off of each corner, beveling the same. These drumheads are pasted smoothly over each end of the package.

FIG. 190.—Identification tags.

IDENTIFICATION TAG.

These tags are stamped out of 50-pound strawboard, having various shapes concordant with the surface form of the identification disk. Figure 190 shows these tags.

OUTSIDE LABEL.

The outside label is similar to those used on the inside of the package and on the individual lights. It is shown in figure 191.

PARAFFINING.

The package is now dipped in molten paraffin for the purpose of waterproofing.

PACKING.

Twenty-five packages with two lights in each are packed in a tin box, the cover of which is soldered with soft solder.

FIG. 191.—Lights wrapped and labeled.

A small tin attached to the corner permits the latter to be torn readily from the box. This tin container is then packed in a wooden case.

POSITION LIGHT FLOW SHEET

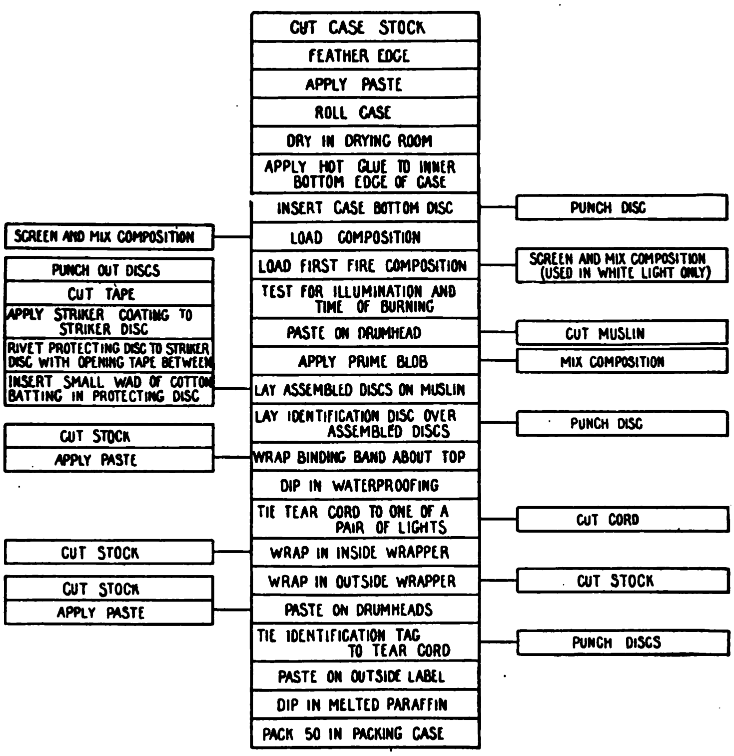


PLATE 14.—Position light flow sheet.

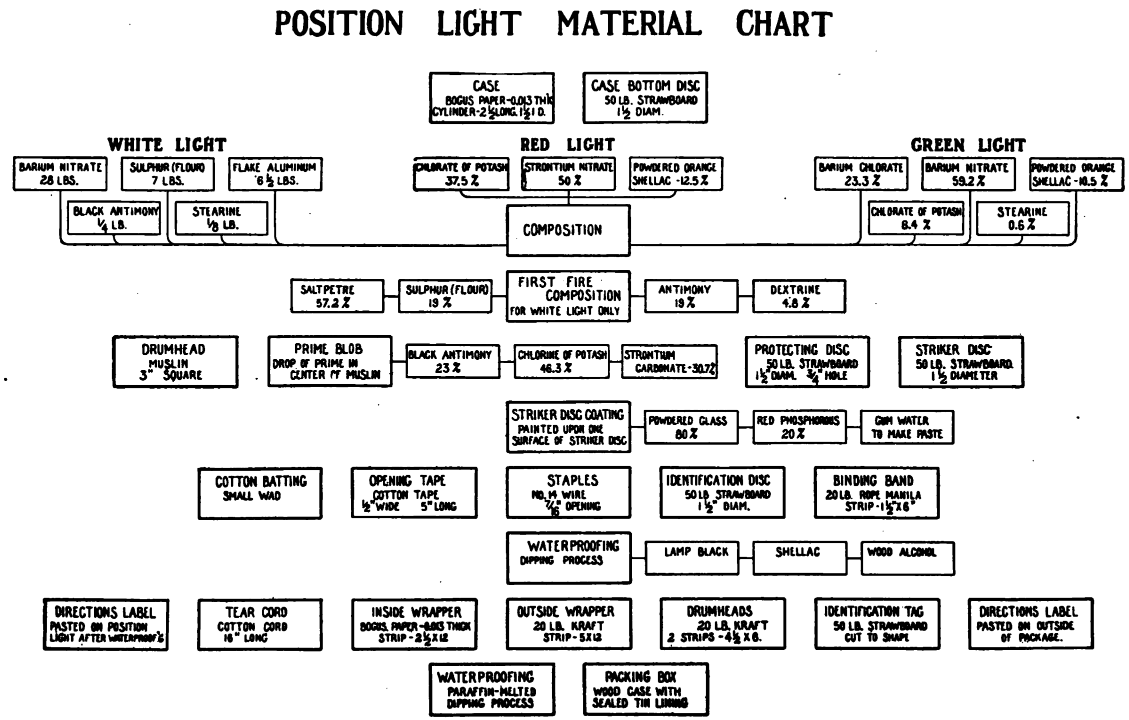


PLATE 15.—Position-light material chart.

FIG. 192.—Wing-tip flare.

CHAPTER VII.

WING-TIP FLARE.

The wing-tip flare is a pyrotechnic device used for illuminating and signaling purposes. These flares are manufactured in both white and colored lights. The flare by means of suitable rigging is attached to the extremities of the wings of an aëroplane, and are ignited by means of an electric spark controlled by the aviator. This method of illumination may serve to aid the aviator in making a landing.

FIG. 193.—Rigging for wing-tip flare.

Figure 193 shows the rigging which is suspended from the tip of the plane and which holds the flare clamped firmly in place. The pivoted arm of this rigging moves in a horizontal position and is automatically brought to the vertical by means of a rubber cord, should the plane fly so low that the flare strikes the ground. A white-light flare and a red-light flare are usually used in conjunction, it being claimed that the red rays of light have a superior penetrating value in a fog or mist. The wing-tip flare is designed to burn for one minute, giving an illumination of 22,000 candlepower for the white light and from 12,000 to 15,000 candlepower for the red light.

Referring to figure 194, it will be noted that the wing-tip flare consists of a paper case with a wood plug inserted in one end, thus making a chamber into which is loaded the illuminating composition. An electrically operated igniter with suitable wires is an essential part of this device.

FIG. 194.—Case and plug.

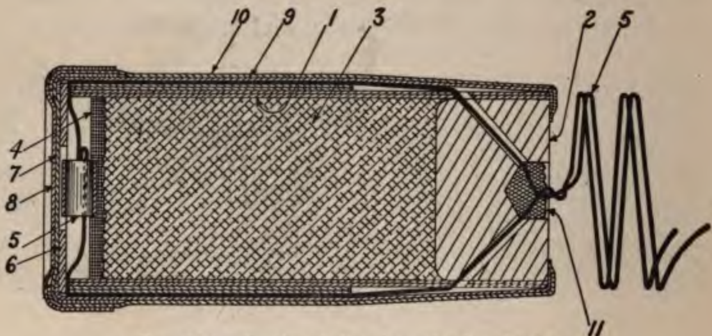


FIG. 195.—Sectional drawing of wing-tip flare.

1. Case.
2. Plug.
3. Composition.
4. First-fire composition.
5. Igniter
6. Cover.
7. Inside drumhead.
8. Outside drumhead.
9. Inside wrapper.
10. Outside wrapper.
11. Plug seal.

CASE.

The wing-tip flare measures $1\frac{5}{8}$ inches inside diameter by $4\frac{1}{4}$ inches in length. The carton is made of two thicknesses of two-ply rocket hardware paper, cut $4\frac{1}{4}$ by $12\frac{1}{4}$ inches from sheets 25 by 36 inches. The smaller sheets are given a coat of paste and rolled on a mandrel, the operation being similar to that described in rolling the rocket case. When rolled this case should have an internal diameter of $1\frac{5}{8}$ inches. A strip of Bird's hardware paper, cut $2\frac{1}{2}$ by

7 inches, or a strip of Sawyer strawboard paper, 2½ by 12½ inches, is given a coat of paste and rolled around the carton flush with one end.

This produces a carton which has a slight shoulder, caused by the additional wrapper, at a distance of 1¾ inches from the end. The smaller end of the flare is designed to fit into the metal holder of the rigging attached to the wing of the aëroplane. After the cases are rolled they are thoroughly dried.

BASE PLUG.

A hardwood plug, 1$\frac{11}{16}$ inches outside diameter and 1-inch thick, is turned and a recess, ½ inch in diameter and $\frac{3}{16}$ inch deep, is cut at one end. Two holes ⅛ inch in diameter are drilled from the bottom of this recess through the plug. The channels so formed make an angle of 90°, each of them being at an angle of 45° with the short axis of the plug. These channels are bored for the purpose of allowing the threading of the electric wire used for igniting purposes.

Figure 195 shows the construction.

The end of the plug which is inserted into the case is slightly beveled to facilitate easy assembly. This plug is forced into and glued to that end of the case having the smaller outside diameter and also is secured by means of two tacks at opposite sides. After the plug is glued in place holes are punched through the walls of the case, registering with the holes drilled through the plug so that the electric wires may pass down the outer side of the case, thus connecting with the ignition at the far end.

COMPOSITION.

WHITE LIGHT.

The white-light composition consists of—

	Per cent.
Barium nitrate	81
Flake aluminum	13.7
Sulphur (flour)	5.3

This mixture is dampened and made slightly adhesive by adding a shellac binder. The composition is mixed in quantities of 77 pounds of barium nitrate, 13 pounds of aluminum, and 5 pounds of sulphur. Barium nitrate which has been thoroughly pulverized is mixed with the other two ingredients, the same method of hand mixing being used as previously described. The mixture is screened twice through a 30-mesh sieve. After screening the mass is dampened with a binder, as described above, and is again rubbed through the 12-mesh sieve. Variations from the above formula are adopted by different manufacturers. It would appear that one of the important points in connection with the composition is that when loaded in the case it should be driven home with a sufficient pressure, or that the composition should be of such ingredients as to prevent the shrinking of the composition during the setting of the binder. Such shrinking would produce a space of lesser resistance close to the inner walls of the case, permitting the gases during combustion to work their way in between the charge and the walls of the case to blow out the contents before functioning. As it is desirable to get an illumination of 22,000 candlepower, burning for 1 minute, the compression of the charge is an important factor.

RED LIGHT.

The red-light composition consists of—

	Per cent.
Strontium nitrate	$66\frac{2}{3}$
Sulphur (flour)	$16\frac{2}{3}$
Flake aluminum	$16\frac{2}{3}$

This mixture is made up in batches consisting of 24 pounds of strontium nitrate, 6 pounds of aluminum, and 6 pounds of sulphur. It is mixed by hand in a fiber tub and passed three times through a 16-mesh sieve. Great care should be taken to see that the mixture is homogeneous, it being desirable to mix by hand after sifting. This mixture is then dampened with a binder consisting of two ounces of shellac in a quart of alcohol. About a pint of this solution is used for a batch. The mixing of the composition and the thoroughness with which it is packed in the case, as previously mentioned in connection with the white composition, influence the proper burning and candlepower of the light. Manufacturers claim that the alcohol contained in the binder shows a marked influence upon the candle-power. It is, however, not unlikely that the variation in the alcoholic content causes the difference in the mass of the composition.

LOADING COMPOSITION.

The composition is best loaded into the case by means of an air press. The press is constructed with two plungers and a movable platform having two metal shelves supporting the cases. This is not unlike the type of press used for loading rockets. The metal shelves are operated by an eccentric lever, receiving the paper cases in such a manner that they can be securely clamped. After the cases are clamped in position on the shelves they are filled with the loading composition and subjected to a 60-pound pressure. Three successive charges are rammed home in this manner. The compressed composition fills the case to within $\frac{5}{16}$ inch of the top. The first-fire composition is then put in, occupying about $\frac{1}{8}$ of an inch, which gives clearance for the igniter.

FIRST-FIRE COMPOSITION.

The first-fire composition is a simple black-powder quick-fire mixture consisting of—

	Per cent.
Saltpeter	54.5
Sulphur (flour)	36.3
Fine charcoal	9.2

This mixture is slightly dampened with the shellac-alcohol solution previously mentioned.

The composition is mixed in batches consisting of 12 pounds of saltpeter, 8 pounds of sulphur, and 2 pounds of charcoal. These dry ingredients after being mixed by hand are passed through a 16-mesh sieve, again thoroughly mixed, and the screening is repeated. The composition is then dampened with a pint of the solution of shellac and alcohol. The first-fire composition is loaded on top of the illuminating composition while the cases containing the illuminating composition are still in the press, the composition being rammed home by means of the plungers used in compressing the light composition. A stratum of from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch of this composition is thus formed on top of the light composition.

IGNITER.

The igniter for the wing-tip flare is an article made by the Du Pont de Nemours Co., Wilmington, Del., called the Du Pont flash igniter. The composition of this igniter is shown in figure 197. This igniter consists of a small squib or tubular case, filled with gunpowder, used as a firing charge. The tubular case is of paper, $\frac{1}{4}$ inch in diameter by $\frac{3}{4}$ inch long, and has attached to its ends two insulated electric wires, approximately 2 feet in length. When a current is passed through these electric wires or leaders, the charge of gunpowder loaded into the squib is exploded, which in its turn ignites the prime that fires the illuminating composition.

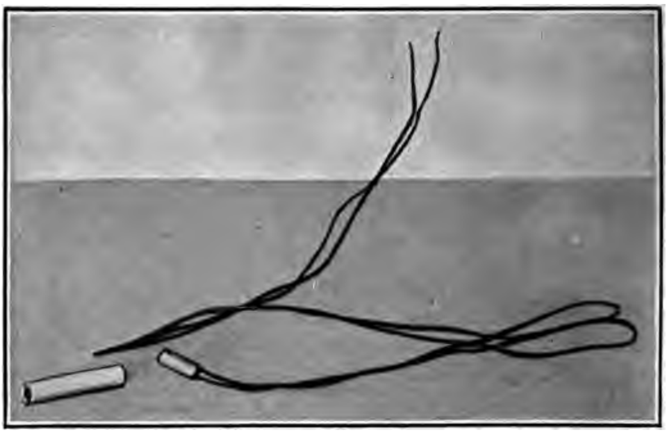


FIG. 196.—Igniter and leaders.

The electric wires or leaders are carried along the outside surface of the case and are threaded through the $2\frac{3}{32}$-inch holes in the wooden plug, issuing out of the plug through the central orifice. These wires are drawn toward, and fixed snugly against, the side of the case.

Figure 196 shows the igniter and connecting leaders; the squib or small tube is shown beside the igniter.

Figure 197 is a longitudinal cross section of the flare in which the igniter and connecting wires are clearly shown. These igniters or squibs are tested by means of a galvanometer three times: first, before they are put into place; second, after they have been installed in the light case; and finally after the light case is completely assembled. These squibs are tested by means of a light current sufficient to give a reading on the galvanometer, but not to an intensity that might cause ignition of the charge.

COVER.

The cover for the top end of the light case consists of a strawboard washer, punched from No. 20 strawboard 1⅞ inches in diameter. This washer has a ¾-inch-diameter hole in the center, and is held in place by means of the cloth inside the drumhead.

Fig. 197.—Cross section of flare.

INSIDE DRUMHEAD.

This inside drumhead is made of muslin and measures 3 inches square. It is pasted on the cardboard cover at the top end of the flare, over the igniter, and is drawn about the sides and securely attached to the case by means of paste.

OUTSIDE DRUMHEAD.

This consists of a piece of Kraft paper 3 inches square, cut from sheets 24 by 36 inches, of 30-pound stock. This drumhead is pasted over the muslin drumhead and drawn down about the end, being attached firmly to the case.

INSIDE WRAPPER.

A muslin wrapper 4½ inches wide by 8 inches long is pasted around the case, having one of its edges flush with the igniter end of the case and extending beyond the other end of the case. That portion of the inside wrapper which extends beyond the edge of the case is now pasted down over the wooden plug.

OUTSIDE WRAPPER.

The outside wrapper is made of 20-pound Kraft paper cut in pieces 4¾ by 7 inches long. This paper is pasted around the outside of the flare, having its edge flush with the top end at which the igniter is placed and overlapping the other end where it is pasted down firmly on the wood plug.

PLUG SEAL.

This seal is for the purpose of holding firmly the electric wires which pass through the base plug and project beyond. Melted sulphur is poured into this hole and fills the small cavity in the base plug.

PAINT.

After the completed flare is dried it is dipped in a black paint, made from lampblack and shellac dissolved in alcohol.

NAME LABEL.

The name label is printed on white paper for the white flare and on red paper for the red flare. It is 1½ inches wide and 5¼ inches long. This label is pasted around the flare at the base-plug end.

FIX THIS END IN HOLDER.
WING TIP FLARE MARK 1
RED—ONE MINUTE
This flare must be tested by galvanometer before attaching to plane.
October, 1918.
Manufacturer.

PACKING CONTAINER.

The packing container consists of the ordinary mailing tube of strawboard, measuring 2½ inches in diameter and 12 inches long, with metal bottom and metal screw cap. This container holds two of the flares.

PACKING WADS.

In packing the flares in the container three packing wads are used. These are of felt, 2½ inches in diameter, one at the bottom of the container, one between the two flares and the other on top just below the screw cap. Care is exercised in packing to insure proper disposition of the wires.

CONTAINER BAND.

A band of 30-pound Kraft paper, 12 inches long and 1½ inches wide, is pasted around the top of the container to cover the joint between the screw cap and the body.

DRUMHEAD.

The drumhead is made of Kraft paper 6 inches square. This is pasted over the top of the container cover, drawn down over the sides and firmly attached.

OUTSIDE LABEL.

Another label is pasted on the side of the container designating the character of the article.

WATERPROOFING.

After the container is thoroughly dry it is dipped in melted paraffin.

PACKING BOX.

Wooden boxes with tin lining are used for packing cases, the flares being tightly sealed by soldering the lining forming the inner tin container. 100 flares are packed in each box.

WING TIP FLARE FLOW SHEET

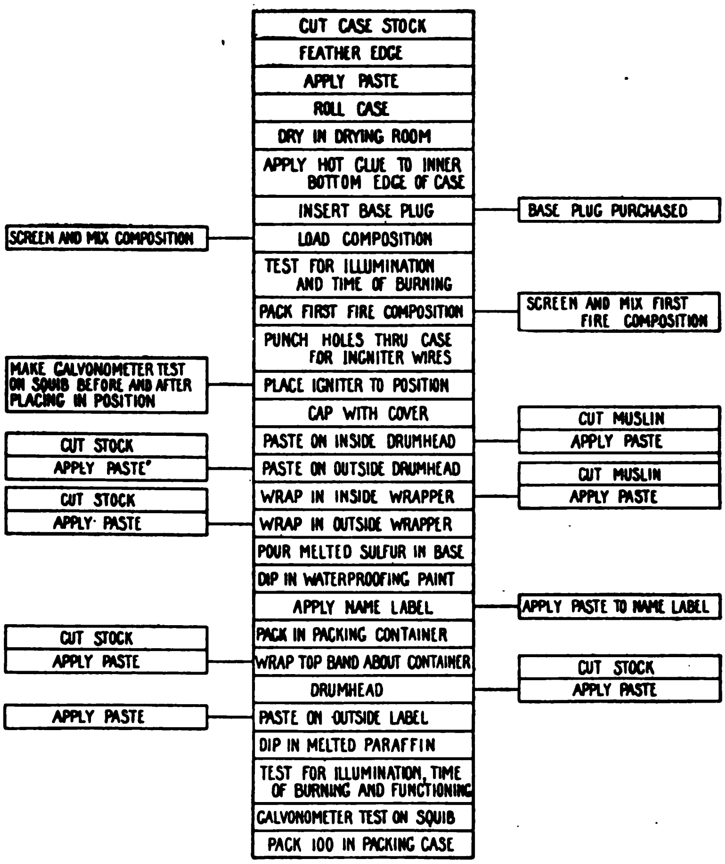


PLATE 16.

WING TIP FLARE MATERIAL CHART

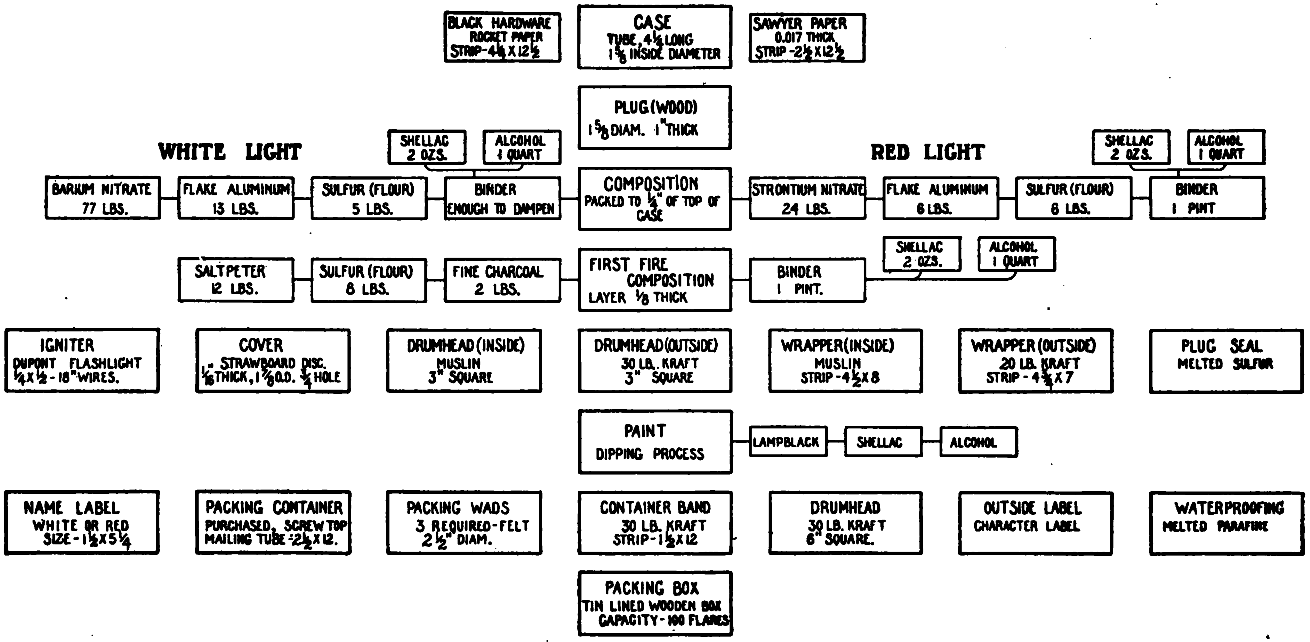


PLATE 17.

Fig. 198.—Smoke torch.

CHAPTER VIII.

SMOKE TORCH.

The smoke torch is a pyrotechnic device which produces a dense cloud, used primarily to form a smoke screen for the purpose of concealment.

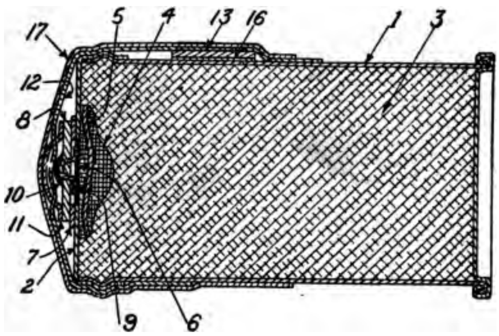


FIG. 199.—Sectional drawing of smoke torch.

SMOKE TORCH.

1. Case.
2. Cover.
3. Composition.
4. First-fire composition.
5. Match (imbedded).
6. Prime.
7. Paper disk.
8. Cardboard.
9. Match (through cardboard).
10. Strike-blob composition.
11. Blob guard.
12. Tape.
13. Card.
14. Staples.
15. Striker composition.
16. Striker protector.
17. Drumhead.
18. Waterproofing.
19. Label.
20. Wrapper.
21. Box.
22. Box lining.
23. Box strap and nails.

Figure 200 shows the concealing effect produced by the functioning of half-a-dozen smoke torches. Climatic conditions and the velocity of the wind materially influence the effectiveness of the smoke torch. Following is given a series

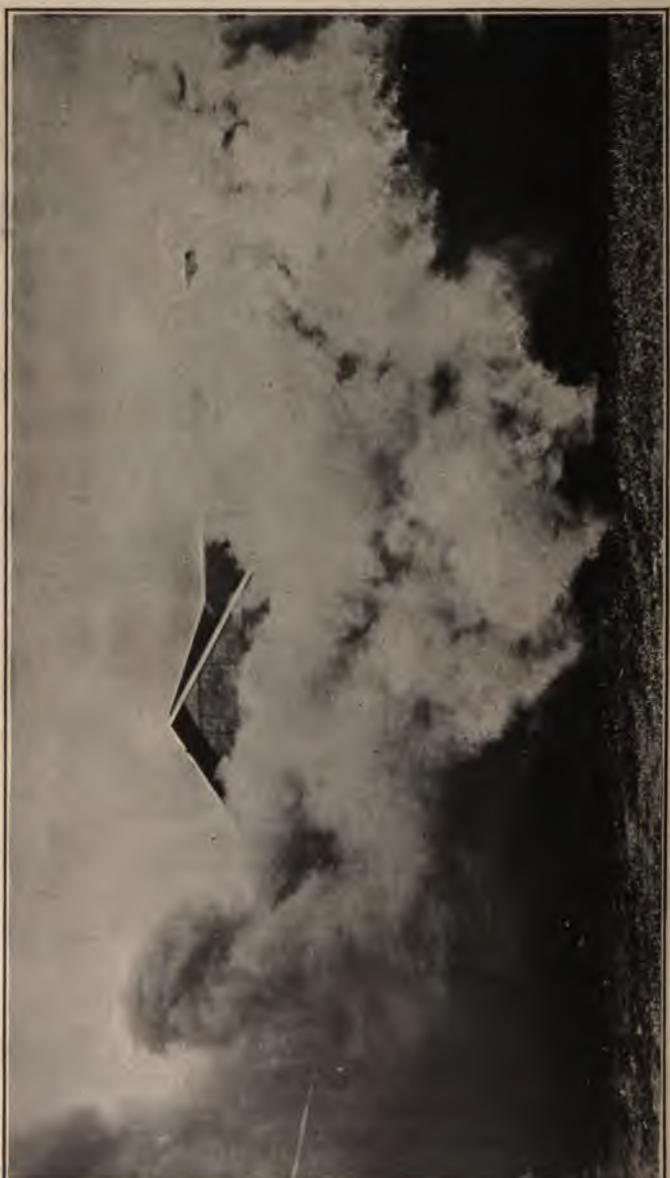


FIG. 200.—Smoke screen.

FIG. 201.

FIG. 202.

FIG. 203.

FIG. 204.

FIG. 205.

Successive stages half-minute intervals of smoke screen under high wind.

of pictures showing the development of a smoke screen under a very unfavorable condition of high winds, as indicated by the way the smoke is blown almost horizontally from the stacks in the background. Despite this unfavorable condition the smoke screen produced from the 16 smoke torches has almost concealed the plant in the background which covers an area of approximately six acres.

The smoke is a dense white cloud with a slight tinge of yellow and apparently does not injure the membrane of either eye or throat. The smoke torch consists of a 20-gauge tinned-iron cylinder, 3⅜ inches in diameter by 6¼ inches high, which is filled with a smoke-producing composition. The cylinder has a cover of tinned iron through the center of which is an orifice 1 inch in diameter, that allows for the ignition of the charge and the emission of the smoke. In firing the smoke torch a striker, which is a small cardboard strip coated on one side with a striking composition, is rubbed across a blob of quick-firing mixture. The blob envelopes a fuse or match, which carries the fire to a prime of first fire placed on top of the smoke-producing composition within the can.

Figure 206 is a photograph of the case to which the cover has been attached. This case is made in the form of a cylinder from No. 20-gauge tinned iron with a double side seam and a double-seamed bottom of the same material. The seam along the side of the cylinder is double-lapped as is also the bottom, so that soldering is unnecessary. This case measures 3⅜ inches in diameter by 6¼ inches high. At a distance of ⅜ of an inch from the top of the cylinder a groove is expanded, which serves as a snap lock to hold firmly in place the cover when forced on the cylinder.

COVER.

The cover is made of the same material as the case, being stamped with the sides drawn to a depth of ¾ inch, and is made to fit snugly over the case. A groove is rolled in the cover to correspond with the groove in the case, thus providing a simple means of assembling or locking the cover in position. A secure lock between the case and the cover is found to be necessary in order that when the torch is in operation a sufficient gas pressure shall be generated in the container to cause the emission of the gases from the orifice

FIG. 206.—Case and cover showing orifice and locking groove.

in the cover to a height of approximately 2 feet. Unless the cover is held firmly in place it is likely to be blown off.

COMPOSITION.

The formula for the smoke-producing torch composition is as follows—

	Per cent.
Barrett-specification pitch	29.2
Saltpeter	47.4
Powdered borax	10.6
Powdered calcium carbonate	4.9
Screened sand	4
Sulphur (flour)	3.9

This formula remains fairly constant. The variable factor, however, is the saltpeter. It is the saltpeter that causes the rapid burning and high heat-producing effect necessary in order to produce the combustion. If the composition burns too freely, producing too high a heat of combustion to function properly, the saltpeter is decreased slightly, and the reverse in the event that the composition is too slow in burning.

MIXING THE COMPOSITION.

Three hundred and ninety-five pounds of saltpeter are ground in a Coggswell mill. Where a number of different

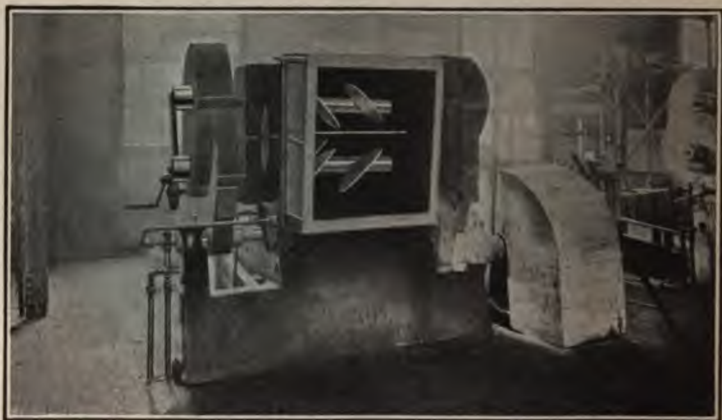


FIG. 207.—Composition-mixing machine.

lots of saltpeter are to be used, it is desirable to sample and make a blend of the several lots, in order to insure uniformity. Ground sand is screened through a mechanical sifter with a 30-mesh screen and dried on a steam table; the steam table being of simple design. Thirty-two pounds of sifted sand are mixed with 395 pounds of saltpeter, and set aside to be introduced into the mixing kettle later. Two hundred and forty pounds of Barrett-specification pitch are melted in a steam-jacketed kettle and introduced into a steam-heated composition mixer, shown in figure 207.

After the pitch has been introduced into the mixer, the previously blended saltpeter and sand are introduced, having been screened a second time. Thirty-five pounds of flour of sulphur, 33 pounds of powdered chalk, or powdered calcium carbonate, and 88 pounds of powdered borax are first screened through a 30-mesh sieve and added, along with the sand, to the melted pitch. The mixing machine is then operated for 30 minutes in order to knead the composition and thoroughly incorporate into the pitch the various constituents above mentioned.

Referring to figure 207, it will be noted that the container is in a tilted position. In this position it is easy to pour the melted composition into portable containers from which it may be transferred to the loading machines. The mixing machine has a steam-jacket container equipped with two shafts on which specially formed blades are keyed. These blades sweep close to the bottom of the container during each revolution of the shaft and prevent the sticking and balling of the magma. These shafts may be revolved in either direction and are so designed that when the container is tilted the shafts may still be in motion.

LOADING.

The melted composition is taken from the mixing machine by means of a small two-wheel bogie holding a container, such a truck as is used for transporting molten slag. The molten composition is now introduced into a steam-jacketed hydraulic press. This is a simple hydraulic press with an orifice in the bottom into which is set a nozzle, having a diameter of three inches. The ram exerts a pressure of approximately 3,000 pounds per square inch, which causes the composition to flow in a plastic form through the 3-inch orifice at the bottom of the press and into the cylinders which are set directly below the orifice. Three and one-half pounds of composition are by this means loaded into these cylinders. As each case is filled, it is trimmed off flush with the top, and a round depression is made in the center of the composition with a knife. The depression is 2 inches in diameter and ½ inch deep. This cavity is for the purpose of containing the first-fire composition.

Figure 208 shows the case filled with composition, in the center of which a depression has been made for the first fire.

FIRST-FIRE COMPOSITION.

The object of the first-fire composition is to ignite the smoke composition. This first-fire composition is a quick-burning mixture, consisting of—

	Per cent.
Saltpeter	63
Black antimony	10.6
Sulphur (flour)	15.8
Meal powder	10.6

This composition is made by screening 18 pounds of saltpeter through a 30-mesh screen. To this are added 3 pounds of black antimony, 4½ pounds of flour of sulphur, and 3

FIG. 208.—Case loaded with composition showing depression for first-fire composition.

pounds of meal powder. These constituents are thoroughly kneaded by hand and then screened through a 30-mesh screen, before introducing the first-fire composition into the depression cut in the smoke composition. The first-fire composition is poured into the depression while the composition is still in a plastic condition.

MATCH.

The match or fuse used in the smoke torch is similar to that used in various other pyrotechnic units, and consists of cotton cord of various strands thoroughly impregnated with a match composition. The formula for this composition is as follows—

	Per cent.
Saltpeter	64.2
Sulphur (flour)	14.3
Powdered charcoal	21.5

Starch water is added, sufficient to make a paste of the combined ingredients.

MIXING COMPOSITION.

This composition is made up in batches of 14 pounds, having 9 pounds of saltpeter, 2 pounds of sulphur, and 3 pounds of charcoal. It is first separately screened through a 30-mesh screen and thoroughly mixed together by hand. The mixture is then twice screened through a 30-mesh screen. A mixture of starch and water is made up, in the proportion of about ½ pound of starch to 2 gallons of hot water. The starch is added to the water in sufficient quantity to form a plastic paste.

MAKING MATCH.

Figure 103 shows the apparatus used for the manufacture of this match. It will be noted that the cotton cord is furnished in spools, which are placed on spindles in such manner that two or more strands of the cord can be combined to form a match of the desired ply. The match used in the smoke torch is what is called "the two-ply," in which two strands from two separate spools are combined, and are passed through the wet composition in the tub. It will also be noted that, after the cotton strands have passed through the composition in the bottom of the tub, they are passed through a small hole, which acts as a wiper to remove the surplus composition. The composition must be sufficiently dampened, so that the cord will be thoroughly impregnated. The match is drawn through the composition and wiper, and reeled upon drying racks, as shown in figure 104. This rack is mounted in front of the mixing tub in such a manner as to move upon its shaft so that the operation of reeling can be done rapidly by one man, and so that the strands are separated from each other.

To make this match a quick-match, meal-powder dust is sprinkled on it while it is still in a damp condition. After the racks have been filled they are set aside to dry. A slow drying at room temperature is preferable to rapid drying, in order to prevent the match from becoming excessively brittle. Open-air drying is to be preferred to drying in drying rooms. After the match is thoroughly dry, requiring approximately twenty-four hours, it is removed from the rack and is then ready for cutting into the required lengths.

The match is cut into lengths about two inches long, and two of these are crossed and imbedded in the first-fire composition.

PRIME.

The cover of the container is slipped on and forced firmly into place, being locked by the seam previously mentioned. Through the 1-inch hole in the cover is poured a special prime mixture, which serves to ignite the first fire and also to seal the hole in the cover. The composition of this prime is as follows:

	Per cent.
Meal powder	97
Orange shellac	3

Enough denatured alcohol is added to make a stiff paste.

The two dry ingredients—namely, meal powder and powdered orange shellac—are first thoroughly mixed by hand in the proportions of 8 pounds of meal powder to ¼ of a pound of orange shellac. The denatured alcohol is now added and worked into the mass until a mixture is formed having the consistency of stiff paste. This prime is introduced through the hole in the cover and thus comes in direct contact with the first-fire composition. The action of the alcohol upon the orange shellac readily hardens the mass and forms a cementlike seal over the top.

PAPER DISK.

After the prime is hardened a Kraft-paper disk, 2 inches in diameter, with an inch hole punched through the center, is pasted over the top of the case, the hole concentric with the orifice in the top of the case. The Kraft paper used for this disk is 80-pound stock. (Fig. 209.)

CARDBOARD DISK.

This consists of a cardboard disk, 2 inches outside diameter, cut from No. 50 strawboard. Through the center of this disk are punched two small holes, about ¼ of an inch apart, through which is threaded the two-ply quick match, which has already been attached to the prime. This match extends

FIG. 209.—Case with protecting disk, striker, and strike blob.

over the cardboard disk about an inch, and is held firmly in place by means of the strike blob. The cardboard disk is attached to the paper disk by means of paste.

STRIKE BLOB.

The strike blob is a quick-firing composition, composed of—

	Per cent.
Chlorate of potash	89
Red gum	7.4
Charcoal	3.6

This composition is mixed in the proportions of 24 pounds of chlorate of potash, 2 pounds of red gum, and 1 pound of charcoal. The chlorate of potash is first thoroughly pulverized and the three ingredients are then carefully mixed, and water is added to bring the mass to the consistency of heavy paste. A small blob of this paste is supplied by means of a brush to the exposed match on top of the cardboard disk.

BLOB GUARD.

The blob guard consists of a tin disk, ½-inch in diameter, stamped in the form of a shallow hat with a $\frac{3}{16}$-inch rim, the crown of the hat being $\frac{3}{16}$ inch high. On two opposite sides of the crown of the hat are cut slots ⅞ inch long, just above the rim, of a width that will permit the threading of the tape.

TAPE.

A woven cotton tape, ¾ inch wide and 7 inches long, is passed through the slots in the blob guard.

STRIKER CARD.

The striker card consists of a piece of No. 100 strawboard cut ⅝ by 1½ inches. This striker card is shown very clearly in figure 209. It is attached about an inch from the end of the tape by means of two wire staples, a stapling machine being used for this purpose.

STRIKER COMPOSITION.

The materials used for this composition are as follows:

Red phosphorus and fine charcoal, dampened with gum water.

Gum water is made by adding 5 pounds of gum arabic to 2½ gallons of water. The red phosphorus and gum water are added to make a thick paste, and a slight amount of charcoal is added to roughen the mixture when dry. A thin coating of this composition is then applied to the card, similar to that on the side of a safety-match box.

The tape is threaded into the blob guard with the two ends of tape projecting over the opposite sides of the case. Figure 209 shows the completed case, the cardboard disk, and striker blob, with the blob-guard tape and striker ready to be put in proper position.

STRIKER PROTECTOR.

A piece of oil paper, 1½ inches long and ⅝ inch wide, is glued on the side of the cylinder in such a position as to come directly beneath the striker when the tape has been pulled over the top into its required position. The object of this protector is to prevent the paste of the drumhead from causing the striker to adhere to the side of the cylinder.

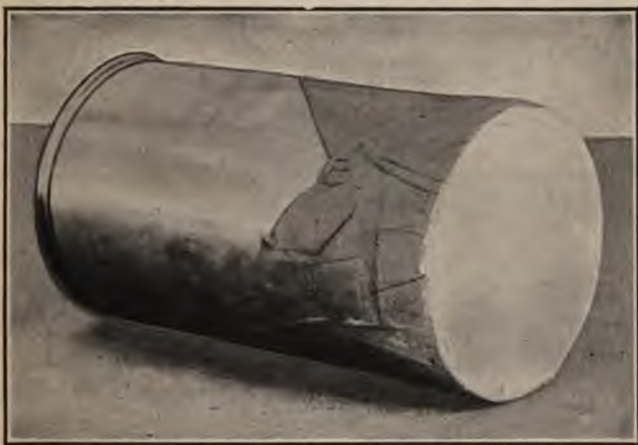


FIG. 210.—Case showing drumhead in position.

DRUMHEAD.

A piece of Kraft paper, 80-pound stock, is cut 6¾ inches square, with 1¼ inches off at each corner. This drumhead is pasted over the top of the case in such a manner as to inclose the entire top and down over the sides, holding the tape and striker, with a small portion of the tape projecting from under the paper to be used for readily tearing off the drumhead when it is desired to use the torch, as shown in figure 210.

WATERPROOFING.

A waterproofing composition of asphaltum dissolved in gasoline is made up and the entire smoke torch is dipped therein. This hardens and forms a thorough waterproofing for the torch.

LABEL.

Below is a facsimile of the label, printed on yellow paper, which is pasted on the side of the case:

> SMOKE TORCH MARK 1.
>
> To Fire—Tear tape right off to expose firing composition, rub the tablet of red composition (which is attached to the underside of tape) smartly but firmly across exposed black dot of composition in center of top.
>
> Keep Dry. Stand Upright.
>
> *October, 1918.*
>
> Manufacturer.

WRAPPER.

Before packing for shipment, each torch is inclosed in a wrapper made from 200-pound Bogus paper, cut 6 by 13½ inches. This wrapper is shaped around the torch in the form of a cylinder, and is not secured in any way. It is held in place when the torches are packed in their shipping case, preventing abrasion and adhesion.

BOX LINING.

A tin lining, 18 by 6 by 14½ inches, is inserted in the wood case, which will hold 20 completed smoke torches. A tin cover is clenched in place and hand soldered. It is also waterproofed with the asphaltum-gasoline mixture, such as is used for waterproofing the torch.

BOX STRAP AND NAILS.

After the tin cover has been waterproofed a wood cover is nailed on the box by means of coated-wire nails, and short pieces of box strap are also nailed over the top and around the ends for additional security.

SMOKE TORCH FLOW SHEET

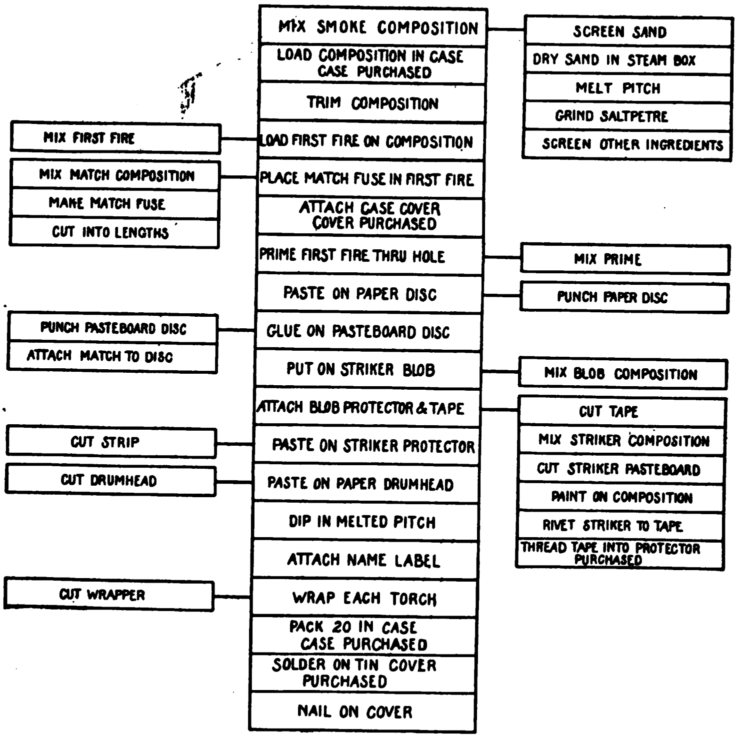


PLATE 18.

SMOKE TORCH MATERIAL CHART

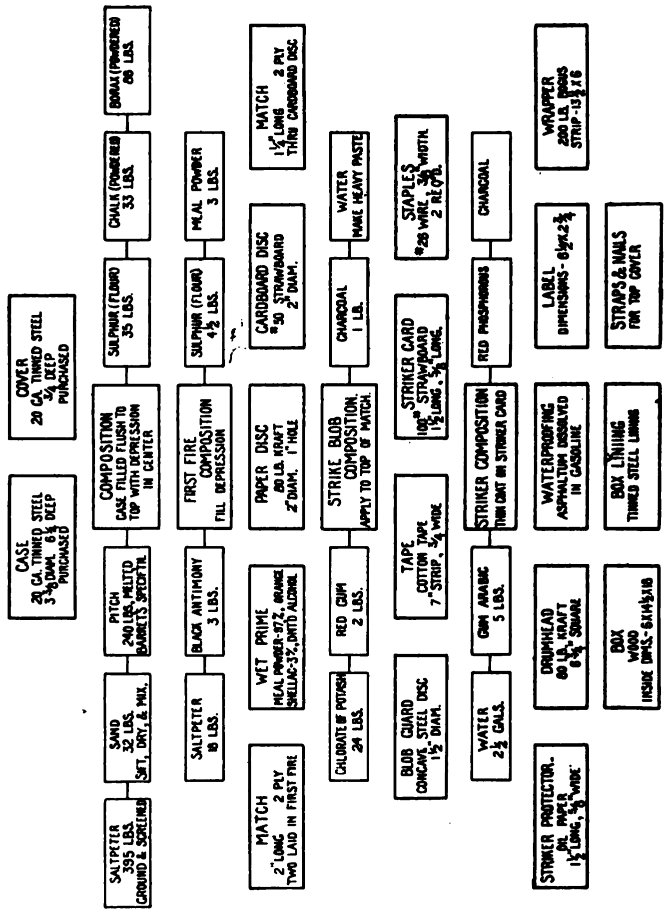


PLATE 19.

FIG. 211.—Standard photometer used in the Government testing laboratory.

CHAPTER IX.

PHOTOMETRY.

The measuring of the intensity of light given off by the burning of pyrotechinic pieces designed for signaling and illumination is an important factor and deserves careful consideration. Consequently a chapter on photometry is a necessary part of this work. The light given off by the burning of a signal must be of such an intensity as to make it visible from a distance prescribed by military specifications; also, the degree of illumination where pyrotechnic pieces are used for this purpose must be of such intensity as to throw a light over a definite area from a given height for which specifications are prescribed. It is necessary that there be devised means of testing for both signaling and illuminating articles that shall insure their conforming to specifications.

Intensity of light must be measured by means of its quantity of illumination upon a given surface and a comparison of this illumination made with that of a light source having a known value. Thus a photometer is an apparatus by which we may compare the luminous intensities of two given sources of light. The fundamental principle of the photometer depends upon throwing the illumination produced from two different sources upon a given surface and adjusting the distance between the source of light and the screen until the degree of illumination shown by each is equal.

This fundamental principle, which is the basis of every photometer, is an immediate consequence of the fact that the eye appreciates with maximum precision the equality of the illumination of two surfaces, while the precision with which this organ can determine the ratio of two illuminations is illusory.

As a means of making a comparison and giving valuation to an unknown source of light, some definite value must be fixed upon for the known source of light. The candle, owing to its common use at a time when photometric investigations were at their inception, was first taken as a standard, and though its proportions have varied in the course of time, it remains to-day as the unit for comparison.

The second fundamental feature to be considered is that the light rays emanating from a given source radiate in all directions, though each ray is promulgated in a straight line, in consequence of which it will be seen that the quantity of illumination falling upon a surface of given area will be in some ratio with its distance from the source of the light. Furthermore, it is evident that if the light is at the center of a hollow globe the total illumination will fall upon the inner surface and will be constant, no matter what the size of the sphere. Consequently, as the area of a sphere is in proportion to the square of its radius, the quantity of light upon a unit area must vary inversely as the square of the radius.

The unit distance at which to observe the illuminating power of a candle has been taken as 1 foot, hence our unit is the foot-candle. When moved to any other distance the proportionate illumination becomes $\frac{I}{d^2}$ where I is the unit or multiple of the unit, depending upon the number of candles to which it is equivalent, and d is the distance, in feet, of the illuminated surface from the light source. This value is the fundamental one for all determinations.

The specifications of the standard English candle are as follows:

In external dimensions it shall be 10 inches long, with 0.9 inch diameter at its bottom and tapered to 0.8 inch at its top.

The wick contains 3 strands of cotton plaited together, each strand consisting of 18 threads. The strands should be plaited with such closeness that, when the wick is laid upon a rule and extended by a pull just sufficient to straighten it, the number of plaits in 4 inches shall not exceed 34 nor be less than 32.

The wicks should be steeped in a liquid made by dissolving 1 ounce of crystallized boracic acid in a gallon of distilled water, to which 2 ounces of liquid ammonia have been added.

The wicks are then to be pressed until most of the liquid has been removed and to be dried at a moderate heat. Twelve inches of the wick thus made should not weigh more than 6.5, nor less than 6, grains. Ten untreated wicks when burned should have a weight of ash of not more than 0.025 grain.

The spermaceti of which the candles are made should be extracted from crude sperm oil, and should be so refined that it has a melting point lying between 112° and 115° F. Since the candles made from the spermaceti alone are brittle, and the cup which they form in burning has an uneven edge, it is necessary to add a small portion of beeswax or paraffin to remedy these defects. The best air-bleached beeswax, melting at about 199° F., is to be added to the spermaceti in proportions of not less than 3 and not more than 4½ per cent.

Candles should weigh about ⅙ of a pound and the tension on the wick during molding should be about 24 ounces. The rate of consumption on burning should be 120 grains per hour. The height of the flame now accepted is 1.77 inches. The wick must be observed carefully and snuffed to maintain this height.

The standard candle has several disadvantages. The candlemakers have never been able to meet the specifications with a degree of accuracy to insure a uniform flame. The open flame is sensitive to air currents and the height of the flame difficult to maintain constant, due to a certain irregularity of cupping and the attention and skill called for in snuffing. At the present time the unit is so small as to add further difficulties in comparison with the size of the units to be measured.

LAMPS.

Many different types of burners have been designed and built in the attempt to obtain a flame of known value and capable of reproduction without variation. The lamp which has up to the present time met with approval and is the best known reliable standard is the Pentane lamp. This has undergone several modifications, and the present pattern, intended to represent ten times the candlepower of the Parliamentary candle described above, is the official standard of the London Metropolitan Gas Referees.

The Pentane lamp consists of a steatite ring, or Argand burner, to which pentane vapor is supplied from a flat tank located well above the burner. This tank holds liquid pentane, over the surface of which air passes. The air, becoming saturated with the heavy pentane vapor, falls through a syphon pipe to the burner. The flow is regulated by a tap on the outlet, or a valve on the air inlet of the pentane saturator. No wick is needed. A tall chimney draws the flame up with a considerable draft and insures a steady light. A second outer chimney, concentric with the first, warms the air that is supplied to the flame. No glass chimney is required, but the top of the flame may be inspected for adjustment through a mica window. The top of the flame facing the photometer is shielded by a screen giving a clear opening of 1.85 inches; notwithstanding this, the height of the flame must be carefully adjusted. The total height of the apparatus is about 2 feet 10 inches.

The first satisfactory and practical method of measuring candlepower was the Bunsen method. This method consists in placing a semi-transparent screen of parchment or paper in the path of a line drawn between the two lights, so that the surface of the paper is perpendicular to this center line, and one side of the paper is illuminated by the standard light, and the other side by the light to be measured. A spot in the center of the screen is treated with paraffin to give it a greater transparency. By observing the spot on the paper, or translucent screen, this spot will appear either lighter or darker than the surrounding surface, in proportion as the light thrown against its surface varies. This screen should be shifted until such a distance is reached as shall cause the spot to blend its shade with the surrounding surface. At this point, the screen may be regarded as in balance. The exact point at which this balance occurs is sometimes difficult to determine, but by moving the screen to one side and then to the other until the spot becomes discernible in both directions, a mean position can be established. Owing to the difficulty of viewing both sides of the screen in this method, several auxiliary devices have been devised, by means of which both sides of the screen can be viewed with the full vision. The proper location of mirrors is the usual scheme. This elimiway of precision and has been largely adapted for both laboratory and practical work in which portable instruments are required. This method is known as the Lumner-Brodhun photometer, and, owing to its almost universal adoption, will be described in detail here.

The illustration shows the essential parts. Light from lamps in the directions A and B falls on the two opposite sides of an opaque screen S. This screen is made of some carefully prepared white material, such as compressed magnesia or barium sulphate. Two mirrors or totally reflecting prisms are placed at M_1 and M_2, and a pair of prisms are

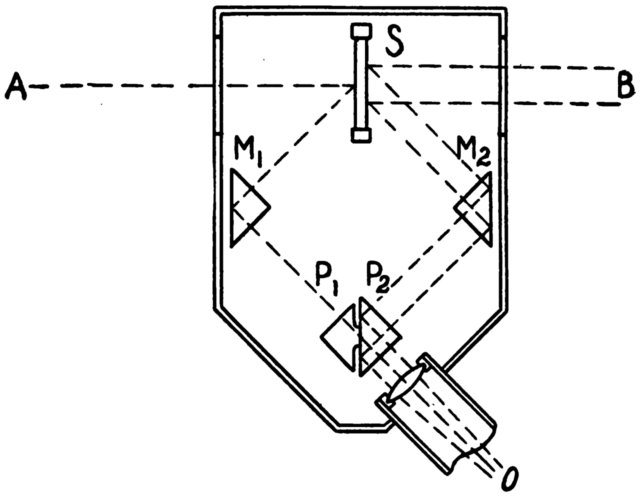


FIG 213.—Diagram of essential parts of Lumner-Brodhun photometer.

placed at P_1 and P_2. These consist of an ordinary right-angled prism P_2 with a flat base, and a prism P_1, also right-angled, but having part of its base removed by sand blasting or etching. The two bases are brought under pressure into optical contact. The whole arrangement is contained in a blackened box. Light from the direction A falls on the screen S, and is reflected in the mirror M_1. Thence some of it passes straight through a telescope to the observer in the direction O while the rest, falling on the sand-blasted portion of the base of prism P_1 which is not in optical contact, is stopped.

The light from the direction B, shown for clearness by a double line, is reflected from the other face of the screen S, onto the mirror, or prism, M_2. Some of it passes straight through the prism P_2 and is lost, while the rest falls on that part of the base of P_2 which is not in optical contact and is totally reflected to the telescope.

When looking through the eyepiece of the telescope, an unbalanced condition exist: a field of light is observed in which a center spot is revealed in unequal brightness. By moving the apparatus to the proper position between the lights the field assumes a uniform luminosity. The solving for the candlepower of the light to be measured is then performed in the same way as with the simpler Bunsen apparatus.

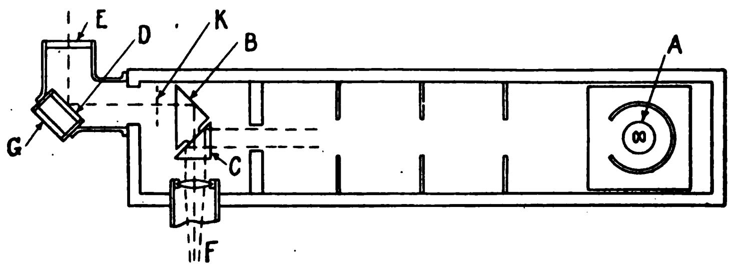


FIG. 214.—Diagram showing details of portable photometer.

Photometric work carried on at one of the pyrotechnic manufacturing plants was performed with satisfactory results when a portable commercial instrument was used. This instrument was designed by C. H. Sharp and P. L. Millar. Its adaptability to pyrotechnical work merits notice here.

The test lamp A in this case is the adjustable member, instead of the prisms. B and C are two prisms arranged to carry the illuminations from the two sources of light to the telescope F in the same manner as in the Lumner-Brodhun photometer. In this adaptation of the Lumner-Brodhun device, the center or common screen is not present. Rays from the tested light fall upon the diffusing screen E, whose absorption value is known, then reflected by the mirror D to the prism C, and thence to the eyepiece. In case of stronger light sources than that to which the scale indicates, an absorption screen K can be mounted on a swivel device to be thrown into the path of light. The values then indicated will represent a definite per cent. of the true candlepower, according to the known value of the absorption screen. This known value of the absorption screen is a calibrated one and introduces only a negligible amount of error. A still further reduction is available in the reversible elbow piece G D whose surface C is of a diffusing character. The scale reading is directly in candlepower and only requires further computation in case the additional absorbing means are used. In such a case, in the formula, I is the actual candlepower. R is the candlepower reading on the scale and M and N are the per cent values of the light transmitted, respectively, by the diffusion reflector and the absorption screen, and d the distance, in feet, of the tested light from the instrument.

Fig. 215.—Exterior view of photometer laboratory.

The test lamp employed is an incandescent bulb and uses a current and voltage obtainable by the use of four standard dry cells. The lamp is calibrated to be of the correct intensity for the scale. The electric current must be watched closely with an ammeter, and an adjustable resistance.

Figure 211 of the front of the photometer, shows the large knob, used to move the test lamp into balance, as well as the graduated scale indicating the candlepower of the adjusted position of the lamp. The movement of the lamp is effected by means of a non-stretchable cord, which passes around pulleys, and comes to a drum turned by the large external knob.

In the installation mentioned previously for pyrotechnic testing, the apparatus is used to measure the candlepower of aëroplane flares and other pyrotechnic pieces. An external view of the building used is shown in figure 215.

The fireproof enclosure used for burning the pieces to be tested is shown in figure 216.

FIG. 216.—Fireproof chamber for testing samples.

The photometer is located at a distance of 48 feet from the burning piece.

FIG. 217.—Interior view of photometer laboratory.

Fig. 217 shows the burning chamber at this 48-foot distance. At this distance candlepowers ranging from 3,000,000 down to 6.4 can be measured with the aid of absorption screens which can be placed in the path of light from the test lamp or the tested pieces.

With certain precautions, results within reasonable accuracy can be obtained. The amperage flowing through the test lamp must be maintained at the tested value. All reflected light must be screened so as not to fall within the field. Adjacent background must be of a dark color and rough of surface. In the case of pyrotechnic pieces proper draft must be maintained to remove the smoke. The full flame of the tested piece should be exposed to the field.

Periodic recalibration of the ammeter and test lamp must be made. When a convenient laboratory is not available a test ammeter and lamp should be provided for this purpose.

CHAPTER X.

STORAGE OF MILITARY PYROTECHNICS.

The large production of military pyrotechnics required correspondingly large storage facilities, which prompted the Ordnance Department to request a report.

In December, 1918, the following report was drawn up, based upon the best information obtainable at that time. This report covers merely the essential points as to the storage of pyrotechnic articles, with a short statement in reference to the dangerous factors, where such exist, occurring in the various compositions.

Considerable study could well be undertaken on this subject as it is one concerning which only experience can give us definite information. Such experience as the manufacturers of fireworks have had is indicative, but by no means conclusive.

The following list of representative formulas used in compositions covers a wide range, and may be used for the purpose of comparison with other formulas of a similar nature, with regard to their fire and explosion hazard.

REPRESENTATIVE FORMULAS USED IN COMPOSITIONS.

No. 1.—Rocket-driving, fuse, signal-expelling charge, and meal-powder composition—

	Per cent.
Saltpeter (KNO_3)	56.0
Sulphur (flour)	12.2
Charcoal (No. 10—No. 20—10XX) (D. C. XX—No. 20 coarse—No. 36 coarse.)	31.8

No. 2.—Rocket smoke-signal and rocket smoke-tracer composition—

	Per cent.
Saltpeter (KNO_3)	37.2
Sulphur (flour)	25.6
Arsenic disulphide (realgar; As_2S_2)	37.2

No. 3.—Rocket white-signal composition—

	Per cent.
Barium nitrate ($Ba(NO_3)_2$)	71.4
Aluminum powder	10.7
Aluminum flake or bronze	7.2
Sulphur (flour)	10.7

No. 4.—Rocket red-signal composition—

	Per cent.
Strontium nitrate ($Sr(NO_3)_2$)	66.6
Potassium chlorate ($KClO_3$)	25.0
Orange shellac (powdered)	8.4

No. 5.—Rocket green-signal composition—

	Per cent.
Barium chlorate ($Ba(ClO_3)_2$, $2H_2O$)	55.5
Barium nitrate ($Ba(NO_3)_2$)	33.3
Orange shellac (powdered)	11.2

No. 6.—White rifle-light and white Véry-light composition—

	Per cent.
Barium nitrate ($Ba(NO_3)_2$)	70.6
Aluminum, powder	19.6
Aluminum flake or bronze	9.8

No. 7.—Red rifle-light and red Véry-light composition:

	Per cent.
Potassium chlorate ($KClO_3$)	72.7
Strontium carbonate ($SrCO_3$)	15.2
Orange shellac (powdered)	12.1

No. 8.—Green rifle-light and green Véry-light composition—

	Per cent.
Barium chlorate ($Ba(ClO_3)_2$, $2H_2O$)	90.0
Orange shellac (powdered)	10.0

No. 9.—White position-light composition—

	Per cent.
Barium nitrate ($Ba(NO_3)_2$)	69.8
Sulphur (flour)	16.3
Aluminum flake or bronze	13.0
Antimony sulphide (Sb_2S_3)	.6
Stearin	.3

No. 10.—Red position-light composition—

	Per cent.
Potassium chlorate ($KClO_3$)	37.5
Strontium nitrate ($Sr(NO_3)_2$)	50.0
Orange shellac (powdered)	12.5

No. 11.—Green position-light composition—

	Per cent.
Barium chlorate ($Ba(ClO_3)_2$, $2H_2O$)	23.2
Barium nitrate ($Ba(NO_3)_2$)	59.0
Potassium chlorate ($KClO_3$)	6.3
Orange shellac (powdered)	10.5
Stearin	1.0

No. 12.—Position-lights first fire—

	Per cent.
Saltpeter (KNO_3)	56.5
Arsenic disulphide (As_2S_2, realgar)	9.4
Antimony sulphide (Sb_2S_3)	9.4
Sulphur (flour)	18.8
Dextrin	5.9

No. 13.—Aëroplane-flare and white wing-tip-flare composition—

	Per cent.
Barium nitrate ($Ba(NO_3)_2$)	76.0
Aluminum flake or bronze	9.9
Aluminum powder	8.1
Sulphur (flour)	4.0
Castor oil, AA	2.0

No. 14.—Aëroplane-flare first fire—

	Per cent.
Barium nitrate ($Ba(NO_3)_2$)	44.5
Saltpeter (KNO_3)	33.3
Orange shellac (powdered)	11.1
Sulphur (flour)	11.1

No. 15.—Wing-tip flare (red tinge)—

	Per cent.
Strontium nitrate ($Sr(NO_3)_2$)	66.6
Sulphur (flour)	16.7
Aluminum powder	16.7

Add sufficient liquid orange shellac to make adhesive.

No. 16.—Smoke torch—

	Per cent.
Saltpeter (KNO_3)	47.4
Pitch (medium or soft, low melting point, Black Diamond roofing)	29.2
Borax ($Na_2B_4O_7,10H_2O$)	10.6
Chalk ($CaCO_3$)	4.9
Sand (SiO_2)	4.0
Sulphur (flour)	3.9

No. 17.—Smoke-torch firs fire—

	Per cent.
Saltpeter (KNO_3)	63.0
Sulphur (flour)	15.8
Antimony sulphide (Sb_2S_3)	10.6
Meal powder (see formula No. 1 above)	10.6

No. 18.—Smoke-torch blob—

	Per cent.
Potassium chlorate ($KClO_3$)	88.9
Red gum (gum Kauri)	7.4
Charcoal (fine)	3.7

No. 19.—Smoke-torch striker—

Red phosphorous.
Charcoal (fine).

No. 20.—Prime composition—

	Per cent.
Meal powder (see formula No. 1 above)	97.0
Orange shellac (powdered)	3.0

No. 21.—Detonating caps: Formula not specified.

No. 22.—Matches: Formula not specified.

No. 23.—Rifle smokeless powder: Formula not specified.

DISCUSSION OF THE POSSIBLE CHEMICAL REACTIONS IN THE REPRESENTATIVE FORMULAS ON PROLONGED STORAGE.

No. 1.—In this formula, saltpeter, sulphur, and charcoal are the constituents. The general consensus of opinion of the manufacturers is to the effect that this formula, which is the driving charge of rockets, will not deteriorate on protracted storage; however, it has been pointed out by one of the manufacturers that changes in temperature might cause a separation of the compressed charge from the wall of the tube, due to the fact that there is a different coefficient of expansion between the compressed mass and the tube, which would cause the driving charge to operate too sharply and not to function as originally designed.

No. 2.—This formula consists of saltpeter, sulphur, and arsenic disulphide, and is used in the rocket-smoke compositions. The consensus of opinion of manufacturers seems to indicate that the combination of saltpeter, sulphur, and arsenic disulphide is a stable mixture and will not deteriorate.

No. 3.—In this formula, barium nitrate, aluminum powder, aluminum flake, or bronze, and sulphur are used for the rocket white-signal composition. The consensus of opinion seems to point to the stability of this mixture.

No. 4.—In this formula, strontium nitrate, potassium chlorate, and orange shellac, finely powdered, are used for rocket red signals. One of the manufacturers states as follows:

"This is a dangerous composition, and mixtures of this kind should be kept from all other explosive materials, for the reason that they have a tendency to sympathetic explosion. Such mixtures are extremely active, and with a small percentage of moisture, are, in addition, very dangerous from the standpoint of safety."

It is further pointed out that strontium nitrate tends to absorb moisture from the air. This absorbed moisture will dissolve some potassium chlorate, which solution passes through the walls of the containing tube by capillary action, subsequently forming fine needlelike crystals on the outside. These crystals prevent the proper functioning of the piece and add an element of great danger.

No. 5.—In this formula, barium chlorate, barium nitrate, and orange shellac, powdered, are used. This composition, as reported by one of the manufacturers, is both dangerous and treacherous, on account of the presence of barium chlorate, since chemical reaction may take place. It is not clear, nor are there any records available, as to what chemical reaction actually takes place; the inference being, however, that an acid develops on standing, which in combination with the chlorate and the fine organic powder, such as shellac, makes this mixture rather treacherous.

No. 6.—In this formula, barium nitrate, aluminum powder, and aluminum flake, or bronze, are used. This, according to the manufacturers, appears to be a safe mixture.

No. 7.—In this formula, potassium chlorate, strontium carbonate, and orange shellac are used. We have not obtained any definite recommendations in regard to this mixture, but, due to the fact that the composition contains approximately 15 per cent. of strontium carbonate, the chances of the development of a free acid seem to be more or less remote, and we would be inclined to regard this mixture as other than in the treacherous or dangerous class.

No. 8.—This composition consists of barium chlorate and shellac. Criticisms might be made regarding this mixture that have been previously made where chlorates and finely powdered organic materials are mixed. There appear to be no data in regard to the stability of this mixture and, in the absence of further information, we would be inclined to include it with formula No. 5, although the presence of barium nitrate in the latter formula would probably make it more dangerous than the simple mixture of barium chlorate and orange shellac.

No. 9.—This formula consists of barium nitrate, sulphur, aluminum powder, antimony sulphide, and stearin. The dangerous constituent in this mixture is the antimony sulphide, which, according to the manufacturers, has a tendency to develop acid. However, it is pointed out that if the antimony sulphide is kept down to a reasonably low per cent. this danger is minimized.

No. 10.—This consists of potassium chlorate, strontium nitrate, and orange shallac, powdered. As this composition has the same ingredients as No. 4, except that the proportions are different, we would give it the same classification as No. 4.

No. 11.—This consists of barium chlorate, barium nitrate, potassium chlorate, shellac, and stearin. It is classified by manufacturers as unsafe, the same argument being used as in the case of No. 5 composition.

No. 12.—This consists of saltpeter, arsenic disulphide, sulphide of antimony, sulphur, and dextrin. Referring back to the discussion under formula No. 9, we have pointed out criticisms made by manufacturers in reference to the amount of antimony sulphide in the compositions where the percentage is rather large. We would, therefore, classify this mixture as dangerous.

No. 13.—Here barium nitrate, flaked aluminum, powdered aluminum, sulphur, and castor oil are used. This composition is rated by the manufacturers as one of the safest.

No. 14.—Here barium nitrate, potassium nitrate, shellac, powdered, and sulphur are used. This composition is regarded as safe by the manufacturers.

No. 15.—Here strontium nitrate, sulphur, aluminum powder, and orange shellac are used. This is likewise regarded as reasonably safe.

No. 16.—Here potassium nitrate, pitch, powdered borax, chalk, sand, and sulphur are used. This also is regarded as reasonably safe.

No. *17.*—In this formula saltpeter, sulphur, antimony sulphide, and meal powder are used. The same argument as previously made in reference to the presence of antimony sulphide applies in this case, and the manufacturers regard the mixture as dangerous.

No. 18.—This consists of potassium chlorate, red gum, and charcoal. It is regarded as a dangerous mixture.

No. 19.—This is composed of red phosphorus, fine charcoal, and gum arabic. The presence of red phosphorus is indicative of the treacherous character of this composition, and it should be regarded as dangerous.

No. 20.—This is composed of meal powder and ground shellac, and is regarded as safe.

Nos. 21, 22, 23.—These are not specified by formulas. Any formula for detonating caps and matches would be indicative of an unsafe composition. The rifle smokeless powder mentioned in No. 23 may be stored with reasonable safety.

DISCUSSION OF CLASSIFICATION AND FORMULAS.

Concerning the foregoing formulas, it should be noted that all discussion of the proportions of the different ingredients has been purposely avoided, for the reason that the practice of the manufacturers varies in this respect almost from day to day.

The percentages mentioned with the various formulas represent average practice rather than actual proportions used. The manufacturers state that the variations in the quality in the different lots of chemicals obtainable by them require constant changes in their composition. Their results are a matter of trial only, and they vary their compositions until proper functioning is obtained, often groping in the dark for some time before succeeding. They state that this applies particularly to certain chemicals of American manufacture, the grade of which is more uneven than that of the chemicals of foreign origin obtainable before the war.

Regarding the relative safety during storage of pyrotechnic pieces containing these formulas, it can be said in general terms that those including fulminating caps or matches may possibly be regarded as a little more dangerous than the others. Instances are known where these matches have detonated merely from dropping on the floor.

All mixtures represented by formulas that do not contain chlorates may probably be regarded as relatively safe, since decompositions are less likely to take place. The presence of moisture to the extent of 0.5 per cent. or more, in mixtures containing chlorates or nitrates, is regarded by some as contributing elements of danger during storage, owing to the decompositions that may take place after a lapse of time.

In the foregoing formulas we have quoted the opinions of manufacturers who have handled these various compositions: some for a period of many years, in the manufacture of fireworks of various sorts; others for only a short time, in the manufacture of military pyrotechnics. Their suggestions are based wholly on experience and not on the possible or probable chemical reactions which might take place under adverse conditions of storage. It is our opinion that we must not neglect the study of these compositions from the standpoint of the intimate contact of the various substances which is produced by the pressure used in the formation of the different pieces. The interpenetration of the substances may be increased, but certainly will not be decreased, by the lapse of time. Take the two well-known cases where the intimacy of contact between two substances results in a mutual exchange, such as carbon into iron and iron into carbon during the old and well-known cementation process for the manufacture of steel; and the well-known experiment of Rose, establishing the mutual interpenetration of lead into gold and gold into lead, when plates of lead and gold are placed in intimate contact. A very striking case is the interaction between dry sodium carbonate and barium sulphate when compressed; as high as 80 per cent. of the barium sulphate being converted into barium carbonate under these conditions.

Taking these examples into consideration, and the further fact that a large majority of these compositions exist in a state of compression, the possibility of chemical changes must be considered. The growing intimacy of the mixtures may have a tendency toward spontaneous combustion on the one hand, or toward a deterioration of the composition on the other.

GENERAL DISCUSSION ON THE EXPERIENCE OF MANUFACTURERS WHO HAVE STORED PYROTECHNICS.

A number of pyrotechnic manufacturers have expressed their opinions, based on their experience over a number of years, as follows:

As regards the length of time pyrotechnic pieces may be safely stored, one manufacturer states that he has held pieces in storage as long as twenty years and found them to still function properly. However, he quotes the European rule of destroying material after a period of three years. He also states that signal rockets as used on shipboard are usually destroyed after a period of three years' storage, except where the ships ply in southern climates, when such units are destroyed after the second year.

Another manufacturer states that he has stored pyrotechnic articles for ten years without serious depreciation. Another manufacturer states that during a period of thirty years he has stored fireworks at various times, frequently during long periods, and has never had a fire or found that any serious changes had taken place in the material.

As regards the relative functioning efficiency after certain periods of storage, one manufacturer states that the article, if properly stored and kept dry, will not deteriorate. Another states that practically 100 per cent efficiency was obtained from units stored in a proper manner, over quite a long period of time. Another states that the only difficulty experienced in the storage of rockets lay in the driving charge, in which changes of temperature will cause a parting of the compressed powder charge from the wall of the paper case, causing the rockets to operate too sharply. However, he states that after eight or nine years of storage ordinary commercial rockets have functioned perfectly, despite the fact that these rockets had not been protected with the wrapper envelopes, dipped in paraffin, as is now the practice.

As regards the manner in which the stored material should be packed, one manufacturer recommends packages of from 100 to 150 pounds each, piled 4, 5, or 6 cases high, avoiding the storage of loose or broken material.

As regards precautions with reference to moisture, temperature regulation, and light during storage, one manufacturer states that it is to be taken for granted that the storage magazine should be dry, and advises that no direct light be permitted, recommending that wire netting is desirable over glazed or colored glass windows.

Another states that they were accustomed to storing in wooden buildings, single story, of simple construction, unheated and dry, and that no lights or windows were used.

Another manufacturer states that the essential factor is a weather-tight, dry building. He makes no attempt to regulate temperature, nor the moisture, with any form of desiccator.

As regards the size of units stored in any one place at a time, one manufacturer stores from 50,000 to 100,000 pounds and claims that up to 200,000 pounds can be stored safely.

Another manufacturer is accustomed to storing from six to seven carloads at a given point.

As regard the character of storerooms, construction and ventilation, one manufacturer states that brick or stone is preferable as building material, or galvanized-iron walls with sawdust-filled spaces to maintain a cool temperature and to prevent sweating. The only ventilation recommended here is two cupolas in the roof or on the end walls, these cupolas being covered with fine-mesh screen, equipped with steel or iron protection. These buildings should have the dimensions 50 by 200 feet or 40 by 100 feet.

Another manufacturer states that the storage buildings they use are simply tight frame shells, with floors a short distance above the ground; they have no windows, but ventilators in the gable ends, and the roofs are of steel.

The experience of these manufacturers was largely confined to ordinary commercial fireworks, such as unprotected rockets and Roman candles, of which varying amounts were stored for different periods of time.

GENERAL DISCUSSION ON THE REGULATIONS IN REFERENCE TO STORAGE OF PYROTECHNICS, INCLUDING RECOMMENDATIONS.

In regard to regulations concerning the storage of pyrotechnics, the following boards and bureaus have been referred to:

New York Board of Fire Underwriters.

Underwriters' Laboratories.

National Board of Fire Underwriters.

Bureau of Explosives of the American Railway Association.

Bureau of Fire Prevention.

Also certain publications, as follows:

Suggested Ordinance Regulating the Manufacture, Keeping, Storage, Sale, Use, and Transportation of Explosives.

Suggested Protection for Munition Magazines.

Regulations Relating to Explosives and Hazardous Trades.

Report, New York Board of Fire Underwriters, March 26th.

On the following pages will be found a brief resumé of the suggestions from these sources of information, as well as recommendations as to the proper storage of pyrotechnics.

LOCATION OF ARSENALS.

It is recommended that arsenals for the storage of pyrotechnic material be built as far away from habitations as is practicable.

The accompanying table gives the distances as recommended by the National Board of Fire Underwriters and the National Fire-Protection Association in reference to the nearness of these storage arsenals to highways, railroads, and neighboring buildings.

It will be noted that where large quantities, such as 500,000 pounds, are stored, the building should be located 3,000 feet from the nearest railroad and 2,000 feet from the nearest highway. This requirement, however, can be modified where such building, highway or railroad is effectually screened from the storage building, either by natural features of the ground or by an artificial barricade.

In reference to the location of buildings, the following is recommended:

Storage buildings to be located at a considerable distance from habitations, if practicable, and isolated so as to avoid the possibility of danger from external fires.

A unit spacing of not less than 400 feet to be observed and to be not less than 1,000 feet from any highway.

A space not less than 50 feet around each building to be cleared and kept free from brush, and a space around building at least 10 feet wide, covered with cinders or some similar material that will prevent the growth of vegetation.

Quantity and distance table.

Column 1. Quantity that may be kept or stored from nearest building, highway, or railroad.				Column 2. Distance from nearest building	Column 3. Distance from nearest railroad.	Column 4. Distance from nearest highway.
Blasting caps.		Other explosives.				
Number, over.	Number, not over.	Pounds, over.	Pounds, not over.	Feet.	Feet.	Feet.
1,000	5,000			30	20	15
5,000	10,000			60	40	30
10,000	20,000			120	70	50
20,000	25,000		50	200	120	80
25,000	50,000	50	100	240	140	100
50,000	100,000	100	200	360	220	140
100,000	150,000	200	300	520	310	200
150,000	200,000	300	400	640	380	260
200,000	250,000	400	500	720	430	290
250,000	300,000	500	600	800	480	320
300,000	350,000	600	700	860	520	340
350,000	400,000	700	800	920	550	360
400,000	450,000	800	900	980	590	380
450,000	500,000	900	1,000	1,020	610	400
500,000	750,000	1,000	1,500	1,060	640	420
750,000	1,000,000	1,500	2,000	1,200	720	480
1,000,000	1,500,000	2,000	3,000	1,300	780	520
1,500,000	2,000,000	3,000	4,000	1,420	850	570
2,000,000	2,500,000	4,000	5,000	1,500	900	600
		5,000	6,000	1,560	940	620
		6,000	7,000	1,610	970	640
		7,000	8,000	1,660	1,000	660
		8,000	9,000	1,700	1,020	680
		9,000	10,000	1,740	1,040	700
		10,000	20,000	1,780	1,070	710
		30,000	40,000	2,410	1,450	960
		40,000	50,000	2,680	1,610	1,070
		50,000	60,000	2,920	1,750	1,170
		60,000	70,000	3,130	1,840	1,250
		70,000	80,000	3,310	1,990	1,330
		80,000	90,000	3,460	2,080	1,380
		90,000	100,000	3,580	2,150	1,430
		100,000	200,000	3,670	2,200	1,470
		200,000	300,000	4,190	2,510	1,680
		300,000	400,000	4,670	2,800	1,870
		400,000	500,000	5,110	3,070	2,040

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CONSTRUCTION OF ARSENALS.

The consensus of opinion seems to point to the use of separate one-story units of not more than 10,000-square-feet floor space, with ceiling not less than 10 feet high. These buildings should include a fireproof roof, and the floor should withstand a load of 550 pounds per square foot. Details of the construction of buildings of a somewhat similar type may be found in the Construction Section, Ordnance Department, class 19, division 2, drawing 60, the Standard Prime and Fuse House, type No. 2; the Curtis Ordnance Depot, class 19, drawing 9; the Charleston Depot, job No. 6243, plan No. 49, dated May 22, 1918; the Pig Point Ordnance Depot, class 19, division 19, drawing 6.

The composite drawing figure 218 has been made from the above-mentioned drawings, and shows an ideal storage magazine which can be used as a basis for further recommendations on this subject.

Recommendation is made in reference to the construction of these buildings as follows:

Building for storage of pyrotechnics to be not more than 200 by 50 feet, with one floor and ceiling not less than 10 feet high.

Floor to be of concrete, raised from the ground on piles, to avoid ground moisture.

For convenience in loading, the floor or platform to be 3 feet 9 inches above track rail.

Floor must stand a load of 550 pounds per square foot.

Entire building should be fireproof throughout, with walls of hollow tile.

Where partitions are used, they should be hollow tile, extending to the roof and across the entire width, without openings, and with separate outside fireproof doors for each compartment.

Roof should be constructed of gypsum slabs, covered with standard-specification roofing material.

FIRE PROTECTION.

There seems to be a difference of opinion in regard to an automatic sprinkler equipment, certain of the bureaus recommending that an automatic sprinkler system should be in-

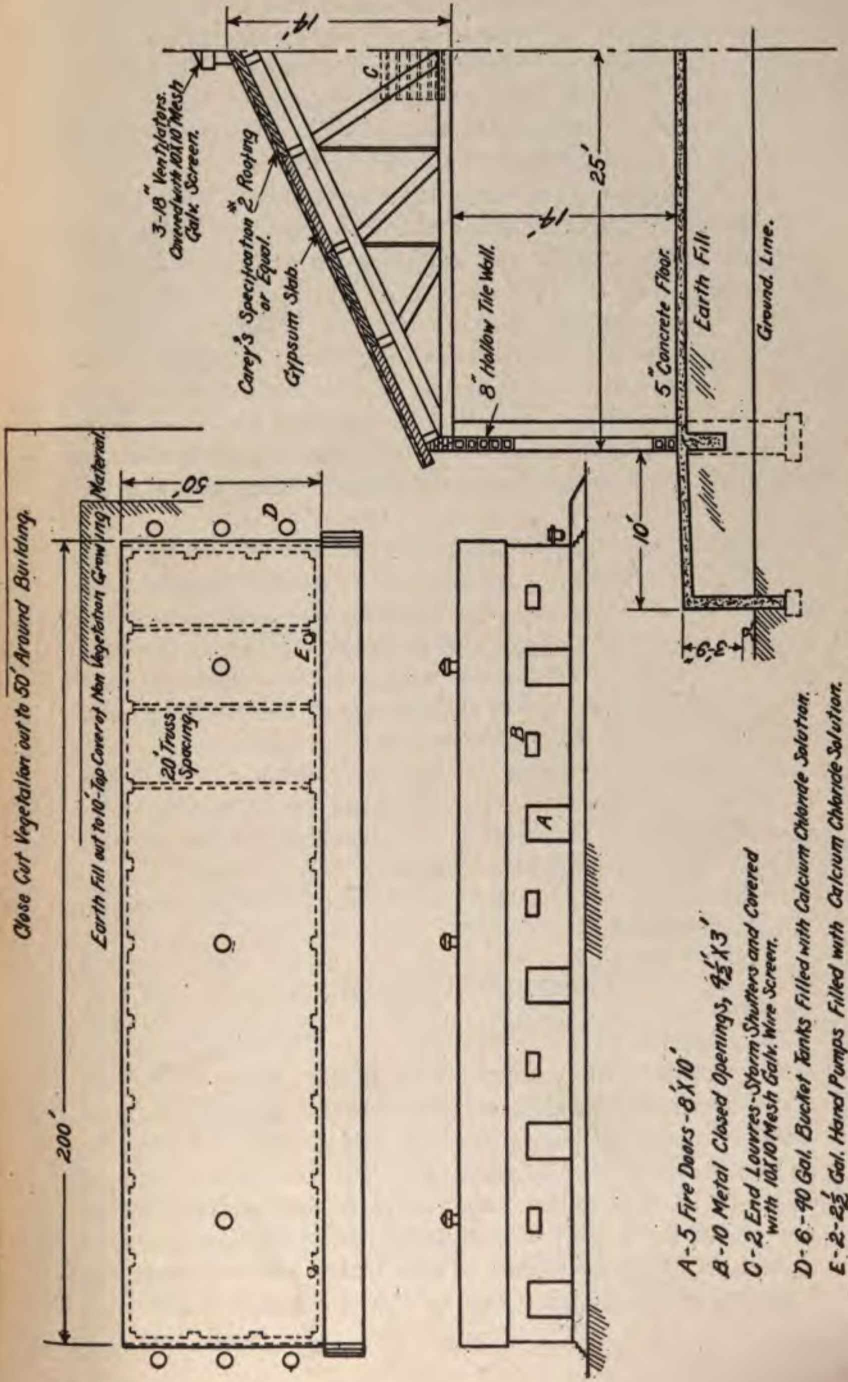

FIG. 218.—Composite drawing for storage warehouse.

stalled. However, the arguments advanced by others indicate that a sprinkler system would not be altogether desirable, particularly in regard to dead storage, with isolated buildings. Certain fire-prevention apparatus, however, is recommended for protection against small fires occurring in the vicinity, which could be put out by hand.

They recommend the use of the standard-construction fire-extinguishers and refer particularly to a generous supply of 40-gallon bucket tanks containing calcium-chloride or sodium-chloride solutions, as well as 5-gallon hand-pump tanks. They advise also that the Ordnance Department in its construction section of arsenals use 2½-gallon arctic extinguishers. (These consist of calcium chloride with small carbon-dioxide cylinders.) It is understood that all these extinguishers should be outside the building and accessible for the purpose of renewing the evaporated water at stated intervals.

Recommendations for fire protection are as follows:

Sprinkler system not recommended with the dead storage of pyrotechnic material, due to sprinkler heads not being affected promptly enough, and to the possibility of freezing.

Standard 2½-gallon arctic extinguishers placed at convenient points, both inside and outside of building, with one unit for not more than 2,500 feet of floor space.

A number of 40-gallon bucket tanks containing calcium-chloride or sodium-chloride solution, to be conveniently placed outside of building, easily accessible for the purpose of renewing the evaporated water.

Spark arresters to be used on all locomotives in proximity to all storage houses.

LIGHTNING PROTECTION.

Du Pont de Nemours Powder Co., of Wilmington, Del., have gone into this subject more deeply than any of the above-mentioned bureaus, and have a treatise on the subject, based on the experiments made at the experimental station on Mount Blanc some 10 years ago. The consensus of opinion seems to be that unless very carefully designed lightning-prevention equipment is installed, such as the Faraday cage system, properly grounded, it were better not to attempt the installation of lightning rods or steel lightning fences.

VENTILATION.

There seems to be a general feeling in regard to the need of ventilation for the storage of pyrotechnics, the main argument in its favor being that, in hot weather, ventilation will tend to reduce excessive temperature in the magazines.

Recommendations are as follows:

Ventilators of approved design to be placed in roof of each compartment and also ventilators in each door to provide circulation, these ventilators to be properly protected with heavy wire screen.

All ventilators to be storm- and weather-proof.

LIGHTING.

It is generally recommended that no artificial lights be used in any of the storage magazines, and that, where windows are used for lighting purposes, translucent fireproof glass be used, with wire-screen protection.

Recommendations are as follows:

No windows to be provided.

No artificial lighting to be provided.

Where artificial lighting is required, electric hand torch to be used, but it is strongly recommended that the storage house be entered and necessary work performed during daylight.

MAINTENANCE.

A variety of suggestions have been made in regard to the proper maintenance of the storage magazines, the principal points, however, being that the surrounding grounds should be kept free from brush, to avoid the possibility of fires, and that a vegetation-free path should surround each of the magazines not less than 10 feet from the walls of the magazines.

Recommendations are as follows:

No smoking or carrying of matches to be allowed.

Each compartment to be carefully and periodically inspected.

Not more than two men to enter building at one time.

All fire-protection apparatus to be kept ready for instant use.

Grounds to be kept clear of brush and rubbish.

Where freight cars are used for receiving or delivering goods, they are to be immediately loaded or unloaded and taken from the premises.

When repairs and alterations are required, all material must be carefully removed and the compartment thoroughly cleaned.

Provide adequate inspection to see that all requirements are observed.

PILING AND HANDLING OF PACKAGES.

The following recommendations are made on the above subject:

Each particular kind of pyrotechnic material to be segregated into separate rooms.

Care must be used in the handling of packages, especially those containing detonating caps.

When convenient, as is the case with the aëroplane flare, the detonating cap to be removed and stored separately.

It is recommended that not over 500,000 pounds of gross pyrotechnic material be stored in any one building.

All packages or cases to be piled so they are readily accessible by means of aisles, and each package or case spaced from the floor and from each other to provide ventilation.

The greatest care must be taken to avoid shocks and falls.

When an inclined chute is used, such chute to be constructed of planed boards not less than 1 inch in thickness, with side guards extending not less than 3 inches above the top face of bottom of chute and throughout its length, fastened with brass screws; D-shaped strips or runners, not more than 6 inches apart and running lengthwise of the chute, to be fastened to the upper pegs extending through the bottom board of the chute and through the runners. Chutes should be occasionally wiped down with waste moistened with machine oil when packages are being handled. A stuffed mattress, not less than 4 feet wide by 6 feet long, and not less than 4 inches thick, or a heavy jute or hemp mat of like dimensions, must be placed under the discharging end of the chute while packages are being handled.

TESTING PYROTECHNIC UNITS.

Recommendations are made:

That the pyrotechnic units to be stored be carefully sampled and that a record of their compositions be placed on file prior to the placing of them in storage.

That periodically (not less than once in 6 months) samples be withdrawn from the several magazines representing the several lots analyzed and comparison made to demonstrate whether or not there is any deterioration taking place.

That physical tests also be made upon these units in order to determine whether they will function in accordance with the original specifications.

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